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Agroforestry Research

Effect of Calliandra Calothyrsus Alley Cropping on Soil Fertility and Maize Production at Bako, Western Oromia

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Abstract

Alley cropping is a production system that combines the elements of agriculture with that of trees/shrubs, and offers many potential benefits for Africa's small-scale farmers. The objectives of this study are to test the impact of alley cropping of Calliandra calothyrsus when integrated with inorganic fertilizers within maize production and to evaluate the effect of Calliandra calothyrsus alley cropping on soil fertility. The study was conducted at Bako Agricultural Research Center for four consecutive years from 2016 to 2019. A total of 6 treatments were used by RCBD arrangement with 3 replications. Grain yield and yield component parameters of maize BH-661 were collected and analyzed. Composite soil samples from 0-15cm depth before sowing and after harvesting each year were collected and analyzed. The maize grain yield results showed a slight variation across the year, which might be due to the effects of Calliandra calothyrsus alley cropping which can directly contribute for improving the soil fertility. LA and LAI was significant effect on the sole maize treatment with recommended fertilizer where the mean of trend showed the highest grain yield in quintal per hectare. According to the results of soil samples analysis the soil pH in the study site was belongs to strongly acidic whereas, after the implementation of the experiment the availability of OC and OM slightly increased, across the treatments. The results of exchangeable bases (Ca and Mg) also showed some variations among the treatments throughout the implementation period. Finally, we recommend that, Calliandra calothyrsus alley cropping with maize production can be considered as part of conservation agriculture so that mono-cropping will be substituted with diversified and multipurpose farming system.

Key Words: **agroforestry, alley cropping, *Calliandra calothyrsus*, maize yield, soil analysis**

Introduction

Farming systems in most African countries are under serious threat due to the ever-increasing population growth and environmental degradation. These difficulties have highlighted the need to take an overall view of land husbandry which is not limited solely to production but also includes the need to conserve natural resources on which production is based (CTA, 1994). Agroforestry is one of such farming systems that combine production with conservation of natural resources. It is about integrating multipurpose trees, like *Calliandra calothyrsus*, in existing land use patterns so as to improve soil fertility and make food production sustainable from both environmental and economic standpoints.

Soil fertility depletion is considered as the major threat to crop production, and food security in Ethiopia. Low soil fertility is the greatest factor to increased productivity of maize in Western Ethiopia. However, decreasing productivity can be alleviated by use, among others, of inorganic nitrogen fertilizer (Tolera *et al.,* 2014) as well as alley cropping (integrating multipurpose trees).

Alley cropping is a production system that combines the elements of agriculture with that of forestry and offers many potential benefits for Africa's small-scale farmers. The trees in alley cropping system act as pumps, moving nutrients down from the lower soil horizons, while at the same time adding organic materials to the soil through litter fall. In addition, the woody perennials used in this system are usually nitrogen-fixing species and thus providing another important boost to soil fertility, and hence it can be under taken with no, or little, the use of costly inputs such as chemical fertilizers. Moreover, our farmers are small and they are not in a position to use these artificial inputs or can use them only in small quantities (Bishaw et al., 1989 and Kilimwiko 1994).

Calliandra calothyrsus belongs to Fabaceae (Mimosoideae) family and a small tree or a large shrub that usually grows 4 to 6 m tall but might reach 12 m under favorable conditions (Orwa *et al.,* 2009;. *Calliandra calothyrsus* is a leguminous shrub or small tree species that biologically fixes free atmospheric nitrogen and hence provides nitrogenous fertilizer for the companion food crop such as maize. It is a promising agroforestry species because of its biological fixation of atmospheric nitrogen, good coppicing ability, rapid growth, dense foliage and deep root system, and hence particularly suitable for erosion control and for rejuvenating degraded soils (Tomaneng, 1990).

Calliandra calothyrsus is used for fodder, apiculture, fuel wood, fiber, erosion control, shade or shelter, nitrogen fixing, soil improver, ornamental, boundary or barrier or support, intercropping (Orwa *et al.,* 2009; Powell, 1997), reduce fallow periods and improve soil fertility (Powell, 1997). In agricultural systems, it is used to reduce weed growth, conserve soil moisture, and improve soil structure and fertility (Powell, 1997).

Proven information regarding the integration of tree species and inorganic fertilizer with maize varieties (BH-661) is not practiced at Bako and surrounding farmers. Therefore, selecting the integration of tree species with appropriate rate of inorganic fertilizer that may be high yield maize variety (BH-661), increasing in nutrient concentration associated with soil and maize yield for successful establishment and management of alley cropping multipurpose tree species at this area. For example, *Calliandra calothyrsus* alley cropping with maize production should be considered and more demonstrated as part of conservation agriculture so that mono-cropping will be substituted with diversified and multipurpose farming system, specifically in maize belt areas of Bako and similar sites.

Objectives

- To test the impact of *Calliandra calothyrsus* alley cropping integrated with inorganic fertilizers in maize production.

- To evaluate the effect of *Calliandra calothyrsus* alley cropping on soil fertility.

Materials and methods

Description of the study site

The study was conducted at Bako Agriculture Research center-on station for five consecutive years from 2016/17 to 2020 and its located in between 37°1'00"E to 37°3'40"E and 9° 4'20''N to 9°7'20"N as indicated in Figure 1.

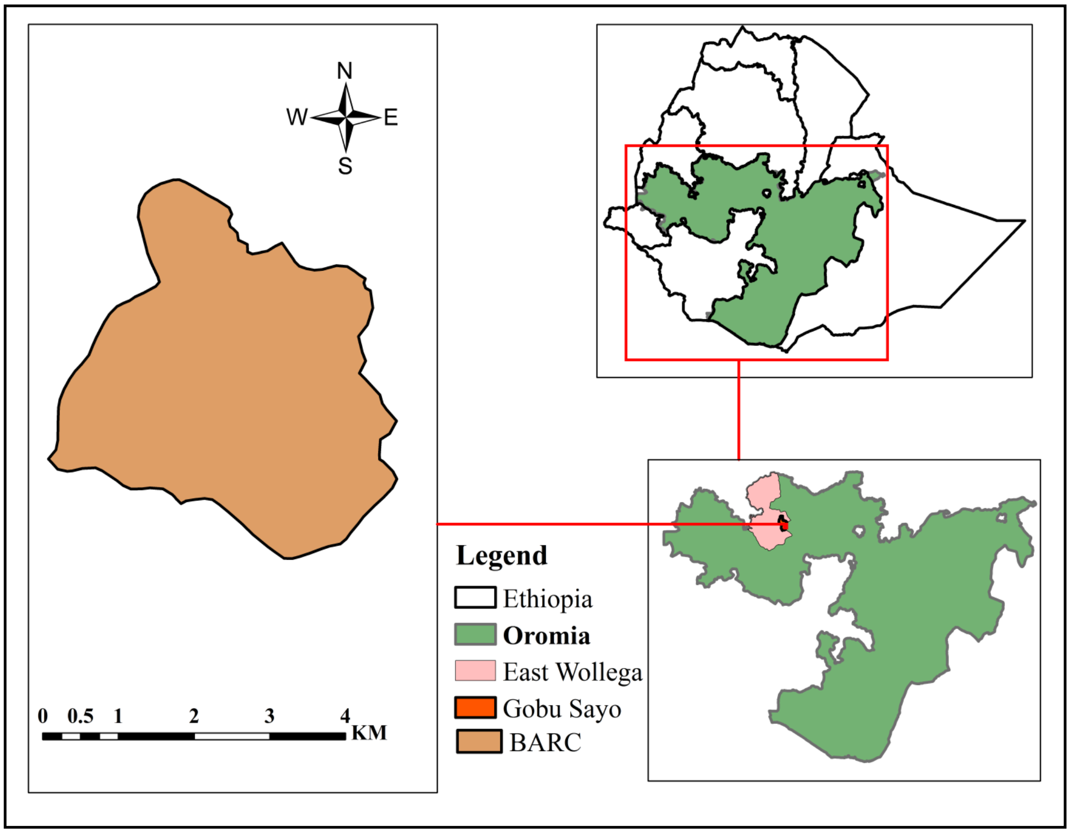

Fig. 1: Map of the study site.

Composite soil samples before sowing and after harvesting were collected and analyzed. A total of 6 treatments were used by RCBD arrangement with 3 replications. Here are treatment combinations of the experiment: T1=Sole maize without fertilizer, T2=Sole maize with recommended fertilizer (N-P-S), T3= *Calliandra calothyrsus* alley cropping only, T4= *Calliandra calothyrsus* alley cropping + 75% of recommended fertilizer (N-P-S), T5= *Calliandra calothyrsus* alley cropping + 50% of recommended fertilizer (N-P-S) and T6= *Calliandra calothyrsus* alley cropping + 25% of recommended fertilizer (N-P-S).

Experimental Designs

Plot area 11.25*12=135m^2 which means width of a plot = 11.25 m (i.e., 15 rows x 0.75 m b/n rows) from 15 total rows 3 consecutive rows maize starting and one rows *Calliandra calothyrsus* alley cropping (A plot contain 12 rows maize and 3 rows *Calliandra calothyrsus)* and Length of a plot 12 m, Spacing between blocks = 2 m**,** Spacing between plots = 1.5 m, Spacing between Maize= 75 cm*30 cm, Spacing between *Calliandra calothyrsus* trees 0.5 m (Intra row spacing of trees 0.5m). A plot contains 12 rows maize and 3 rows *Calliandra calothyrsus***.** Maize and multipurpose trees were established concurrently on the same plot. Seedlings of multipurpose trees were raised at nursery and then transplanted to field plot. Field between maize rows was maintained during the main rainy season (maintaining in the desired maize population). One suitable maize variety **(BH-661)** was selected for the trials. After establishment, multipurpose trees/shrubs were thinned to an appropriate population density. Multipurpose trees/shrubs were managed through repeated cutting back to the ground level to protect interference with the crop.

Collected Data

Growth performance parameters of maize such as days to emergence, days to flowering, days to maturity, plant height, dry matter yield, maize grain yield and yield components were collected. Top soil samples at the depth of 0-15 cm) were collected before planting and after harvesting. During each cropping season to assess the impact of treatments on soil physical and chemical properties particularly organic matter, total nitrogen, available P, Ca, Mg, and pH before and each implementation year to check the change on soil properties.

Method of data analysis

Data were analyzed using Statistical Analysis System (SAS) version 9.3 and subjected to ANOVA to determine significant differences among treatments. Means were separated using Least Significant Difference (LSD) test at 95% confidence interval. Pearson Correlation analysis was also performed to reveal the relation between different parameters.

Climate Data of the Study Area

The four year climatic information of the study site were displayed in the graph below and helps to show the distribution of rainfall, temperature and relative humidity of the site during the implementation periods.

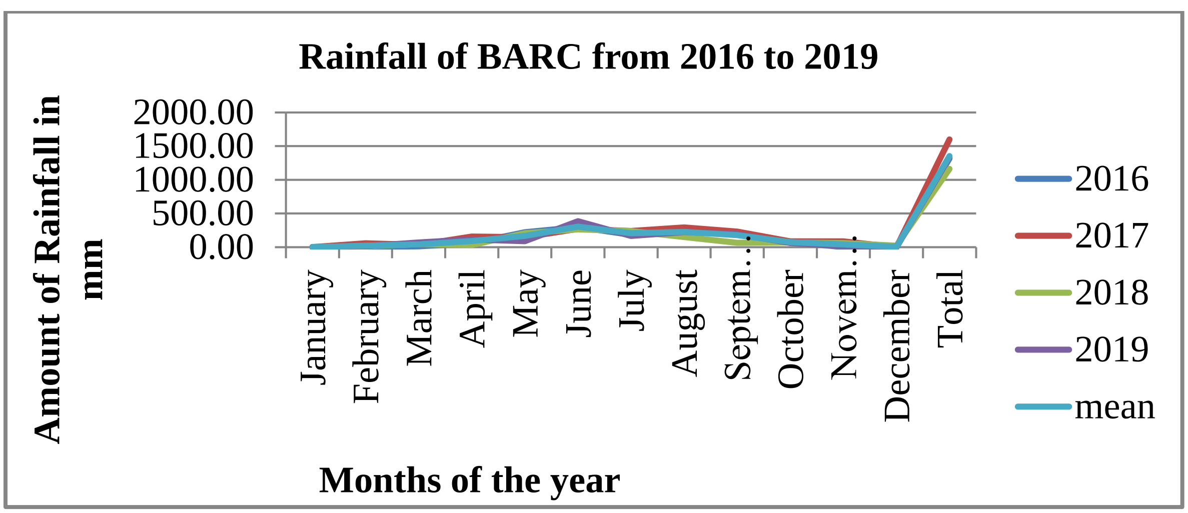

Fig. 2: Rainfall of the study site.

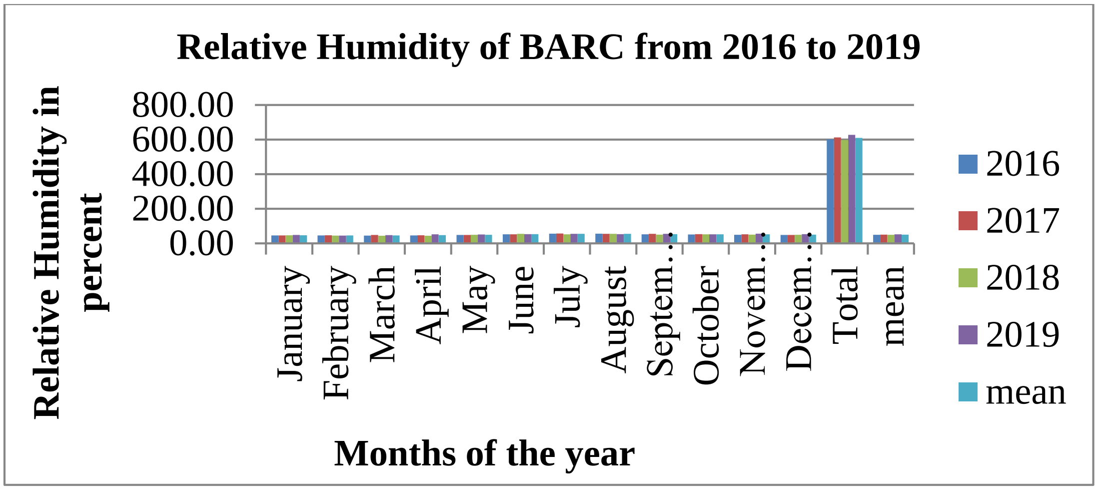

Fig. 3: Relative Humidity of the study site

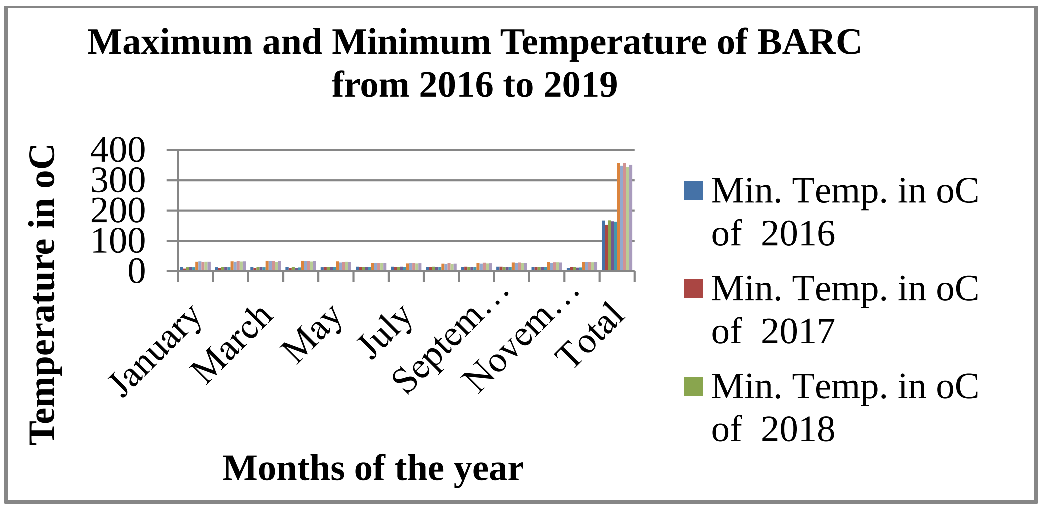

Fig. 4: Minimum and maximum temperature of the study site.

Soil Sampling and Laboratory Analyses

The study was conducted for four consecutive year using *Calliandra calothyrsus* as alley cropping practices which mainly bring a positive impact on maize yield production and soil properties (table 1,2,3,4). Composite soil samples were taken in each experimental field from 0-15cm depths to determine the baseline fertility status of the experimental fields at the beginning of the experiment.. Then the collected soil samples were analyzed at BARC soil laboratory. Soil organic carbon (OC) content was determined by using Walkley-Black method (Walkely and Black, 1934). Available phosphorous (AP) was determined by Bary II method (Bray and Kurtz, 1945). Total N was analyzed using the Kjeldahl method, as described by Black (1965). Exchangeable bases (Ca, and Mg) were determined after extracting the soil samples by ammonium acetate (1N NH4OAc) at pH 7.0. Exchangeable Ca and Mg in the extract was analyzed using atomic absorption spectrophotometer. The pH of the soil was measured potentiometrically with a digital pH meter in the supernatant suspension of 1:2.5 soils: water ratio (Jackson, 1973).

Result and Discussions

Grain Yield and Yield Components

Trends of Yield within Treatments

The maize grain yields during the four cropping season displayed in comparing with different treatment (table 1). The results showed a slight variation across the year, the change might be due to the implementation of *Calliandira* as alley cropping. Since the species has a legumes behaviors directly contribute in improving the soil fertility which provide nutrients for the maize crops.

Table 1: Comparison of Grain Yield (GY) values within treatments from 2016 to 2019

Treatments	GY-2016	GY-2017	GY-2018	GY-2019
1	8.09	9.15	15.83	13.42
2	34.62	39.72	50.51	47.98
3	8.58	12.16	9.61	3.71
4	28.45	36.52	19.99	23.4
5	23.03	33.64	17.23	12.75
6	19.57c	22.68b	13.45bc	13.04c
Grand Mean	**20.39**	**25.65**	**21.10**	**19.05**
LSD (5%)	**4.75**	**8.87**	**6.69**	**6.34**
CV	**12.81**	**19.45**	**17.82**	**18.69**

Treatment description: T1= Sole maize without fertilizer, T2= Sole maize with recommended fertilizer (121kg/haNPS+100 %(87kg/ha N (urea), T3= Maize with *Calliandra calothyrsus* alley cropping only, T4= Maize with *Calliandra calothyrsus* alley cropping + (Recc.121kg/ha NPS+ 75% (59.5kg/ha N (Urea)), T5= Maize with *Calliandra calothyrsus* alley cropping + (Recc.121kg/haNPS+50 %(32kg/ha N (urea)), T6= Maize with *Calliandra calothyrsus* alley cropping + Recc.121kg/ha NPS+ 25% (4.5kg/ha N (urea))

According to our observation from the above table, yield reduction from the initial revealed which might be due to the erratic rainfall distribution of the site across the years (fig.3). The general yield trend showed relatively higher in treatment 2 and 4 which produced higher yields than other treatments across the years.

Mean of Yield and Yield Components

The leaf area (LA), leaf area index (LAI), dry biomass (DM), harvesting index (HI), thousand seed weight (TSW), normalized difference vegetation index (NDVI) and grain yield (GY) of maize during the four cropping year were presented (table 2). LA and LAI was significant effect on Sole maize with recommended fertilizer and grain yield of maize was significantly different on Sole maize with recommended fertilizer (121kg/haNPS+100 %(87kg/ha N (urea).

Table 2: Overall average of grain yield and yield components with treatments from 2016-2019

Treatment	LA (cm^2)	LAI	DBM (kg)	HI	TSW (gm)	NDVI	GY(Q per ha)
1	3549.65	1.60	18.18	0.32	271.37	0.65	11.6225
2	6502.43	2.96	52.93	0.38	347.70	0.75	43.2075
3	3406.50	1.48	16.67	0.27	278.83	0.66	8.515
4	5617.00	2.46	42.59	0.35	329.73	0.75	27.09
5	5703.20	2.50	34.50	0.34	309.33	0.73	21.6625
6	5251.48	2.31	30.19	0.31	296.04	0.72	17.185

Note: LA = Leaf area, LAI = Leaf area index, DBM= Dry biomass, HI = Harvest Index, TSW= Thousand seed weight, NDVI= Normalized difference vegetative index, GY= Grain yield.

LA, LAI, DBM and NDVI ranges between 3567.1-6176.6, 1.57-2.79, 17.61-47.70 and 0.64-0.75, respectively. Yields of maize in 2019 production year were declined due to presence of high rainfall and occurrence of logging effects. Due to this effect, overall maize grain yields in average of the study site become decreased. High rainfall variability has an effect on maize yield variability (Adamgbe and Ujoh, 2013; Koimbori, J.K., 2019).

Analysis of soil properties

The results of soil properties of the study site were presented in table 3. According to the results for the soil pH in pH (1:2.5 (H_2O) suspension were 5.43. This showed that the study site was belongs to strongly acidic (5.1-5.5) range (Horneck *et al.*, 2011; SPA, 1995; Jones, 2003). In soils with pH below 5.5, Ca or Mg may be deficient (Jones, 2003).

Table 3: Overall average of grain yield and soil parameters with treatments from 2016 to 2019

	pH	OC (%)	OM (%)	P	TN (%)	Mg	Ca	GY(Q per ha)
Composite soil (2016)	5.43	1.40	2.04	8	0.12	7.3	8.00	--------
Treatment								
1	5.17	1.84	3.17	9.45	0.16	8.00	9.19	11.62
2	5.10	1.91	3.20	10.02	0.16	7.32	10.40	43.21
3	5.29	1.86	3.21	10.30	0.16	12.92	10.93	8.515
4	5.08	1.82	3.13	11.30	0.16	8.33	7.50	27.09
5	5.09	1.87	3.21	6.72	0.16	8.06	9.58	21.66
6	5.16	1.93	3.33	10.21	0.17	11.04	8.41	17.19

Note: pH= pH (1:2.5)(H2O), OC= Organic Carbon (%), OM= Organic Matter (%), P= Available Phosphorus (mh/kg) soil, TN= Total Nitrogen (%), K= Exchangeable Potassium ((cmol(+)/kg soil, Mg= Magnesium (meq/100g) soil, Ca= Calcium (meq/100g) soil

Furthermore, the composite soil results for total N (%) and available P (mg/Kg) soil of the study site were 0.12 and 8, respectively as indicated in the table 3. According to the rating range for the composite soil results of the study site the concentrations of total N classified within the range of low rating (0.05-0.12 (Cottenie, 1980; London, 1991; FAO, 1990). A similar trend was obtained for extractable available phosphorus concentration which falls under low rating range with the value of 8 in the study site (5-10) (London, 1991; FAO, 1990). Low available soil P content of the study site was a good indicator of the soil P supply for maize production. Whereas, during the implementation period the values of total N and available P showed variation this variation would be due to the combined effect of the applied treatments. For the composite soil analysis the availability of organic carbon and organic matter concentrations of the study site were found within 1.40 and 2.04 range which were considered in low rating ranges (Low OC ratings between 0.5-1.5 and low OM ratings between 0.86-2.59) (Tekalign, 1991; FAO, 1990). Whereas, across the treatment after the implementation of the experiment the availability of OC and OM slightly increased, this might be due to the practice of alley cropping and application of different fertilizer rates. The results of exchangeable bases (Ca and Mg) also showed some variations among the treatments throughout the implementation period.

Regarding the soil pH the highest value was recorded at T3 with 5.29 values, while lower pH revealed under the T4 with 5.08 values (table 3). The main reason for the change observed in pH values of the study site might be due to the sole application of alley cropping using *Callaindra* species that directly modified the level of pH availability of the site.

Correlation of soil properties and Grain Yield

The correlation impact of different soil properties against grain yield were displayed across the implementation periods. As presented in the table 4, at the early stage of the experiment the maize grain yield was showed a positive correlation with OC, OM and TN, having the value of 0.254, 0.249, and 0.1875, respectively. The contributions of using legumes species as alley cropping might be showed the positive interaction for some soil chemical properties with maize grain yield production.

Table 4: Correlation analysis of grain yield and some soil parameters

	GY	pH	OC	OM	P	TN	Mg	Ca
GY	1	-0.0037	0.25369	0.24944	-0.04520	0.18747	-0.02186	-0.04997
pH		1	0.13964	0.14199	0.14337	0.16118	0.05105	0.10570
OC			1	0.99983	-0.50217	0.95564	-0.37608	-0.46704
OM				1	-0.49797	0.95547	-0.38170	-0.46456
P					1	-0.50474	0.07253	0.18381
TN						1	-0.32753	-0.49673
Mg							1	0.33553
Ca								1

Conclusion and Recommendation

Alley cropping system is the cultivation of food, forage, or specialty crops between rows of trees. This system is a larger version of intercropping or companion planting conducted over a longer time scale. The current experiment shows us that through alley cropping of *Calliandra calothyrsus* with maize we can diversify our products: food, feed, fuel and fences, and also we can simultaneously sustain productivity and improve soil fertility. This alley cropping trial has tried to observe and identify the shrub/crop intercrops where trends of yield and yield components negatively/positively correlated with soil parameters in average. The experiment could also identify that the fertilizer rate and other agronomic management only will not a matter for successful alley cropping practices, but also identified that alley cropping practices can be challenged with rainfall amount, temperature and relative humidity. Farmers may also use alley cropping to transition from one farming system to another system. The annual crops grown in alley cropping can provide short-term annual income until the trees are mature. The versatile nature of this system allows a producer to react to markets, labor limitations, and changing goals. Like all agroforestry systems, alley cropping must be considered as part of the whole farm operation.

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The effect of provenance on survival and growth performance of Moringa stenopetala (Bak.f) in two districts of Bale, southeast Ethiopia

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Abstract

In Ethiopia study on provenance effects on survival and growth performance of Moringa stenopetala is very scarce despite it is one of the most exciting plants that we have to see closely for its conservation and genetic improvement. Study was undertaken to evaluate provenance effect on survival and growth performance of M. stenopetala at Dello-menna and Goro research sites of Sinana Agricultural Research Center of Bale, Southeast Ethiopia. The tested provenances were Konso, Abay and Bale collecting their planting materials from the respective Arbaminch, Filiklik and Dell-menna locations. The experiment laid out in RCBD design with three replications. In study, the necessary data parameters (survival rate, plant height, root collar diameter and diameter at breast height) were recorded and analyzed by R software. As to results, provenance effects on these parameter is considerably ($p < 0.05$) varied. Accordingly, survival rate at Dello-menna research sub site reported within a range of 70.30% to 85.19%. While at Goro, it ranges from 33.33% to 73.5% among the provenance. Height growth ranged 121.3 cm to 251.3 cm at Dello-menna site, and from 46.4 cm to 117.9 cm at Goro. Besides, root collar diameter at Dello-menna site reported within a range of 2.59 cm to 7.17 cm among provenances, and 3.83 cm to 5.90 cm at Goro. The result pointed that over both sites the survival and growth of Konso provenance had showed good performance followed by Abay and Bale, respectively. Thus, at the sites maximum M. stenopetala production can be achieved if Konso provenance majorly used as seed source for further plantation. Besides, Abay provenance at Dello-menna and Bale at Goro sites alternatively can be considered in some cases. However, to make a firm conclusion as to the genetic variability among provenances the continued observation strongly recommended.

Keywords; *Abay-provenance, Bale-provenance, Diameter at breast height, Konso-provenance, Plant height, Root collar diameter*

Introduction

Moringa is a genus that represents the family Moringaceae. It represented by 13 to 14 species, of these, *Moringa stenopetala* and *Moringa oliefera* species are the major ones (Wubalem *et al.*, 2012; Hailie *et al.*, 2015). *Moringa stenopetala* considered as '*'East African Moringa tree''* as it is native only to southern Ethiopia and northern Kenya (Alelegne, 2016; Tagay and Yemiru, 2021). Current global developments on Moringa agree for addressing the global issue of poverty and environmental crises. Today the plant is being used to solve poverty among rural dwellers by promoting income generation through rational utilization of vegetation, application of the seed in water treatment, plantation/nursery development/, as well as food supplement to combat malnutrition, supply of the leaf powder, oil and many other (Mamuye *et al.,* 2020). Not only this, it has the highest nutritional content of ever plant tested, and it is named as God's abundant resource.

Environmentally *Moringa stenopetala* has a low demand for soil nutrients and water making its production and management easy (Isah *et al.,* 2014; Chris *et al.,* 2015). Indeed, it is drought tolerant and easily adapted plant to poor soil and arid conditions. This shows that, the species can be easily cultivated on marginal lands where food crop production is not possible. In southern part of Ethiopia *M. stenopetala* tree has long been grown by Konso people for the management of marginal dry lands. Additionally, *M. stenopetala* leaves are the staple food of Konso people. Studies have shown *M. stenopetala* leaves to be an excellent source of vitamins, minerals and protein: perhaps more than any other tropical vegetable (Ashfaq *et al.,* 2012; Diriba *et al.,* 2017). Therefore, it is a strategic plant in being a unique food tree in drought prone areas and need a special attention for its conservation.

In Ethiopia, knowledge on genetic variability and proper management of this valuable multipurpose tree species is very limited. Above all, provenance variability response on its survival rate and growth performance not yet investigated. Provenances of the same tree/shrub species could react differently to different environmental situations (Negash and Mebrate, 2005; Girma *et al.,* 2012; Edward *et al.,* 2014) and the hypothesis is likely true for *M. stenopetala* species. Knowledge on tree provenance variability enables to identify the best performing planting material source to sustain and maximize the productivity of the species in general. Thus, study is conducted to evaluate provenance variability effects on survival and growth of *M. stenopetala* grown at Dello-menna and Goro districts of Bale, southeast Ethiopia.

Materials and Method

Description of the Study Area

The study was carried out at Dello-menna and Goro research sub sites of Sinana Agricultural Research Center, Bale zone of Oromia regional state, southeast Ethiopia. Dello research sub site is located at 6^0 24' 42.45" N and 39^0 49' 55" E while Goro sub site lie at 6°59'20.97" N and $40^0$29'45.16'' E. The rainfall pattern for both areas is bimodal type, which divide the year into two rainy seasons. Accordingly, Dello attain main rainy season middle of March through June and short rainy seasons early September through November. The mean annual rainfall of Dello-menna district is about 986.2 mm with mean annual temperature of 22.5 ^{o}C. Its altitude ranges from 1000 to 2500 meters above sea level with reddish brown clay soil type towards the higher altitudes and tending red-orange sandy toward the lower elevations (Bekele *et al.,* 2021).

Goro district attain the main rainy season June to October and short rainy season March to May. The mean annual rainfall for Goro is between 800 and 1000 mm with Mean maximum annual temperature 26.5°C and mean of minimum temperature 12.4°C (Chimdessa *et al.,* 2019).

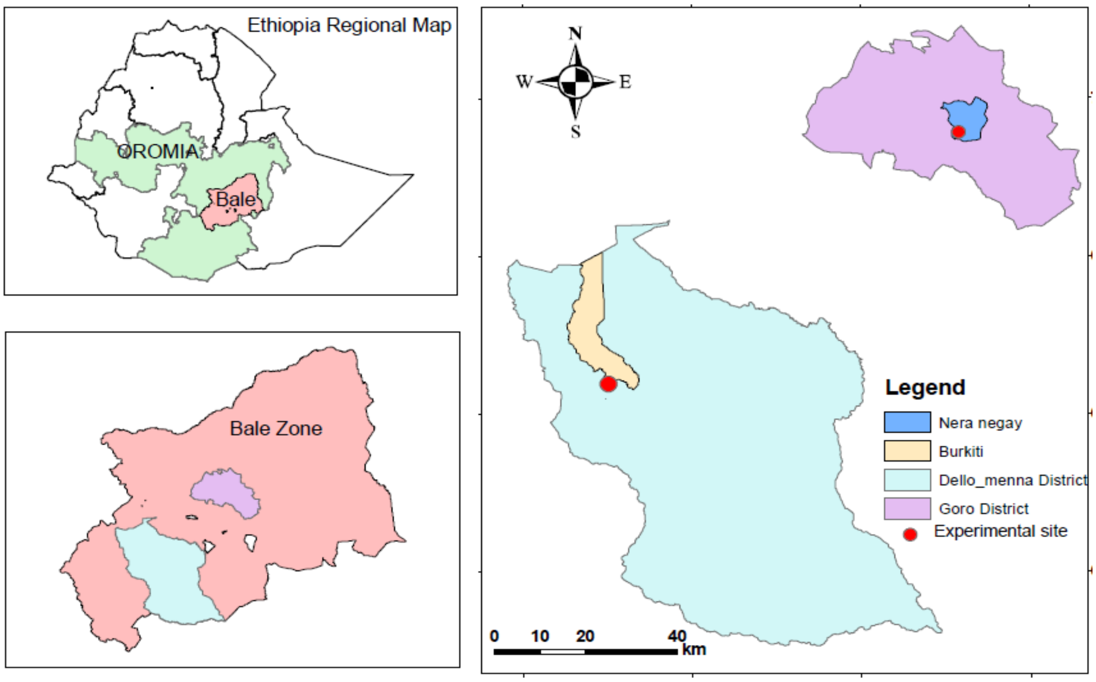

Figure1. Location of the study area

Treatments and experimental layout

Three Moringa stenopetala provenances namely; *Abay, Konso and Bale* had been used. Seeds of Bale provenance from Dello-menna district of Bale zone, Konso provenance from Arbaminch zuria district and Abay provenance from Abay filiklik area collected. Thereafter, seedlings of the provenances produced following the standard tree nursery seedling production techniques. The experiment installed by RCBD design with three replications with a plot size of 8 m x 6 m for each provenance type. The spacing between plants was 2 m x 2 m consisting of 12 plants per plot.

Data collection and statistical analyses

Survival count, root collar diameter, and height data collected at the age of one year after planting and continued for the subsequent years of study period. Diameter at breast height (DBH) measurement obtained starting at the 2nd year of experimental period. Survival count was made for the whole tree/shrub species found in a plot whereas for other parameters about six plants sampled randomly. Root collar diameter and DBH were measured using calipers whereas height was measured using graduated pole and/or measuring tape. The collected data is summarized and analyzed by Microsoft excel and R software computerized programs, respectively. Finally, the existence of relationship among growth performance traits (height, root collar diameter and DBH) examined by Pearson's correlation coefficient

Results and Discussion

Survival rate

Result has shown that, except during the first year of study period at Dello-menna site a significant difference (p<0.05) was reported for the survival rate of tested provenance's (table 1). During the years, the survival rate of Konso provenance found relatively higher over both experimental sites ranging with mean values 73.50% to 88.90%.

Table1. Means of survival rate (%) as influenced by provenance's over the years of study period and locations

Provenances	Dello-menna			Goro		
	1st year	2nd year	3rd year	1st year	2nd year	3rd year
Abay	85.19 [a]	77.78 [ab]	74.08 [a]	41.44 [a]	41.11 [a]	33.33 [a]
Konso	88.90 [a]	88.89 [b]	85.19 [b]	74.83 [b]	74.83 [b]	73.5 [b]
Bale	81.49 [a]	70.34 [a]	70.34 [a]	74.67 [b]	70.56 [b]	66.45 [ab]
CV (%)	14.10	7.40	4.80	20.00	20.10	26.00
LSD (p < 0.05)	27.21	13.27	8.40	28.86	25.35	34.10

N/B: Means in columns with the same letters are not significantly different, CV = Coefficient of variation, LSD= Least significant difference

Provenances grown at Dello research sub site showed good survival rate having more than 70% compared to Goro. At Goro sub site the subsequently reported survival rate ranged from 33.33 to 74.83% among provenances. The lower surviving rate of provenances at Goro may attribute to Moringa species intolerance to the slight waterlogged soil condition of Goro site. This is because *Moringa species* grow best in well-drained soils than waterlogged soil conditions (Edward *et al.*, 2014).

Height growth (H)

Except during the first year of study period, a provenance effect on height is statistically significant (p < 0.05) over both locations (table 2). Accordingly, height growth at Dello site ranged 62.57 cm to 121.3 cm and 73.96 cm to 251.3 cm for Bale and Abay provenances, respectively. At Goro, height growth among provenance reported 31.58 cm for Bale provenance to 117.99 cm for Konso.

Table2. Means of plant height (cm) as influenced by provenances over the years of study period and location

Provenances	Dello-menna			Goro		
	1st year	2nd year	3rd year	1st year	2nd year	3rd year
Abay	73.96 ^{a}	143.3 ^{b}	251.3 ^{b}	30.58 ^{a}	41.37 ^{a}	46.40 ^{a}
Konso	69.47 ^{a}	94.0 ^{ab}	221.0 ^{ab}	38.33 ^{a}	91.09 ^{b}	117.99 ^{b}
Bale	62.57 ^{a}	83.0 ^{a}	121.3 ^{a}	31.58 ^{a}	59.97 ^{ab}	79.50 ^{ab}
CV (%)	14.80	23.00	27.20	6.80	22.50	24.90
LSD ($p < 0.05$)	23.0	55.58	121.9	5.19	32.7	45.94

N/B: Means in columns with the same letters are not significantly different, CV = Coefficient of variation, LSD= Least significant difference

The result has showed at Dello-menna site, superior height growth reported for Abay provenance followed by Konso provenance. However, at Goro, Konso provenance showed superior height growth throughout the years of study period. The differences in height growth within a site attributed to variations in adaptability potential among provenances while between the sites may link to the environmental factors.

Root collar diameter growth (RCD)

Results of provenance effect on RCD growth of *M. stenopetala* planted for both sites reported (table4). At Dello research sub site variation in RCD development was statistically significant ($P<0.05$) in the whole assessment period. At the study site, the superior RCD development was reported for Konso provenance followed by Abay and Bale, respectively. Furthermore, at Goro site the variability in RCD growth within the provenance is non-significant except during the 2nd year of study period. In spite of non-significance variability, the better RCD development with a grand mean of 3.97 cm reported for Konso provenance closely followed by Bale and Abay, respectively.

Table3. Means of root collar diameter (cm) as influenced by provenance over the subsequent years of study period and location

Provenances	Dello-menna			Goro		
	1st year	2nd year	3rd year	1st year	2nd year	3rd year
Konso	3.41 ^{b}	6.00 ^{b}	7.17 ^{bc}	2.62 ^{a}	4.40 ^{a}	5.90 ^{a}
Abay	2.89 ^{a}	4.42 ^{ab}	5.82 ^{b}	2.42 ^{a}	2.44 ^{b}	3.83 ^{a}
Bale	2.87 ^{a}	3.63 ^{a}	2.59 ^{a}	2.67 ^{a}	3.51 ^{ab}	4.67 ^{a}
CV (%)	10.10	23.00	29.70	16.50	22.90	28.50
LSD ($p < 0.05$)	0.47	1.92	2.84	0.59	1.80	3.08

N/B: Means in columns with the same letters are not significantly different, CV = Coefficient of variation, LSD= Least significant difference

The result revealed, provenances grown at Dello research sub site had showed good performance in RCD development than provenances grown at Goro.

Diameter at breast height (DBH)

Similar to other growth performance traits, diameter at breast height growth reported for the studied provenances over both study sites. At the sites, relatively superior Dbh (cm) growth was reported for Konso and Abay provenances with non-significant ($p< 0.05$) variation between themselves (table 4). Oppositely, poor Dbh development reported for provenance obtained from Bale at both study sites.

Table4. Means of diameter at breast height (cm) as influenced by provenances over the years of study period and locations

Provenances	Dello-menna		Goro	
	2nd year	3rd year	2nd year	3rd year
Konso	3.463 b	6.573 b	3.400 b	4.447 a
Abaya	2.896 b	5.477 ab	2.410 ab	3.717 a
Bale	1.723 a	3.137 a	2.103 a	2.880 a
CV (%)	15.60	23.00	16.80	27.30
LSD (P < 0.05)	1.145	2.952	1.030	2.235

N/B: Mean values in columns with the same letters are not significantly different, CV = Coefficient of variation, LSD= Least significant difference

Provenances that showed the highest height and root collar diameter growth also recorded the highest DBH values. The synthesis examined by Pearson's correlation coefficients and substantiated by the results reported during the study (table5). As to results mean DBH growth positively correlated with height ($r = 0.8675$), and with RCD ($r = 0.9355$) and mean height growth positively correlated with RCD ($r = 0.9164$).

Table5. Correlation coefficient (r) between different growth performance traits

	Mean Height	Mean RCD	Mean DBH
Mean Height	1.0000	0.9164*	0.8675*
Mean RCD	0.9164*	1.0000	0.9355**
Mean DBH	0.8675*	0.9355*	1.0000

Note: ns = non-significant at p = 0.05, * = significant at p = 0.05, **= significant at p < 0.01

This has implied provenance with the largest DBH and RCD is the tallest, and the observation is in line with other's finding stating woody perennial growth performance trait exhibit a positive association each other (Bekele *et al.*, 2021).

Conclusion and Recommendation

Moringa stenopetala is one of the most exciting plant that we have to see very closely for its genetic improvement and conservation. In Ethiopia, knowledge on provenance variability effect on survival and growth performance of M. stenopetal is very scarce. Study was planned and undertaken to test the existence of variability within three provenances of *M. stenopetala* depending up on their survival rate, height, RCD and DBH traits. The Study was conducted at Dello-menna and Goro research sub sites of Sinana Agricultural Research Center of Bale, Southeast Ethiopia. As to results provenances effect on survival rate, height, RCD and DBH is statistically considerable over both experimental sites. Survival rate at Dello-menna sub site ranged from 70.30% for Bale provenance to 85.19% for Konso. At Goro, the mean value of survival rate ranged from 33.33% for Abay to 73.5% for Konso. Height growth ranged 121.3 cm to 251.3 cm at Dello-menna site and 46.4 cm to 117.9 cm at Goro. Root collar diameter ranged from 2.59 cm for Bale to 7.17 cm for Abay at Dello-menna study site and 3.83 cm for Bale to 5.90 cm for Konso at Goro.

The results showed that at both experimental sites the survival rate and growth of Konso provenance had showed good performance followed by Abay and Bale, respectively. Furthermore, provenance grown at Dello-menna study site had showed good performance compared to Goro. The difference within a site could be attributed to variations in adaptability among provenances while between the sites might be linked to the soil condition. Indeed, the lower performance of provenances grown at Goro sub site attributed to Moringa species intolerance to the slight waterlogged soil condition of Goro site of than Dello-menna. Despite the variability, maximum *M. stenopetala* production can be achieved if Konso provenance used as seed source for further plantation over both locations. However, in order to make a firm conclusion as to the genetic variability among provenances, the continued observation strongly recommended.

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Evaluation and Adaptation of Moringa Species on Growth Performance at Adola Rede District, Guji Zone, Southern Ethiopia

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Abstract

Being a multipurpose perennial almost all parts of the moringa tree are used for food, oil, fiber, and/or medicine (Bennett et al., 2003).The study was conducted at Adola Rede District, Guji Zone, in Southern Ethiopia for three consecutive years from 2018-2020. The objective of the study was to evaluate the growth performance of two Moringa species namely Moringa Stenopetala and Moringa oleifera for midland agroecology of Guji Zone. The experiment was replicated three times in a randomized complete block design (RCBD). The Moringa seedlings were out planted in a plot size of 7mx7m. Space between seedlings and plots were 2.5m and 2m respectively. On each plot nine Moringa seedlings were planted. , Growth parameters such as survival rate, tree height, root collar diameter and diameter at breast height data were recorded during the study time. The finding of this study showed that survival rate of the two moringa species was significantly different starting from at the age of two years. The highest survival rate 88.7% was recorded from Moringa stenopetala and survival rate of Moringa oleifera was 77.7% at the age of three years. The results of current study showed that there was a significant difference (p<0.05) in height growth, root collar diameter and diameter at breast height (DBH) among the two Moringa species. The maximum tree height was recorded from Moringa stenopetala (4.41m) and the minimum tree height of 2.21m was recorded from Moringa oleifera species. The highest root collar diameter and diameter at breast height of Moringa stenopetala was 7.9cm and 4.42 cm respectively. However, the minimum root collar diameter and diameter at breast height of Moringa oleifera was 6.2cm and 2.46cm respectively. Based on the results of three years growth parameters collected data, growth performance of Moringa stenopetala species is promising and hence it can be considered for further promotion of this multipurpose tree species at midland agroecology of Guji Zone and for sites with similar agro-ecological conditions.

Keywords: *Diameter at breast height, Moringa oleifera, Moringa stenopetala, Root collar diameter, Survival rate and Tree height*

Introduction

Moringa is a tropical plant belonging to the family *Moringaceae* that grows throughout the tropics. The genus *Moringa* is represented by 13 different species, two of which are *Moringa oleifera* and *Moringa stenopetala* species (NRC, 2006). Among various types of Moringa species, *Moringa stenopetala* is native to Ethiopia, Northern Kenya and Eastern Somali and it is the most economically important species after *Moringa oleifera* (Olson, 2001). It is widely distributed in the Rift Valley of southern Ethiopia (Azene Bekele, 1993; Edwards *et al.*, 2000) and it is used as vegetable food for human consumption and animal feed resources during dry period (Abuye *et al.*, 2003).

Moringa oleifera is native to northern India but now cultivated throughout the tropics, especially in arid areas. It is a drought-resistant and valuable tree, introduced to Ethiopia long ago and now naturalized in many parts of Gamo Gofa, Harerge and in the Rift Valley and tried elsewhere. *Moringa oleifera* requires well drained soils with a high water table, but it is drought resistant and occurs at low altitudes in Dry and Moist lowlands agroclimatic zones (Azene Bekele, 2007).

The edible parts of the Moringa tree are exceptionally nutritious (Rams, 1994; Teketay, 2001). Leaf parts are promising as a food source in the tropics because the tree is full of leaves during the dry season when other foods are typically scarce (Fahey, 2005). Leaves of *Moringa stenopetala* are rich in protein (28.2-36.2%) and contain considerable amounts of essential amino acids (Melesse *et al.,* 2009; Negesse *et al.*, 2009).

Moringa species are known as good nutrition sources and because they are highly tolerant of very dry conditions, they are often used as important famine foods, especially for infants and nursing mothers (Mahmood *et al.*, 2010). In addition, the fresh leaves of *Moringa stenopetala* are cooked and eaten as a vegetable in Southern Ethiopia (Yesehak *et al.*, 2011). Moreover, the *Moringa stenopetala* leaves are widely used as a traditional herbal remedy by the local population (Mark, 1998).

Midland Agroclimatic condition of Guji Zone is very suitable for growing of Moringa multipurpose tree species. However, due to lack of adapted and improved Moringa species at midland districts of Guji Zone, moringa trees are not yet diversified and local communities of the study area so far not benefited from this important multipurpose tree species. Thus, the present study was conducted to evaluate the growth performance of two Moringa species at Adola Rede District, Guji Zone, in Southern Ethiopia.

Materials and Methods

Description of the Study area

This study was conducted in Adola Rede District, in Guji zone, in Southern Ethiopia, which is located 468 km away from Addis Ababa to the South. The location of the District is between 5^{o}44'10"N- 60^{0} 12'38"N and 38^{o}45'10"E - 39^{o}12'37"E (Figure 1). It has a total area of about 1401km^{2}. Most topography of the District is characterized by ups and down arrangement. Moreover, it has land surface with an elevation ranging from 1500 to over 2000 meters. The major soil of the District is Nitosols (red basaltic soils) and Orthc Acrosols. The District is characterized by three agro climatic zones, namely high land, midland and lowland and the percentage coverage of each climate zones are highland (11%), midland (29%) and lowland (60%). The type of rainfall of the study area is bi-modal with longest rain season that has the maximum and minimal rainfalls which falls between 800-1800mm annually with an erratic distribution patterns.

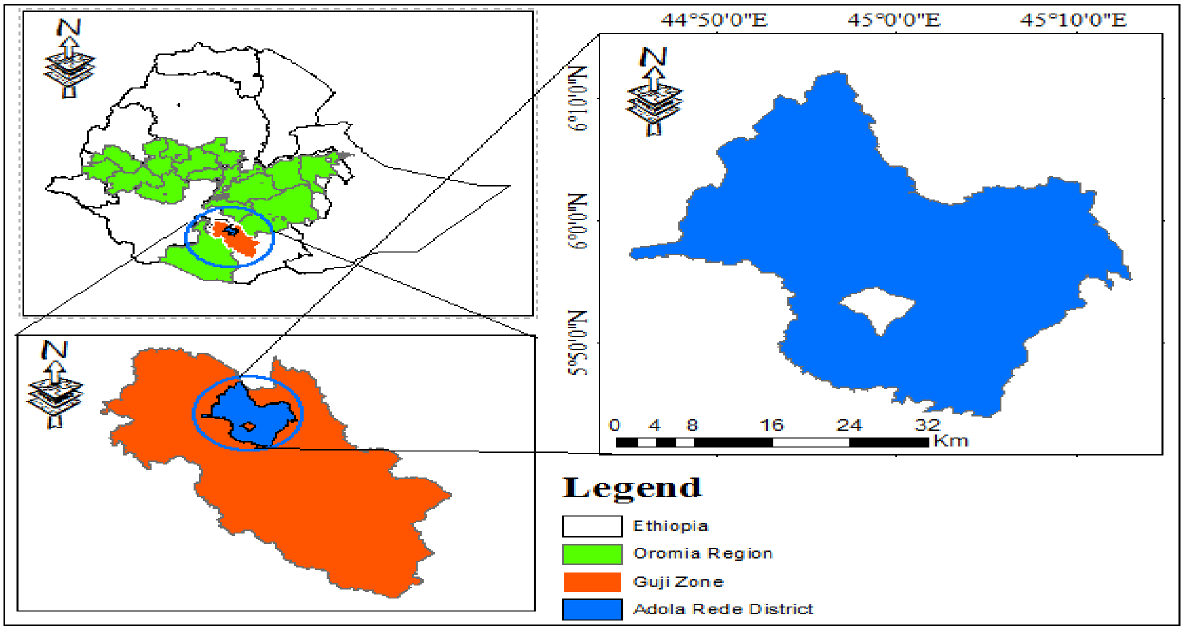

Figure 1: A map showing the study area

Treatments and Nursery Management

Seeds of two Moringa tree species namely *Moringa olifera* and *Moringa stenopetala* included in this experiment (Table-1) were obtained from Central Ethiopia Environment and Forestry Research Center. Seedlings of the two moringa tree species were raised at Adola sub site. Sowing of seeds was done on seed beds and after germination the seedlings were pricked out in polythene tube diameter of 12cm. Optimum care, such as watering, mulching, shading and weeding were provided at the nursery site to produce healthy and vigorous seedlings for field planting.

Table 1. Origin, Distribution, Preservation status and Major uses of *Moringa stenopetala* and *Moringa oleifera* Species selected for the study

Moringa Species	Native to	Actual distribution	Preservation	Major Use
Moringa oleifera Lam.	Asia(India)	Sub tropical regions World wide	Endangered	Multipurpose
Moringa stenopetala(Bak.f.)Cuf	Africa(Ethiopia and Kenya)	Ethiopia, Kenya, Somalia	Endangered	Multipurpose

Plantation and Design of the Experiment

The seedlings of the two Moringa tree species were planted in Adola Rede District, at Adola Sub site of the center in 2018. The experiment was replicated three times in a randomized complete block design (RCBD). During plantation time, a plot size of 7mx7m was used. Space between seedlings and plots used were 2.5m and 2m respectively. On each plot nine Moringa tree species seedlings were planted.

Data collection and Analysis

Survival rate, tree height, root collar diameter and diameter at breast height were the four growth parameters that were measured quarterly for three years. Survival percentage of each species was calculated as the number of trees surviving by the end of the experiment divided by initial tree number times 100. Height growth was determined by using measuring tapes, root collar diameter and diameter at breast height was measured by caliper. The analysis was performed by using Statistical Analysis System (SAS version 9). Survival rate, tree height, root collar diameter and diameter at breast height data recorded from each moringa species were subjected to analysis of variance and Least Significance Differences (LSD) tests to enable comparison of the two moringa species.

Results and Discussion

Survival rate (%)

In terms of their survival rate, significant difference was not observed among the two moringa species at the age of one year (Table 2). However, after one year establishment, survival rate of *Moringa stenopetala* species was significantly higher *(P<0.05)* than *Moringa oleifera* (Table 2). The survival rate of the two moringa species at the age of three years under the present investigation showed that, survival rate of *Moringa stenopetala* species was higher (88.8%) and from *Moringa oleifera* only 77.7% survival rate was recorded (Table 2). In contrast to this study finding, at Bako, Western Oromia higher survival rate of *Moringa olifera*(100%) and 97.33% survival rate of *Moringa stenopetala* was recorded (Dawit *et al.*,2016). In addition, Musa and Bira (2020) indicated that in Harari Region, Ethiopia maximum 83.3 % survival rate of *Moringa oleifera* species was recorded. However, relatively similar to this study finding, in Northern Ethiopia 70.4% of survival rate was obtained from *Moringa Stenopetala* species (Abraham and Kidane, 2014).

Table 2. Survival rate and Tree height growth parameters of *Moringa stenopetala* and *Moringa oleifera* species over three years at Adola Sub site

Moringa Species	Survival Rate (%)			Tree Height(m)		
	2018	2019	2020	2018	2019	2020
Moringa stenopetala	100[a]	92.4[a]	88.8[a]	2.95[a]	3.95[a]	4.41[a]
Moringa oleifera	100[a]	85.4[b]	77.7[b]	1.77[b]	1.95[b]	2.21[b]
Mean	100	88.9	83.25	2.36	2.95	3.31
LSD (5%)	0.00	14.35	13.72	0.152	0.165	0.172
CV (%)	0.00	3.8	3.9	14.21	14.6	11.3

**Means in columns with the same letters are not significantly different at (P<0.05)*

**Means in columns with the different letters are significantly different at (P<0.05)*

Height Growth (m)

As the finding of this study indicated that, in height increment highly significant differences

(P< 0.05) were observed among the two moringa species during the study time. At the age of three years after establishment *Moringa stenopetala* had maximum heights of 4.41m and *Moringa oleifera* had minimum tree height of 2.21m (Table 2). However, the results of the current study is in contrast with (Korsor, M. *et al.*, 2019) indicated that in Central Namibia Semi-Arid Range land Environment the highest average height of 2.814 m was recorded from *Moringa oleifera* as compared to *Moringa ovalifolia*. Moreover, the finding of this study is in contrast with Dawit *et al.*, 2016. On their study results showed that maximum height of 3.97m was recorded in *Moringa oleifera* and the minimum height of 2.63m was recorded in *Moringa stenopetala*. Based on the finding of current study the recorded growth performance of *Moringa oleifera* in terms of survival rate and height increment was very low as compared to *Moringa stenopetala.* This could be due to *Moringa oleifera* species performed well at low altitudes in Dry and Moist lowlands agroclimatic zones, at altitude of 500–1,600 meters above sea level (Azene Bekele, 2007).

Table 3. Root collar diameter and Diameter at breast height growth parameters of *Moringa stenopetala* and *Moringa oleifera* species over three years at Adola Sub site.

Moringa Species	Root collar diameter (cm)			Diameter at breast height(cm)		
	2018	2019	2020	2018	2019	2020
Moringa stenopetala	3.75[a]	6.4[a]	7.9[a]	2.85[a]	4.15[a]	4.42[a]
Moringa oleifera	2.95[b]	5.3[b]	6.2[b]	1.67[b]	2.12[b]	2.46[b]
Mean	3.35	5.85	7.05	2.26	3.13	3.44
LSD (5%)	1.13	2.14	2.56	0.78	1.87	2.12
CV (%)	8.34	11.35	12.21	9.23	12.6	13.3

**Means in columns with the same letters are not significantly different at (P<0.05)*

**Means in columns with the different letters are significantly different at (P<0.05)*

Root Collar Diameter (Cm)

The results of this study showed that, there is significant difference among the two Moringa species in root collar diameter growth rate was observed. Root collar Diameter of both *Moringa stenopetala* and *Moringa oleifera* species significantly different at the age of their establishment increased (Table 3). The highest root collar diameter growth rate (7.9cm) was recorded in *Moringa Stenopetala*, while it was low in *Moringa oleifera* species which was 6.2 cm. Many research findings indicated that tree species having the greatest root collar diameter increment which grown tallest. Therefore, similar correlation between height and root collar diameter growth of multipurpose tree species was reported (Tilahun *et al.*, 2006; Abebe *et al.*, 2000). Similarly the present study also showed that the *Moringa stenopetla* species which have highest root collar diameter is taller than *Moringa olifera* species based on their recorded height data. In line with the present study, research findings conducted in Gimbo District, South western Ethiopa revealed that at the age of *Moringa stenopetala* increased growth rate of root collar diameter also increased (Getahun *et al.*, 2017).

Diameter at Breast Height (cm)

The present study revealed that, growth in diameter at breast height also significantly different among the two *Moringa stenopetala* and *Moringa oleifera* species. As depicted in Table 3, diameter at breast height growth of the two Moringa species was significantly different *(at P<0.05)* starting from first year establishment. As the finding of this study indicated that, *Moringa stenopetala* has show high diameter at breast height (4.42cm), while the recorded diameter at breast height of *Moringa oleifera* species was 2.46 cm.

Conclusion and Recommendation

It can be concluded that the two Moringa species namely *Moringa stenopetala* and *Moringa oleifera* species showing promising performance under the environmental condition of Adola Rede District. However, when the two Moringa species compared each other in terms of their survival rate *Moringa stenopetala* was significantly higher than *Moringa oleifera*. The recorded tree height of the two Moringa species showed that, height growth of *Moringa stenopetala* was significantly higher than *Moringa oleifera* species. The maximum tree height recorded from *Moringa stenopetala* was 4.41m and the minimum tree height of 2.21m was recorded from *Moringa oleifera* species. On the other hand, in terms of their root collar diameter and diameter at breast height growth parameters among the two Moringa species significant differences was observed. At the age of three years, the highest root collar diameter and diameter at breast height of *Moringa stenopetala* was 7.9cm and 4.42 cm respectively. However, the minimum root collar diameter and diameter at breast height of *Moringa oleifera* was 6.2cm and 2.46cm respectively during the third year of establishment. Based on the finding of this study both of Moringa species are a multipurpose tree of significant economic importance as it has vital for nutritional, industrial and medicinal applications. Therefore, for local communities of Midland Agroecology of Guji Zone, *Moringa stenopetala* and *Moringa oleifera* species are recommended for study of nutritional value and promotion for local communities of the study area and for sites with similar agro-ecological conditions.

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Assessment of Existing Agroforestry Practices in East Hararge Zone Oromia, Ethiopia

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Abstract

Agroforestry practices produce different benefits, which enhance household incomes and diversification of products. This study was aimed to identifying existing agroforestry practices and to identify perception behind of agroforestry practice and to identify the opportunities and major constraints related to agroforestry practices in Fedis, Kersa and Jarso Districts of the lowland, midland and highlands agro ecologies, of East Hararge Zone, oromia, Ethiopia. The study was based on a household survey conducted on 154 farm household heads; focus group discussions, key informant interviews and direct field observations were applied. The data was analyzed using analytical (SPSS 20.0) software packages to calculate descriptive statistics. Chi-squared tests were used to compare the agroforestry practices and agro ecologies. The result indicates that six Agroforestry practices (AFPs) exist in the study area namely; scattered trees on croplands (58%), hedge row intercropping (33%), home garden (22%), multipurpose trees on farmland (19%), live fence /boundary planting (18%), and wind breaks (4%) were dominant. *Significant respondent number (51.96%) of practices is involved in agri-silvicultural system, most of the farmer's (45.12%) have positive attitude towards Agroforestry practices in the study area. Most of the respondents agreed on agro-forestry practices increased the construction input, soil fertility, food, and fodder. On the other hand, sacristy of land, moisture stress, diseases and pests, inadequate seedlings availability, and inadequate extension services are the major constraints. Results of the* socio-economic characteristics *respondents showed that gender, age, family size, and land holding positively and significantly influence the decision of the determined practice of household's and were significantly affected the choice of agroforestry practice by the households. Based on the survey, it is concluded that scattered trees on farmland, hedge row intercropping, and home garden AFP dominant practices across agro ecologies and were the most appropriate agro-forestry practices. These agro-forestry practices increased the construction input, soil fertility, food, and fodder in the area of land sacristy, moisture stress, diseases and pests. Therefore, further the tree integration efforts of farmers should be guided by scientific principles, the interaction tree species with annual crops and economic analysis of the individual agroforestry practices, domestication of nitrogen fixing trees, fruit tree species, and promoting sustainable agroforestry should be carried out.*

Keywords: *Agroforestry practices, indigenous knowledge, scattered trees on crop land, multipurpose tree, small holder farmers, and cash crops*

Introduction

Severe land degradation affects the livelihood of many farmers in the lowlands and dry lands of Oromia, eastern Ethiopia. Agro forestry is a kind of land use system that has been practiced since long in many parts of the world. Agroforestry is a dynamic, ecologically based natural resource management system that, through the integration of trees/woody perennials in farm and rangelands, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels (ICRAF, 2006). This land use system has good potential for enhancing farm income diversification and rehabilitating degraded lands. In addition, agroforestry has the potential to reduce poverty and can efficiently be used in poverty reduction strategies of the tropical East African countries (Basamba et al., 2016). As a land use system that combines the three main components i.e. food crop, livestock and forest products, preferably on the same piece of land on a sustained yield basis, agroforestry offers potential for enhancing farm production and household farm income. At the same time, it reduces the conflicts between arable farming, livestock keeping, and forestry interests, especially in the high-potential areas that are facing intense population pressure (Dhakal et al., 2012).

A variety of agroforestry technologies is finding enormous application in the East and Central African region (Basamba et al., 2016). Based on agro-ecological diversity, different localities in Ethiopia undertake different agroforestry systems and practices. Some of agroforestry systems in Ethiopia are farm forestry in the south-western highlands, tree based soil and water management in Konso, forest-based resources management in Borena, Ecologically sound land use system in Gedeo and area closures in Tigray, North Shoa and North Wello (Berhane Kidane et. at 2008). Examples of agroforestry practices are: tree homegarden, Woodlot, Windbreaks/shelterbelts, Boundary planting, Live fences, Hedgerow intercropping, improved fallow, Intercropping under scattered or regularly planted trees, Trees on rangelands, Trees on soil conservation and reclamation structures etc. (Atangana et al.,2013).These contribute considerably to the improvements of household economy and food security (Thapa and Weber, 1994).

Integration trees into farmland, agroforestry helps to diversify income sustaining smallholder production for increased socioeconomic and environmental benefits. Serves as a buffer against increasing human and livestock population pressure, to pursue the scaling up of local efforts of maintaining trees in farm, to overcome the problem resulted from high dependence of the community on natural resource, to reduce the risks and increase the sustainability of both small and large-scale agriculture. They provide fuel wood for the household energy, building materials such as poles (Kebede, T., 2010). Furthermore, there are also fruit tree based agroforestry practices (Badege Bishaw and Abdu Abduilkadir, 2003).

In the management of agroforestry the traditional knowledge of local people is important, and in order to scale up the different agroforestry practices an appreciation of traditional knowledge is needed (ICRAF, 2006) and The existing farming system is the starting point for development (Christiansen et al., 2011). Most development interventions in the past failed due to lack of giving adequate attention to traditional knowledge (Miller et al., 2006). The future of agroforestry lies on the way researchers, workers, and policymakers understand the usefulness of the existing traditional agroforestry practices knowledge about trees in the agroforestry. In Ethiopia, information, on traditional agroforestry practices is generated from limited studies (Abebe, S. 2000., Mehari A. ,2012), Abiyu et al.,2015) and are more specific in terms of site, constraints and socioeconomic benefits (Zebene, A. 2001., Mohammad et al,.2011, Dechasa, Jiru. 1990, Abebaw, Z. 2006., Bishaw, B., and A. Abdelkadir. 2003, Musa, A. et al., 2020).

These studies would not provide adequate information for better understanding of existing agroforestry practices in Eest Hararge zone. There are several indigenous agroforestry practices in different agro-ecological region of Eest Hararge zone, but they are not well studied and documented. Besides to this the benefits of traditional Agroforestry practice on local community is not very much organized and identified specifically in the area. Collection of information on the existing agroforestry practices, assessing of farmers perception towards agroforestry practices and identifying its constraints is a prerequisite for agroforestry research and development work in the study areas. Therefore**,** the study was initiated, to identify the agroforestry practices of the farmers; to assess the perception of farmers towards agroforestry practices, and to identify the opportunities and major constraints related to traditional agroforestry practices in the study area of East Harvge zone, Oromia, Ethiopia

Materials and Methods

Descriptions of the study Area

Eastern Hararge is one of the 20 administrative zones of the Oromia regional state. It is located in the Eastern part of the country about 600 km of the capital, Addis Ababa (Figure 1). East Harerge Zone is geographically located 9^0 42' 41" North latitude and 42^0 0' 9" East longitudes. The zone is bordered on the southwest by Bale, on the west by West Hararge Zone, on the north by Dire Dawa and on the north and east by the Somali Region. The Administrative center of this zone is Harar. The capital town of the Zone is Harar, which is located at a distance of 526 km East of Addis Ababa. The area coverage of the Zone is 2,260,000 ha (22,600 km^2), comprising of 20 districts with a total population of 2,723,850, an increase of 48.79%. Hararge has a population density of 151.87. While 216,943 or 8.27% are urban inhabitants, a further 30,215 or 1.11% are pastoralists, 17% agro-pastoralists, and the rest are agriculturalists (74%).

A total of 580,735 households were counted in this Zone, which results in an average of 4.69 persons to a household, and 560,223 housing units. East Harerge zone is subdivided in to three major climatic zones known to be temperate tropical highland, locally known as dega (8%), semi temperate/tropical rainy mid land or woina dega (25%), and semi-arid/tropical dry or kola (67%) with the altitude ranges from 500-3405 masl and the temperature ranges from 130^c to 280^c, characterized with erratic rainfalls .Due to the huge population pressure, the population density of these zones is estimated at 0.025m2 per person with a land holding size of less than quarter of a hectare per household.

The major Agricultural activity in the area is mixed farming system. The dominant food crops grown in the study areas are Sorghum, Maize, Wheat, Barley, Pulses, Potato, Tomato and Groundnuts in their order of importance. *Khat* and Vegetables are the known cash crops. While high value tree crops such as *Mangifera indica*, *Percea Americana*, *Papaya crack*, *Psidium guajava (Guava)* in the lowland and midland and *Malus domestica* (Apple) in the highlands of Jarso woreda's are produced in some quantities. Major livestock reared in the zone are Cattle, goat and sheep are among the livestock species reared by the community.

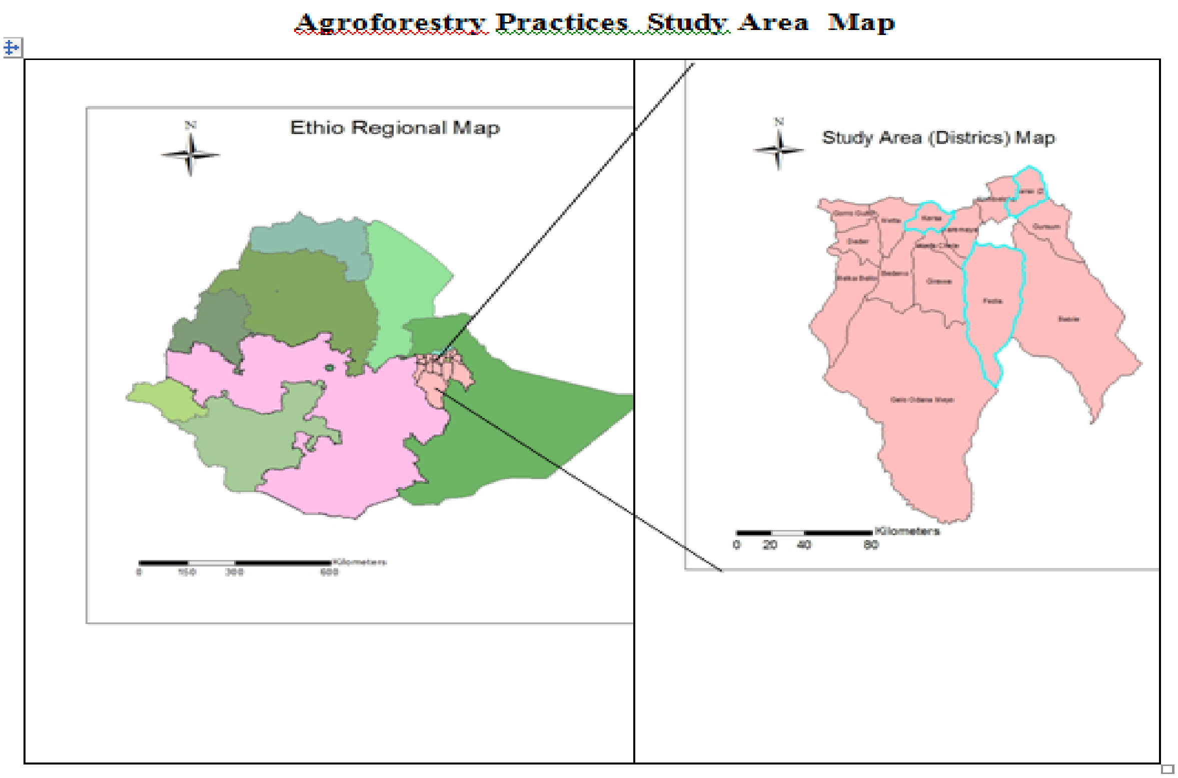

Figure 1: Study area map

Methodology

Selection of the Study Area

Indigenous agroforestry practices in the low, mid and highlands of East Hararge Zone were studied according to the following approaches. Secondary information was collected from reports, maps, censuses, thesis and other publications to have an overall picture of the agro ecologies. The specific sites for the study were identified in collaboration with a multidisciplinary research team, local people and administrative bodies. Reconnaissance surveys were undertaken. The study districts, Fedis, Kersa and Jarso were selected purposively based on it's their altitude range that from low land, mid land and highland of agro ecologies zones and their experiences of agroforestry practices. Two districts from each cluster were purposively selected. Then, from each district, two Kebeles were chosen purposively, based on their experiences of agroforestry practices and accessible to road.

Households were selected systematically from the three agro ecologies of the study area. The households were selected randomly from the listed farmers of the three districts of East Hararge zone. Informal surveys were conducted to gather qualitative information about an agroforestry practices and other related activities. Checklists were developed for the informal survey activities. Major issues that were included in the checklist were site for the practices, perception of farmers, opportunities and constraints. A formal survey was carried out using structured questionnaire to quantify and verify the informal survey findings. The formal survey involved direct field observation of the agroforestry practices, discussions with individual and group interviews, and key informant interviews techniques.

Sampling procedures and sample Size

The cluster sampling methods were employed. Accordingly, districts were clustered based on their altitude range that from low land, mid land and highland of agro ecologies zones and their experiences of agroforestry practices. Two districts from each cluster were purposively selected. Then, from each district, two Kebeles were chosen purposively, based on their experiences of agroforestry practices and accessible to road. Finally, farm households for interview were selected randomly from the sample Kebeles based on proportional to population size using (Yemane, 1967) formula. Two Kebeles were purposively selected among the 35, 19 and 18 rural Kebeles of lowland, midland and highland respectively in consultation with experts and development agents. The two Kebeles, Melka and Nage Umar kulle from lowland were selected; Ifa and Handhura kosum kebeles from midland were selected and Afugug and Amaddhiro kebels were selected based on the presence, success and in agroforestry practices.

A simple random sampling technique was employed to select sample households. Using the list of households in the Kebeles as a sampling frame, a total of 154 households were selected for the study. Accordingly, 52 households from lowland, 51 households from midland and 51 households from highland were respectively assessed.

Method of Data Collection

Both qualitative and quantitative techniques were employed to generate data. Accordingly, determining factors in agroforestry practice, reasons for their participation in agroforestry practices and opportunities and constraints they faced were assessed. The data were collected from two main sources: primary and secondary sources. Primary data was obtained through field observations, key informant interview, a formal survey/questionnaires and focus group discussions. Various information on demographic, household socioeconomic characteristics and institutional factors that may influence and/or support agroforestry practice were gathered.

The input of all inquiries from each individual and focus group checklists' data/ feedback, including the tree species occurs which are mainly serving in agroforestry system, perception of farmers on agroforestry utilities and constraints, and the types of agroforestry practices in the study area were collected for analysis.

Method of data Analysis

The primary data collected from household survey were checked, arranged, coded and entered into computer and cleaned and analyzed using Statistical Package for Social Science (SPSS version 20.0). Data collected from field observations, key informant interviews and focus group discussions were also qualitatively assessed using descriptive statistics that include frequency distributions, means and percentages. The socio-economic characteristics of the respondents such as age, gender, household size, land holding, level of education, marital status, role of household, occupation, labor, livestock holding, and crop production of agro forestry were analyzed. The descriptive analysis employed the tools such as mean, standard deviation, percentage, and frequency distribution. In addition, chi-square statistics were employed with respect to some explanatory variables. Hence, the collected data were analyzed using descriptive statistics such as frequency; average and percentage were used for data analysis. Pair wise ranking also were used to analysis the farmers 'constraints in agroforestry practices.

Result and Discussion

Household Characteristics of Sample Households
The results of this study are presented in four sections; the first deals with the household and socio-economic characteristics. The second presented identification of major agroforestry practices within the three different agro ecologies. The third description of perception about agroforestry practices of households is presented. The final section presented reasons for their participation in agroforestry practices and major constraints were assessed.

Age of the Household Head
The age of the sampled household heads had a range from 18 to 75 years and the average age of the sampled household heads was 34.69 years with standard deviation of 11.58. As indicated in Table 1 the presents the descriptive characteristics of the respondents, an average age of 34.69 years was dominated by working age group. This means that, on average, smallholder farmers in the study areas were relatively middle-aged. Therefore, the study found out that the populations of the surveyed areas were dominated by working age group.

Table 1: Descriptive Statistics of socio-economic characteristics of respondents (n = 154)

Socio-economic Variables	Mean	SD	Min	Max
Age of household	34.69	11.58	18	75
Household size	6.31	2.42	1	17
Land holding	0.44	0.40	0.13	2
Livestock holding	4.11	2.44	1	9
Crop production	2.90	2.51	1	7

Source: Survey Result, 2020

Family Size of the household head: Family size in this study is considered as the number of individuals who resides in the household. The average family size of the sample farm households was 6.31 with minimum of 1 and maximum of 17 persons. Therefore, the study found out that the populations of the surveyed areas were relatively higher household sizes (average of six members per household) than national household average size of 5.1 members per household (citation..). The Most of the time, large family size was assumed as an indicator of labor availability in the family to use integrated agroforestry practice and the increasing population number forced the farmers to manage their agroforestry practices at plot level. Household family sizes tend to influence traditional practices of agroforestry due to the fact that it provides more labor to manage agroforestry practices.

With regards to the **Land holding:** Average land holding size of households in the study areas was 0.44 hectare. According to the sample survey data, the land of the sampled household heads had a range from 0.13 to 2 ha and the average land of the sampled household heads was 0.44 ha with standard deviation of 0.4 and had a small acreage of land to planting trees. Land is the main asset of farmers in the study areas. Land size was thought to be a good proxy indicator of wealth which is important resource for any economic activities in the rural and agricultural sector. Hence, the availability of enough land per household is assumed as a potential for agro forestry using and investment for further economic progress. The average livestock holding of the households was 4.11 TLU. Higher proportions of the respondents have livestock number between 1-9 which is manageable around small land and with family labor. They were used integrated agroforestry practice with livestock and the increase their productivity. Crop production and livestock rearing are the main sources of farm income in the study areas.

Gender of the household heads: Sample households were composed of both male and female household heads. The result of the study indicated that out of the total respondents, 120 (78%) of them were male while the rest 34 (22%) of them were female (Table 2).

Table 2: Gender of house hold and education level of house hold of respondents (n = 154)

Variables	Frequency (f)	Percentage (%)
Gender of house hold		
Male	120	77.92
Female	34	22.08
Total	**154**	**100**
Education level of house hold		
Uneducated	75	48.7
Primary school	60	38.96
Secondary school	15	9.74
Diploma	3	1.95
Degree	1	0.65
Total	**154**	**100**

Source: Survey Result, 2020

Results of this study indicated that the existing agroforestry practices are mostly done by men because of the cultural values and responsibilities of men in east Hararge families. From the total 154 sample household heads, about 78 % of them were male and the remaining 22 % were female. The result revealed that the percent of male headed households of practicing agroforestry were higher than that of female headed households. Traditional agroforestry practices are mostly done by men because of the cultural values and responsibilities of men in East Hararge families. Again, generally males are physically stronger than females and can comparatively provide more labor

With regards to the educational status of sample **household heads**: Education is very important for the farmers to understand and interpret the agricultural information coming to them from any direction. Of the total 154 respondents, 48.7 % were uneducated, 38.96 % Primary school, 9.24 % secondary school, and 1.9 % of the respondents were diploma respectively. A better educated farmer can easily understand and interpret the information transferred to them by development agents and any other bodies. **Marital statuses** of the household: Household characteristics of sample households are presented in (Table 3).

Table 3: Marital status of house hold and role of house hold of respondents (n = 154)

Variables	Frequency (f)	Percentage (%)
Marital status of house hold		
Married	151	98.05
Widowed	0	0
Diverse	0	0
Single	3	1.95
Total	**154**	**100**
Role of house hold		
HH head	144	93.51
First spouse	6	3.9
Second spouse	0	0
Third spouse	0	0
Son or doughtier	4	2.6
Total	**154**	**100**

Source: Survey Result, 2020

With regard to marital status, from the total sample respondents 1.95 % was single while the rest 98.1 % were married households. The proportion of married respondents was much larger than the remaining unmarried categories. Hence, there is real difference in marital status of agroforestry married and single agroforestry practitioners in the study areas. Role of house hold: With Role of house hold 93.51% were household head and 3.90% were first spouse House hold head and Son or daughter 2.60%. Results of this study indicated that the existing agroforestry practices are mostly done by house hold head because of the responsibilities has given to head of household in east Hararge families.

With regards to the **Occupation** of the Respondents**:** From the findings, majority of the respondents 98% indicated they are Farming as their occupation. Others were 0.65 % can easily access information or have knowledge on agroforestry and therefore can influence the agroforestry practices in study area .Farmers are more likely to practiced agroforestry than any other occupation since they practice farming. It was conducted to understand the existing knowledge of farm households on the management of trees under different practices in separated agro ecologies. **Source of labor:** Labor is one of the major resources owned by farm families, with regards to the Source of labor of the respondents, 92.86% of the respondents were family labor, 3.25% of them hired labor, and 3.25% was exchange labor. It can be indicated that farming was the main type of traditional farming system in study site.

Table 4: Occupation and source of labor of respondents (n = 154)

Variables	Frequency (f)	Percentage (%)
Occupation		
Farming	151	98.05
Employment	1	0.65
Trading	1	0.65
Unemployment	1	0.65
Total	**154**	**100**
Source of labor		
Family	143	92.86
Hired	5	3.25
Exchange	5	3.25
Communal	1	0.65
Total	**154**	**100**

Source: Survey Result, 2020

With regards to **Districts:** of the total respondents 35.06% were Kersa district found in mid-altitude agro-ecology and 33.12% were Jarso district in highland agro-ecology, 31.82 % were Fedis district found in lowland area.**:** Of the total respondents most were living in mid-altitude agro-ecology. With agro ecologies the respondents, 35.06% of the respondents were midland, 33.12% of them highland and 31.82% was lowland agro ecologies in the study areas.

Table 5: Districts and agro ecological zone of Respondents (n = 154)

Variables	Frequency (f)	Percentage (%)
Districts		
Kersa district	54	35.06
Jarso district	51	33.12
Fadis district	49	31.82
Total	**154**	**100**
Agro ecological zone		
Low land (<1500)	49	31.82
Midland(1500-2300)	54	35.06
Highland(>2300)	51	33.12
Total	**154**	**100**

Source: Survey Result, 2020

Table 5 presents presence of agro forestry practices on farmers' plots in terms of districts with agro ecology**.** agro ecology result showed that in the midland agro ecological zone, household heads grow relatively practices agro forestry more on their farm plots than in the highlands and lowland, but the difference is only weakly significant. Relatively more records of trees on smallholders' farm plots in the midland agro ecological zone than in the highland explains the influence of agro ecology on smallholders' perceptions, attitudes, and management of trees in farmed lands. Agro ecological settings with rich agro biodiversity that include trees growing in farm plots contribute to sustainable livelihood security at the local.

Description of Major Agroforestry Practices

Major Agro forestry components in the East Harghe Zone, Oromia

In study area the land use systems include annual crop production, horticulture and agroforestry. The agroforestry practices include scattered trees in cropland agroforestry, alley cropping as hedge row intercropping agroforestry, home garden agroforestry, and multipurpose trees on farmlands, live fence /boundary tree planting agroforestry, and wind breaks. Food crops (sorghum, maize, wheat) and cash crops production (*Catha edulis*, vegetables and root crops) in large quantities are practiced in different types of Cropland agroforestry along with the annual crops. Agroforestry, trees and shrubs were grown in agricultural fields in association with crops, either as single trees, linear formations or woodlots in the study area. Most of the respondents are practiced agroforestry technology in the study effectively. The result of the study revealed that, among the different existing traditional of agroforestry practices, scattered trees in croplands were grown cash crops (*Catha edulis*) in the scattered trees as agroforestry practices.

Table 6: Types of crops, trees grown in the study area of Respondents (n = 154)

Land use priority	**Household's response**	
	Frequency	**Percent (%)**
Food crops	66	42.86
Crops(cash crops) with trees	58	37.66
Tree with crops	22	14.29
Tree crops with animals	8	5.19
Total	**154**	**100**

Source: Survey Result, 2020

Table 6 presents that about half of the farmers (42.90%) largely depend on annual crop production. A significant number (51.96%) of practices is involved in agri-silvicultural system (cash crops with trees and tree with crops). The study found that people are more interested in pasture culture (5.20%) with annual crop because of its immediate high cash return. Other farmers showed remarkable interest to grow annual crops in order to provide annual household consumption. Other system is practiced by a limited number of respondents. They also wanted to increase income by incorporating trees.

Types of Agroforestry Practice in the Study Area

Most of the farmers in the study learn agroforestry from indigenous knowledge systems and have a tradition of practicing Agroforestry practice. Recently their practices have been reinforced by the need for socio-economic and environmental sustainability. Six common Agroforestry types were found in the study area. The household survey result showed that scattered trees in croplands

(58%), followed by alley cropping as hedge row intercropping (33%), home garden (22%), multipurpose trees on farmland (19%), live fence /boundary tree planting (18%), and wind breaks (4%) (Table 6)

Table 7: Agro ecology and major agroforestry practices (AFP) in study area

Agro ecology *Agroforestry practices	**Agroforestry Practice**						**Total**
	Alley Cropping	Home gardens	MPT on farm land	Scattered trees in croplands	Boundary Planting	Windbreaks	
Highland	9	8	7	18	9	0	**51**
Midland	17	8	10	16	3	0	**54**
Lowland	7	6	2	24	6	4	**49**
Total	**33**	**22**	**19**	**58**	**18**	4	**154**

Agroforestry practices have differed significantly from each other at the 0.05 level.

Chi-Square Tests

	Value	**df**	**Asymp. Sig. (2-sided)**
χ^2-Value	23.275[a]	10	**0.010**
N of Valid Cases	154		

significantly from each other at the 0.05 level

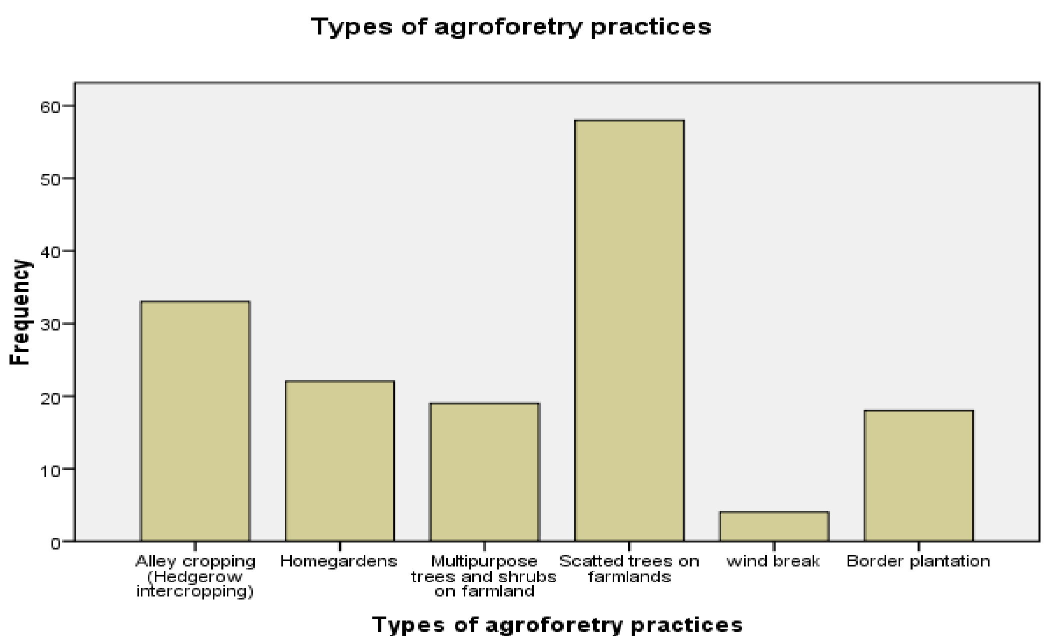

Figure 2: Agroforestry practices by frequency in study area

The major agro forestry practices involved in the study area were scattered trees on the farm land followed by hedge row intercropping agro forestry practices (Figure 3 and Table 7).Scattered trees on the farm land agro forestry practices had higher value with significant difference ($p < 0.05$) between highland and lowland agro ecology than that of the midland in the study area. This indicates that scattered trees on the farm land agro forestry practices are preferred to that of the other agro forestry practices on study area by the respondent farmers. Hedge row intercropping Agro forestry practices also had higher value with significant difference ($p < 0.05$) between highland and midland agro ecology than that of the lowland in the study area. This indicates that hedge row intercropping agro forestry practices is preferred to that of the other agro forestry practices on study area by the respondent farmers.

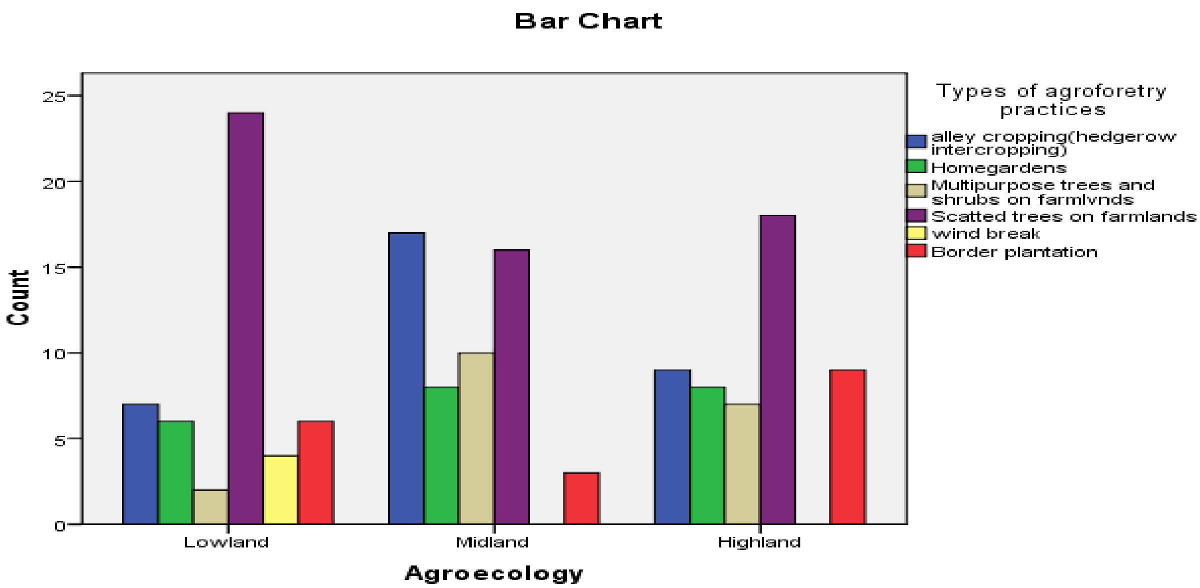

Figure 3: Types of agroforestry practices within agro-ecology in East Hararge Zone

Scattered Trees and Shrubs on the Farm:

Scattered trees on the farm have been a long tradition in the study area, within farm lands scattered trees are found and cover large areas. 58% dispersed trees grown in farmlands characterize a large part of the study areas .In this agroforestry practice, trees are managed to produce timber, firewood, fodder, fruit and shade. Common tree species, *Cordia africana*, *Olea africana*, *Acacia albida*, *Croton macrostachyus*, *Casuarina equisitifolia*, *Podocapus falucatus*, *Cupressus lusitenica*, *Eucalyptus camadulesiss*, *Eucalyptus globulas* and *Gravillea robusta* were wide spread on their farm. The crops grown in association with scattered agroforestry practice are sorghum, maize, wheat, barley and pulses such as beans. The fruits tree species: *Psidium guajava*, *Mangifera indica*, *Annona seneglensis,* and *Zizipus* are common. Particularly the decision to take new agroforestry technology may vary depending on their farm land size, as when their farm land size large and labor availability is low, then the farmers can be more ready to adopt agroforestry practice such as tree on crop land.

Alley Cropping (hedge row intercropping):
Out of 154 agroforestry practice 33% respondents are practice alley cropping in their farm land. Alley cropping is an agroforestry practice contains growing of food crop in the middle of hedge rows of planted trees and shrubs. The sorghum/maize and chat (*Catha edulis*) hedgerow intercropping in the eastern parts of Ethiopia and the growing of food crops between hedgerows of planted shrubs and trees, preferably leguminous species. The main objective ofthis practice is to improve soil fertility and water conservation.

Boundary planting: The planting of trees along the perimeters of farmers‟ properties for land delimitation, timber, fuel wood, soil conservation and wind protection. 18% Respondents planted or retained trees/shrubs along the boundary of their farms to protect their crops and as a source of different wood products. *Eucalyptus camaldulensis, Allophilus abssyinicus, Olea africana,* and *Doviyales abysinicus* were the familiar trees planted on farm boundaries.

Homegarden: A home garden is one of the agroforestry system practiced in the study area (22%). The main objectives of this practice are to produce food, fodder, construction materials and to gain income from the product. Crops such as chat, coffee, and numerous kinds of vegetables are dominant components of the study area homegerdens. The common fruit trees in the homegardens were *Psidium guajava*, *Mangifera indica*, *Annona reticulate*, and *Casimiroa edulis* are also practiced in homegardern agroforestry. Feed trees, *Leucenea*, *susbania*, *Catha edulis* and *Cordia africana* were planted in the home garden. Trees such as *Cordia africana*, *Grevillea robusta*, and *Acacia* species are among the species that form the upper story of home garden. Home gardens integrated mostly fruit trees combined with fodder crops, vegetable, beans and even maize on small gardens near to homestead. The result is also similar with the findings (Berhane Kidane *et. al*, 2008).

Multipurpose trees on crop land: trees are grown for fodder, cash income and soil fertility improvementTree species found in this area; *Cordia africana, Olea africana*, *Croton macrostachus*, and *Capparis tomentosa* species were commonly grown trees to provide fuel, building, fodder and improve soil fertility, conserve soil moisture and improve the microclimate of the area.

Wind breaks: Windbreaks are narrow plantings of trees and shrubs protect their land from heavy wind and animal damage. *Doviyales abysinicus,* and *Entada abyssinica* were planted for windbreak

Socio-economic Factors Affecting Agroforestry ractices
Major Agroforestry practices within the three different agro ecologies with the suggested socio-economic factors. There are different socioeconomic factors such as, gender, age, family size, land holding, education, marital status and occupation in agroforestry practices have been assessed. From among those, only gender of house hold, age of the household, and family size were important factors significantly and positively related to agroforestry practices and influencing practices (table 8).

Table 8: Correlation results of agroforestry practices with factors affecting the stud area

Socio-economic factors affecting agroforestry practices	AF Practices with P value
Gender	0.054*
Age	0.03*
Family size	0.004*
Farm land size	0.069*
Education level	0.55^{ns}
Marital status	0.99^{ns}
Occupation	0.77^{ns}

* Correlation significant at less than 5% probability level, ns=not significant

The analysis showed that male households relatively more practice agroforestry practices on their farm plots than female-headed households. But no significant mean differences (P<0.05) (table 8) were observed. The gender distinction in agroforestry practice on farm plots was ascribed to many different reasons, including that it was too difficult job for females, it is unfamiliar to females, because there is a perception that it is believed as a duty of men, and due to its work burden, social classification dictates that females' engagement should be in indoor activities, where their income is low. The relation of agroforestry practices differs with average age groups of smallholder farmers. The results of the study showed that middle (35 age) informants integrate more trees, along with possessing relatively more knowledge than younger people, with a significant difference (P<0.05). This agrees with the general fact regarding age-wise distribution of indigenous botanical and ecological knowledge among rural farming communities (citation). This needs to be focused on in future selection and expansion of tree plants on farmed landscapes; participation of knowledgeable becomes critical.

An increase in the household size by one member increases the likelihood of choosing agroforestry technologies by 5.57% (Ayuya *et al.,* 2012). Larger households with sufficient labor source tend to embrace agroforestry practices compared with those of small households. However agroforestry adoption may as well increase in small household sizes, perhaps for the reason that agroforestry is less labor demanding. Another study by Bzugu *et al.,* (2012) agrees that, much labor used in small scale farms emanates from the household, and therefore the larger the household the more labor available to carry outagricultural practices like agroforestry. Madalcho *et al.,* (2016) argues that larger households would have enough labor to practice agroforestry and are able to provide adequate management for the agroforestry practices, than smaller households. This is in agreement with Tefera (2016) who indicated that farmer's socio-economic characteristics namely household size, had a significant positive influence on the adoption of agroforestry.

Farmers Reason for Planting and Managing Trees in Study Area

Agroforestry practiced households are knowledgeable on the use of different trees they have grown on the farmland and have developed their own set of criteria for choosing what tree species to plant. During key informant interview, it was mentioned that tree species to be incorporated in to farmland must have a role in increasing farm income and soil fertility. Tree species with evergreen leave characteristics were kept around the residence, farm boundary and grazing land to provide shade and livestock fodder. The survey results indicated that increase farm income and provision of construction materials are the best criteria followed by tree species that are conducive for ability to increase soil fertility. Ability to increase shade service for human and livestock (Table 9). Accordingly, *Gravillia robusta, Cordia africana, Acacia* and *Sesbania* tree species were grown deliberately together with other crop components, while trees like *Eucalyptus cammaldulensis* and *Cuppressus lustanica* were grown around homes and as wood lots for construction and income generations purpose. Farmer's important reasons for planting and managing trees involved in the study area were identified. Small holder farmers in the study area have great awareness about the benefits of agroforestry practices. Most of the respondents believe that agroforestry practice is enhancing the overall productivity. The major reasons and benefits for planting trees species in agroforestry practices in the study area are in the order of its use includes: as provide construction materials, increase farm income, improvement in soil fertility, potable leaves by animals, provision of shade by trees (table 9).

Table 9: Farmer important reasons for planting and managing trees

Reasons for planting trees	**Household's response**	
	Frequency	**Percent (%)**
Provide construction materials	112	72.73
Increase farm income	22	14.29
Ability to increase soil fertility	9	5.84
Potable leaves by animals	9	1.30
Used for shade purpose	2	5.84
Total	**154**	**100**

Source: Survey Result, 2020.

This supports the findings of Biruk (2006), who concluded that farmers in south east langano, Ethiopia maintained trees/shrubs on their farms for different socio-economic purpose including medicinal products, provision of shade shelter, fodder, fuel wood and the like.

Perception of Farmers Towards Agroforestry Practices

The farmers' interest for practices of new agroforestry technology depends on their perception about agroforestry which indicated in table 10 below that most of the respondents were aware of both environmental and economic benefits of agroforestry. More specifically most of the respondents' perception towards agroforestry practices is that it increased farm income, soil fertility, decreased complete crop failure and a potential of solving their fuel wood needs. The farmers also believed that agroforestry practices are more profitable and less risky than other agricultural alternatives. However, the main problems of the farmers' attitude towards agroforestry are their negative thinking that this activity takes long time to generate income, and as a result they tried to practice activities that generate income in short period such as to fulfill their basic needs. The combination of different varieties of products which are both subsistence and income generating, support farmers to fulfill basic needs and decreased the risk of complete crop failure. The results in table 10 shows that most of the respondents agreed that agroforestry practice increase soil fertility 48.7% of the respondents, 37.01% of the respondents are strongly agree and 12.34% neutral only the rest are disagree perception. The farmer's perceptions about agroforestry practice increase farm income are positive about 43.51% are agree and 35.71% are strongly agree and 20.13% neutral and the rest of the respondent are disagree about agroforestry practice increase farm income. Their perception towards agroforestry practice reduce complete crop failure 44.8% are agree, 26.6% strongly agree, 25.7% neutral and the rest of the respondents are dis agree response. The fourth statement are about agroforestry practice saved time on collecting fuel wood from forests 43.5% are agree, 30.5% strongly agree, 24.7% neutral and the rest of the respondents are dis agree response. The others sustain natural conditions 44.8% are agree, 29.9% strongly agree, 23.5% neutral and the rest of the respondents are dis agree response.

The other statements are agroforestry practice takes long time to generate incomes and more respondents are 44.3% are agree, 31.2% are strongly agree, and the other are disagree and neutral response. Improve the surrounding conditions and for this more respondents are 46.7 % agree, 33.1% strongly agree, 18.0% neutral, and the rest of the respondents are dis agree response. The farmer's positive perception is shown as necessary steps in practices of agroforestry practice (Franzel *et. al*, 2002). The main problems of the farmer's attitude towards agroforestry are their negative thinking that this activity takes long time to generate income as a result they tried to practice activities that generate income in short period such as to fulfill their basic needs. The combination of different varieties of products which are both subsistence and income generating, support farmers to fulfill basic needs and decreased the risk of complete crop failure

Table 10: Perception of respondents about Agroforestry in the study area

Attributes of agroforestry practices	Response					
	1	**2**	**3**	**4**	**5**	**Total**
Increased soil fertility	1(0.7%)	2(1.3%)	19(12.34%)	75(48.7%)	57(37.01%)	154(100%)
Increased farm income	0	1(0.7%)	31(20.13%)	67(43.51%)	55(35.71%)	154(100%)
reduce complete crop failure	1(0.7%)	3(1.9%)	40(25.9%)	69(44.8%)	41(26.6%)	154(100%)
saved time on collecting fuel wood	0	2(1.3%)	38(24.7%)	67(43.5%)	47(30.5%)	154(100%)
Sustain natural conditions	1(0.7%)	2(1.3%)	36(23.5%)	69(44.8%)	46(29.9%)	154(100%)
Took a long time to get income	0	3(1.9%)	35(22.7%)	68(44.2%)	48(31.2%)	154(100%)
Improve the surrounding conditions	0	2(1.3%)	29(18.0%)	72(46.7%)	51(33.1%)	154(100%)

Source: Survey Result, 2020. 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree

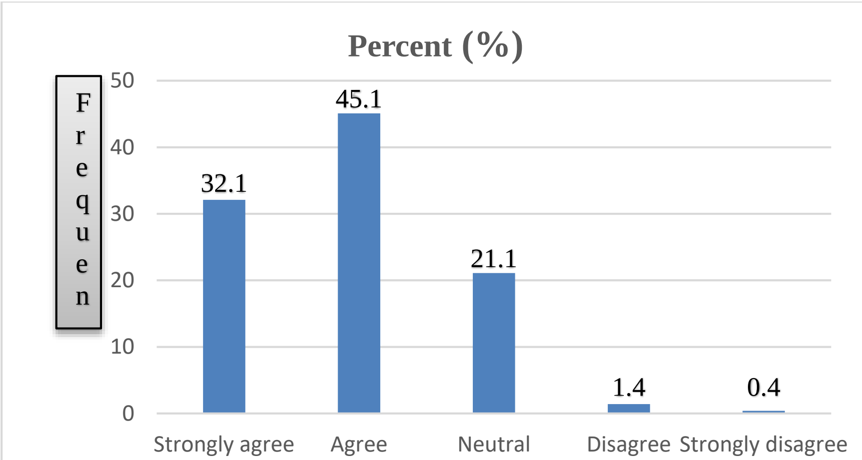

Figure 4: Farmer's perceptions about agroforestry practices in study area

Farmer's perceptions about agroforestry in the study area were found to be diverse (figure 4). The farmers practice agroforestry traditionally within their agricultural cropland, as well as in their homestead. In the study area a remarkable proportion of the farmers think positively about agroforestry systems. They believed that Agroforestry has a great role to increase productivity (36.4%) of land, 17.5% agreed on improved soil, 11% believed increase production in managing, and space utilization to meet their demands of wood, firewood and other forest products. 24.0% respondents agreed with this point of view (Kittur, 2013).

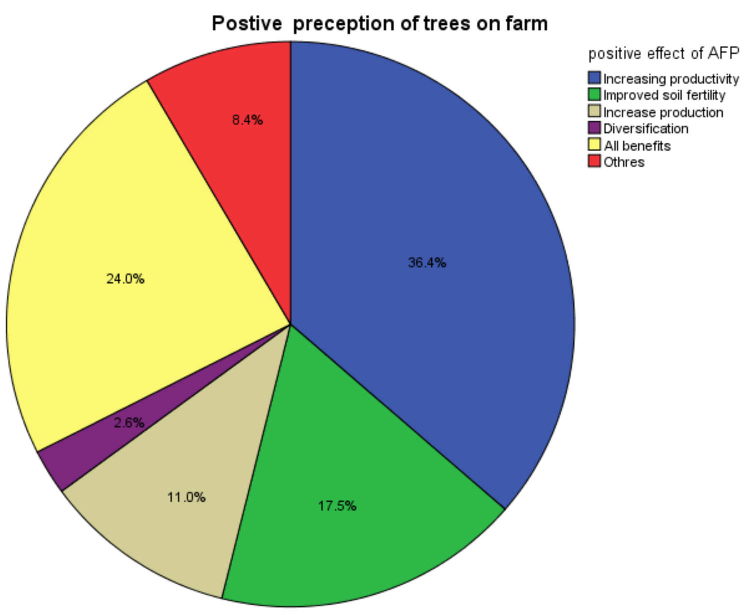

Figure 5: Positive farmer's perceptions about agroforestry practices in the study area

The farmers also perceived that Agroforestry is more profitable and less risky than other agricultural options (8.4%). From agroforestry practice the farmers reported that they can get agricultural crops in the short term as well as earn a large amount of cash from the sale of the trees in the long term. The table 10 below shows the farmers' perception on the tree planting with crops have in maximizing competition of resource 40.01%, shading effects 32.6%, Attract pests and diseases 10.44%, lower water tables 8.92 and attract birds 8.10% out of the total respondents. Similarly negative attitude among the farmers may be the main reasons for less practices of agroforestry technology (Chauhan. *et, al*.2009).

Table 11: Negative perceptions of respondent's bout agroforestry practices

Negative perceptions of trees	**Household's response**	
	Frequency	**Percent (%)**
Competition of resource	60	40.01
Shading	49	32.60
Attract pests and diseases	18	10.44
attract birds	14	8.92
lower water tables	13	8.10
Total	**154**	**100**

Source: Survey Result, 2020

Opportunities and Constraints of the Farmer's Preference of Tree /shrubs Species in Agroforestry Practice

Respondents indicated that there were opportunities for agroforestry expansion in the study area. This includes the increasing demand for wood products, the declined of soil fertilities, shortage of land increasing of climate changes, and effective seedling distribution. The result shows that as the resources become scarce farmers change their survival strategy either by migrating to productive areas or by diversifying their current practices. The agrosilvo-livestock keeping system practiced in the study area helped farmers to produce a wide variety of products such as fodder, fuel wood, livestock and crops. The districts have favorable climate for growing of trees the farmers have a habit of protecting and using trees such as *Acacia albida*, *Eucalyptus camaldulensis*, *Cordia africana* and *Croton macrosthays* in lowland areas and *Juniperus procera*, *Podocarpus fluctus*, *Acacia abyssinica*, *Eucalyptus cammaldulensis* and *Cuppressus lusitanica* in highland area grow naturally on farms. In the midland agro ecologies there is a better potential and experience for improving agroforestry than others agro ecologies because of strong tradition of growing trees and intercropping of trees with fruit trees and vegetables. Therefore, excellent opportunities for improved agroforestry practices. The farmers' plant/protect trees on farmland and appreciate their role in improving soil fertility.

Major constraints to adopt agroforestry practice are shortage of land for tree planting 58.44%, shortage of Rainfall 29.87%,and Disease and pastes 5.19% more barrier to adopted agroforestry practice. Therefore; farmers need to be provided with appropriate seedlings and encouraged to plant on farms. Appropriate planting and management techniques need to be developed and extended to farmers. Besides, screening should be carried out to select suitable varieties or provenances for distribution to farmers. Hence it is necessary to carryout agroforestry trials in relation to intercropping designs, spacing, planting techniques, and management of shaded trees.

Table 12: Constraints that influences farmer's not participating agroforestry practice

Major constraints	Frequency (f)	Percentage (%)	Rank
shortage of land for tree planting	90	58.44	1st
Shortage of Rainfall	46	29.87	2nd
Disease and pastes	8	5.19	3rd
Lack of seedlings availability	7	4.55	4th
Inadequate extension agents	3	1.95	5th
Total	**154**	**100**	

Source: Survey Result, 2020

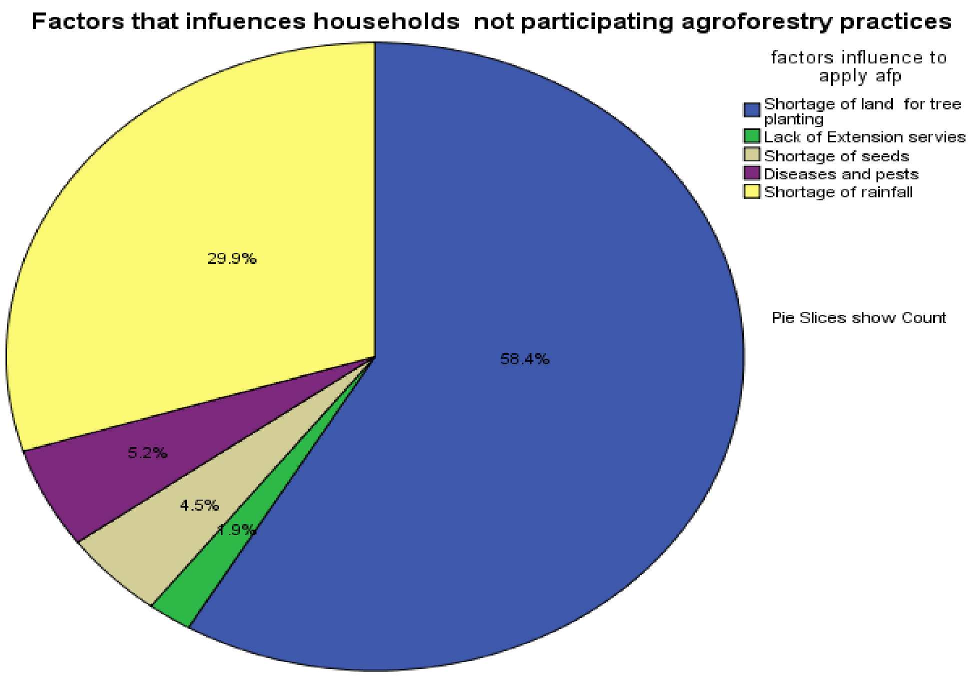

Figure 6: Major constraints to adopt Agroforestry practices in the study area

Conclusion and Recommendations

This study addressed assessments of agroforestry practice, perception of farmers towards agroforestry practice and opportunities and major constraints related to traditional agroforestry practices in the three agro ecologies of East Hararge zone. Respondents' demographic variables : age, gender, household size, land size, level of education, marital status, role of household, occupation, and labor were discussed as influenced the implementation of agroforestry practices. There was also significant correlation between the respondents' characteristic variables of age, gender, family size, and land size with their perception of agroforestry. Some of the major Agroforestry practice that has commonly practiced in the study areas *a*re scattered trees on farm lands, hedge row intercropping (alley cropping), home garden, multipurpose trees in crop land, farm boundary tree planting/live fence and windbreak planting types of agroforestry practices used in the area. From this study we conclude that agroforestry technologies that are practice in the study area are six types.

The perceptions of farmers towards agroforestry practice are positive and they are aware that agroforestry practices increase farmers' income, soil fertility, decreased complete crop failure and a potential for solving fuel wood shortages. The main challenges associated with adoption of agroforestry practices are shortage of land for tree planting, shortage of rainfall, and disease and pastes, the long time it takes to give benefit and the demands for labor and capital to practice agroforestry technology as a result they tried to practice activities that generate income in short period and with limited capital to fulfill their basic needs. Most of the farmer's (45.12%) have positive attitude towards Agroforestry practices in the districts Therefore, agroforestry practice could be one option to improve small farmer's life in study site. Based on the main finding for the study the following recommendations are made.

1) Agroforestry practices that are practice in the study area are only six it should be diversified through providing the necessary material for adoption of more agroforestry practice for farmers. So, further researches should need diversified.

2) Even if farmer's perceptions towards agroforestry practice are positive most of the farmers still not adopted agroforestry practice in the study area. So adoption of agroforestry practice should be improved in the different agro ecological zone.

3) Further researches should be done on assessment of adoption of agroforestry practice in the future in the study area.

4) Further researches should be done on propagation and interaction tree species with annual crops and economic analysis of the individual agroforesty practices in the future in the study area

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Adaptation and Growth performance of Lowland Bamboo species at Haro Sabu condition

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Abstract

Bamboo is a fast growing plant species than other and starts to yield within three or four years of planting. Even though Ethiopia is one of the most endowed countries in having huge coverage of bamboo resource in Africa, the country has narrow genetic diversity only has two species; Yushania alpine (highland bamboo) and Oxytenanthera abyssinica (lowland bamboo). The adaptation of lowland bamboo at Haro Sabu Agriculture Research Center conducted from 2016 to 2019 to evaluate the adaptability potential of different performance of lowland bamboo species and to identify the best performing of lowland bamboo species around Haro Sabu areas. Based on the objectives, four different lowland bamboo species were collected from Bako Agriculture Research Center. The species are: Oxythenantera abyssinica, Guadua amplexofolia, Dendrocalamus hamlitonii and Dendrocalamus memebranceous among those mentioned only Oxytenanthera abyssinica are indigenous the rest are exotics. The experiment was laid out in RCBD with three replications. The selected bamboo species has good survival and adaptability at Haro Sabu area except some growth variation. Despite this fact, Dendrocalamus asper species is show high difference in new emerging shoots, internodes length, culm height and culm diameter whereas, Oxythenantera abyssinica revealed low in all growth parameters. So, based on these results we recommend Dendrocalamus asper, Dendrocalamus hamlitonii and Dendrocalamus memebranceous for different production since they have a good internodes length, ability to emerge new shoots, culm height and diameter while the growth of Oxythenantera abyssinica is quite different when compare with others. Therefore, the adaptation of lowland bamboo under Haro Sabu and related agro ecologies is reliable so, we recommend for further economic and livelihood benefits for different stakeholders through expanding the plantation.

Keywords: Lowland Bamboo, Exotic, Indigenous, Plantation

Introduction

Bamboo is a perennial plant, which belongs to the Poaceae (sometimes called Gramineae) family (Wang X. 2006). In terms of taxonomy, it is considered as a giant grass. There are over 1,500 species of bamboo (Sharma 1980) and Africa alone has 43 species (Kigomo, 1993). Ethiopia is one of the most endowed countries in area coverage of natural bamboo forest of the country that estimated to have about 1 million ha, which is about 7% of the world total and 67% of the African bamboo forest areas (Embaye ,2000). Bamboos are native to both temperate and tropical climates, and therefore naturally distributed all over the world, with the exception of Europe and Antarctica (McClure 1966).

Even though Ethiopia is one of the most endowed countries in having huge coverage of bamboo resource in Africa, the country has narrow genetic diversity only has two species: *Yushania alpine (High land)* and

Oxytenanthera abyssinica (Lowland). In addition the most puzzling aspect of the bamboo life cycle is its flowering behavior. Bamboo is mostly monocarpic following it dies after flowering; without appreciating its economic return due to lack of scientific information in Ethiopia.*Oxythenantera abyssinica* is a clumping (sympodial) type bamboo with solid culm at maturing age. It has an average culm diameter of 5 cm, and is 7 m high. This species grows at an elevation of between 1000 to 1800 m above sea level and is widely distributed in lowland areas of the country. On other hand bamboos has multiuse and fast growing species that has potential in improving the livelihood of people. It has immense potential in reducing carbon dioxide that is blamed for environmental pollution and the most valuable species for environmental protection. Bamboo is a millennium grass that contributes to government vision of getting itself in the list of the middle-income countries of the world in about the forthcoming two decades by boosting the income of farmers (Poudyal, 1991).Bamboo is also used in Asia, at household and cottage-industry levels, to produce mats, scaffoldings, ladders, sticks, hand tools, brushes, pipes, umbrellas, toys, sports goods, musical instruments, spears, arrows, rafts, fishing rods, caps, baskets, flower pots and many other items (Ohrnberger, 1999; Poudyal,1991 and Oye, R. 1980). In this way, rural people can satisfy their own needs and supplement their income. Bamboo is also the preferred material for shade construction in plant nurseries, and for props to support the growth of agricultural crops like banana, tomatoes, and flowers

Bamboo shoots are a popular food in Asia, and the nutritional value is comparable to those of many commercial vegetables (Suwannapinut, *et al.*, 1990). They are also consumed in Ethiopia by the rural people living near the bamboo forests, albeit less popular. Boiled rhizomes are also eaten in these areas. There are reports indicating that "enset" (Ensete ventricosum) helped the Ethiopian people to limit the effects of drought and famine. Bamboo could also, probably, be used to supplement food requirements in Ethiopia. A panel held under the theme Drought in Ethiopia on 19 August 1999, in Addis Ababa, recommends, among other things, drought resistant crops and income-generating activities to resist and minimize the effects of recurring drought (Kassahun, 2000). As a multipurpose, drought resistant species, bamboo (particularly the lowland species) is suitable for these objectives. Deforestation is one of the most serious environmental hazards in Ethiopia (Kebrom, T. 1999). The country lost 77% of its forest land between 1955 and 1979 (Kassahun, 2000). and this decline has continued to the present. The major consequences are losses in protective cover, soil erosion, flooding, water-quality deterioration, drought, and all the synergetic negative effects of these losses. Because it is a fast growing plant, which is adaptable to low quality sites (particularly lowland species) bamboo has the capacity to redress many of the problems in large areas of Ethiopia. It has high soil conservation potential. The rhizomes and roots grow in all directions forming a complex network of up to more than 1 m depth belowground, which effectively holds soil particles together, thereby, preventing soil erosion and promoting water percolation and the litter fall of Bamboo improves soil structure and fertility (Christant *et al.*, 1996).

The above ground part of bamboo helps to reduce erosion caused by rain, by interception, and also shelters the soil from wind erosion. Bamboo has effectively restored the vegetation cover in denuded lands in the Philippines (Bumarlong and Yagi, 1984). Bamboo is also planted as an ornamental species owing to its grace, attractive foliage, and easy-to-shape clump (Tewari and Bindhi, 1979). The high growth rate of bamboo is of course closely associated with high water and nutrient consumption. This makes it suitable for vegetation filter purposes (Perttu, 1993). a biological means of waste purification, whereby most of the pollutants in the waste are used for biomass production through the plant-growth process. Increased biomass production means that carbon sequestering is enhanced and oxygen release increases. These are not unique characteristics for bamboo, but it does excel most species in growth rate. These qualities all make it an ideal species for urban plantations as hedges, as a buffer near waterbodies and surrounding waste deposits. This is in addition to its uses in production, e.g. to supply biofuel and products for construction and furniture industries for urban populations.

Bamboo is a fast growing and high yielding perennial plant with a considerable potential to the socioeconomic development and environmental protection (Baghel *et al.*, 1998; Kumar *et al.,* 1998; Perez *et al.*, 1998). Therefore it is important to introduce and adapt high economic value of exotic bamboos species to improve the income of small farm holder, to divers the genetic resources of bamboos species and for environmental protection in Ethiopia. However the presence study was conducted to evaluate adaptability potential and growth performance of four lowland bamboo Species under Haro Sabu Condition.

Materials And Methods

Description of Study Area

The study was conducted at Haro Sabu Agricultural Research Center which is located in Kellem Wollega Zone of Oromia Regional State, Ethiopia. It is found at 550 km away from Addis Ababa, 89 and 110 km from the nearby towns, D/Dollo and Ghimbi, respectively. The elevation of the center is 1300-2000 m.a.s.l and temperature 23-34 0c, rainfall 1000-1300mm.

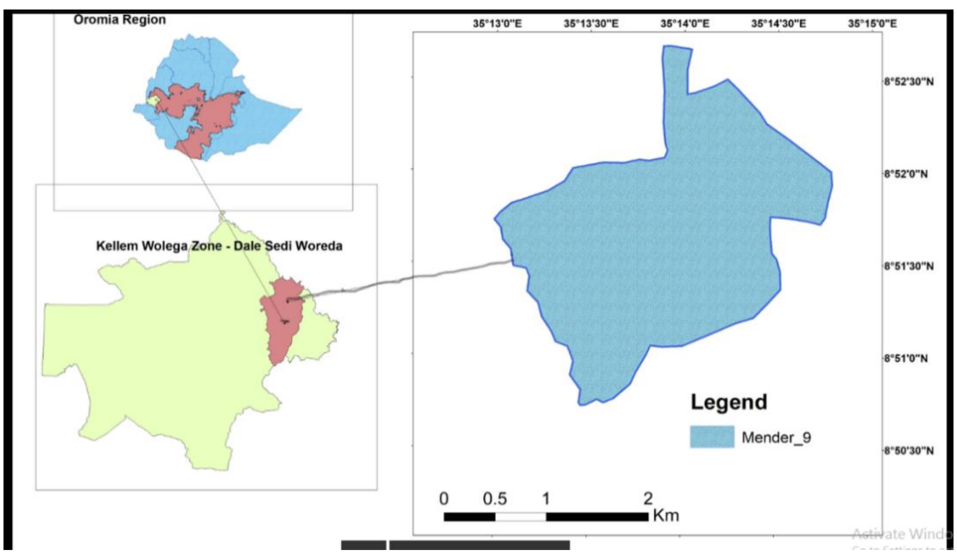

Figure 1. Map of study area.

Treatments and Experimental Design

The experiment was laid out in RCBD with three replications. The distance between blocks and plots was 5 m and 4 m, respectively. The space between each plant was 3 m and the plot size was 1470 m^2 with a total of 4 plants per plot and 48 total plants. As a treatment four lowland bamboo species were *Guadua aplexifolia /Dendrocalmus asper, Dendrocalmus Hamletonii, Dendrocalmus Membracias* and *Oxytenanthera abyssinica.*

Data Collection and Analysis

To achieve the given objective data on such parameter were collected; number of Bamboo seedling survived, Number of new emerging bamboo shoots, RCD of the emerging shoots, Culm diameter, Culm height, Internodes length, and Number of nodes per plant. The collected data were analyzed with analysis of variance (ANOVA) following the General Linear Model (GLM) procedure using SAS statistical software of 91.3 versions. The important variation, mean separation using LSD was conducted at 5 % significance level.

Results and Discussion

Number of Bamboo Seedlings Survived

Mean value of the survival rate showed that there were high significant difference ($p<0.000$) among lowland bamboo species (Table 1). The highest mean was observed from Guadua aplexifolia /Dendrocalmus asper species that followed by Dendrocalmus Hamletonii, while the least mean was recorded from Oxytenanthera abyssinica. Dendrocalmus asper revealed the good survival rate. This might be due to the suit of the species at Haro Sabu condition. However, Oxytenanthera abyssinica illustrate low survival because the seedlings of Oxytenanthera abyssinica are highly preferred by termite which might have contributed to their poor adaptation compared to other species.

New Emerging Number of Bamboo Shoots

There was significant difference ($P<0.000$) in mean new emerging shoot between different lowland bamboo species. Based on the analysis results of the four years data *Dendrocalmus asper* bamboo species revealed a highest mean value on the number of new emerging shoots followed by *Dendrocalmus hamletonii* (Table 1). Dendrocalmus asper species showed a good performance in emerging new shoots. This is due to the well performance, adaptability and producing new emerging shoots ability of the species when compare to the other lowland bamboo species. The result is similar with the report from West Hararghe, Mechara on station (Diriba *et al*., 2019).

Root Collar Diameter

There was significant difference ($P<0.05$) between lowland bamboo species in mean root collar diameters of the species. In 4 years growing season, *Dendrocalmus asper* (3.47 cm), *Dendrocalmus Hamletonii* (2.59cm) and *Dendrocalmus membracias* (0.8cm) recorded the highest root collar diameter. However, *Oxytenanthera abyssinica* recorded the least in root collar diameter (0.36), (Table 1). In present study the highest Root Collar Diameter was recorded for *Dendrocalmus asper*, but study done in West Hararghe, Mechara on station (Diriba *et al*., 2019) recorded the highest root collar diameter for *Dendrocalmus Hamletonii*. The difference in the root collar diameter of species can be due to their difference in adaptation to site condition.

Table 1: Means Comparisons between treatments at 0.05 significant levels (Mean ± SE)**.**

Bamboo Species	Survival Rate (%)	AV.NES(No)	RCDES(cm)
Dendrocalmus Hamlitonii	66.6 ± 2.369	1.8 ± 0.500	2.595 ± 1.224
Dendrocalmus asper	100 ± 0	2.105 ± 0.374	3.477 ± 1.530
Dendrocalmus membracias	25 ± 0	0.585 ± 0.356	0.8 ± 0.543
Oxytenanthera abyssinica.	2.27 ± 0	0.27 ± 0.199	0.366 ± 0.130
P value	0	0	0.05

Culm Diameter

The mean value of Culm diameter showed significant difference at ($p<0.029$) between species.
The highest mean was observed from *Dendrocalmus asper* species that followed by *Dendrocalmus hamletonii* and *Dendrocalmus Membracias*, while the least mean was recorded from *Oxytenanthera abyssinica* (Table 2).

Culm Height

The mean value of Culm Height showed no significant difference at ($p<0.029$) between species. However, study by Terefe et al. (2016) showed that mean value of Culm Height showed significant difference among species in which *Dendrocalmus hamletonii* showed highest Culm height.

Internode Length and Number of Node

The mean value of an internode length showed significant difference at ($p<0.000$) level between treatments. The highest mean was observed from *Dendrocalmus asper* that followed by *Dendrocalmus Hamletonii*, while the least mean was recorded from *Oxytenanthera abyssinica* (Table 2). Moreover, the mean value of number of nodes showed significant difference at ($p<0.000$) between the species. The highest mean was observed from *Dendrocalmus asper* while the least mean was recorded from *Oxytenanthera abyssinica* (Table 2).

Table 2: Means Comparisons between treatments at 0.05 significant levels (Mean ± SE).

Bamboo Species	CD(cm)	CH(cm)	IL(cm)	NN(no)
Dendrocalmus Hamlitonii	2.525±1.347	18.65±30.84	10.68±2.775	15.98 ± 2.775
Dendrocalmus asper	3.302±*1.953*	20.60±34.19	11.46±4.051	26.18 ±7.64
Dendrocalmus membracias	0.82±0.602	6.287±10.86	2.73±1.291	5.6 ±2.382
Oxytenanthera abyssinica.	0.31±0.174	0.386±0.10	1.246±0.388	1.96± 0.492
P value	0.029	0.658	0	0

Conclusion and Recommendation

Among the selected bamboo species *Dendrocalmus asper* were showed highest performance followed by *Dendrocalmus hamletonii and Dendrocalmus memebranceous*, by all parameters. Based on the results of growth parameter, we rank performance of species as *Dendrocalmus asper, Dendrocalmus hamletonii and Dendrocalmus memebranceous* the first, second and third orders respectively. However *Oxytenanthera abyssinica* performed least and failed to adapt in the study site. Generally we recommend pre-scaling up and demonstration for *Dendrocalmus asper*, *Dendrocalmus hamletonii and Dendrocalmus memebranceous* that have high growth performance. However *Oxytenanthera abyssinica* need further investigation to approve the problem.

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Adaptation and Growth Performance of Multipurpose Trees at Meti site Sayo district, Kelem Wollega, West Oromia, Ethiopia

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Abstract
Multipurpose tree and shrubs species (MPTS) play a considerable role in Agroforestry system. *The study was conducted to evaluate Adaptability and growth performance of five tree species at Meti for five years. Seedlings of those species (Acacia Senegal, Pinus patula, Olea africana, Callistmon citrinus and Spathodea nilotica) were out planted on a plot of 14 m x 14 m for each species based on their recommended spacing between and within row. Growth parameters; diameter (RCD and DBH), Height and survival rate were measured and recorded by an interval of 3 months. Among tree species planted in the study area C. citrinus gained maximum height followed by S. nilotica. But A. senegal gained the least mean height during monitoring. Similarly, the High mean value of root collar diameter was recorded for S. nilotica***,** *O.africana while it was low in P.patula. The survival result also showed, S. nilotica were higher (100%) followed by O.africana (987%), A.senegal (98%), and C.citrnus (96.6%), while survival of P. patula were the lowest (66.6 %). Thus, poor survival and growth response were observed on P. Patula that might be explained as a response to the specific site condition of the study area. Generally, these findings may help forest managers (stakeholder) to properly allocate species into the site that grow and adapt well. Further testing of provenances of the best performing species is recommended to select the most adaptable ones for such areas for future forest plantation establishment at wider scale; on which success of forest plantations depend.*

Keywords: Multipurpose trees, growth performance, Survival Rate, Adaptation

Introduction

Vegetation cover of the country in general and that of Oromia in particular have been decreasing from time to time at a faster rate than one can imagine. The reduction in vegetation leads most productive area of the land to severe degradation. Land degradation is the process that lowers the current and/or potential capability of land to produce goods such as crops, livestock or timber, or to provide services such as unpolluted water (Muya *et al*, 1997). The failurity of the land to give such goods will have a direct negative implication on ecologic, economical and soil value of the area. The causative agents for land degradation are both biotic and a biotic, of which destruction of natural vegetation mainly forest by natural as well as man-made is the major and the number one problem in most developing countries like Ethiopia.

As the land is degraded the biological composition will decrease and hence, reduction in economic growth, change in micro and macro climate, loss of valuable species, which in turn leads to the occurrence of wood and food insecurity become the periodical problem in the country. Starting from some time ago, the reduction in land productivity due to land degradation touches the attention of many people from different fields of profession. Land degradation in the Ethiopian highlands (i.e. areas above 1500m a.s.l.) has been a concern for many years (Lakew *et al,* 2000). To overcome this problem, the researcher, bureau of environmental protection, responsible NGOS and over other related professionals in collaboration with the local people have been trying to develop strategies for the rehabilitation purpose. Some among the others of rehabilitation techniques practiced in many parts of the country for more than decades are area closure, reforestation, enrichment planting and the like. All the above mentioned approach have their own limitations like, in area closure method there should be soil seed bank which can regenerate after the area is closed against any external interference. In reforestation program, the soil should have some fertility in order to support the planted tree for initial growth and likewise enrichment planting is practical in areas where the biological entities are less disturbed. But in areas where there is no soil seed bank, lack of soil fertility for initial plant growth and highly disturbed that mean under severe degradation, the rehabilitation strategies listed might not be as such practical. So, such area needs special concern to develop land modification as an alternate method through fertilization and put in practical to rehabilitate. The plant deficiencies of N, P and K may be directly overcome by directly applying organic and/or inorganic fertilizers or through crop rotation and agro forestry (Ramakrishnan, 1994).

Agro forestry system has much potential for supplying fodder, poles, farm equipment, fuel wood and agricultural improvements (Yadessa *et.,al* 2000). Multipurpose tree and shrubs species (MPTS) play a considerable role in addressing such multifaceted demands in the mixed crop-livestock production system (Alemu *et.,al* 2000). The traditional agroforestry practices could be intensified by using fast growing multipurpose tree species (MPTS) to satisfy the demands of the growing population. Thus, before introducing any species to a given agro ecology, there is always a need for a well conducted field trial for matching of the species/provenance to a particular site (Mihretu *et.,al* 2004). Many species screening experiments have been conducted in different parts of the country (Alemu *et.,al* 2000). However information is scarce at kelem wollega to recommend promising multipurpose tree and shrubs species for use in agroforestry practices. Hence, there is a need to investigate adaptable and promising tree and shrubs species in the area. Therefore this trail was designed to evaluate the adaptation and growth performance of five multipurpose tree species to Meti condition.

Material and Methods

Description Study Site

The study were conducted at Ano Michael district which is located in Kellem Wollega Zone, western Ethiopia. It is found at 631 km away from Addis Ababa, and lies between latitude of 8º 52’51” N and longitude 35º 13’18’’ E (Figure 1) and altitude of 1515 m asl with minimum and maximum temperature between 14-34 0c, rainfall 1000mm (Dale Sadi Woreda Agriculture and Natural Resource office, 2020).

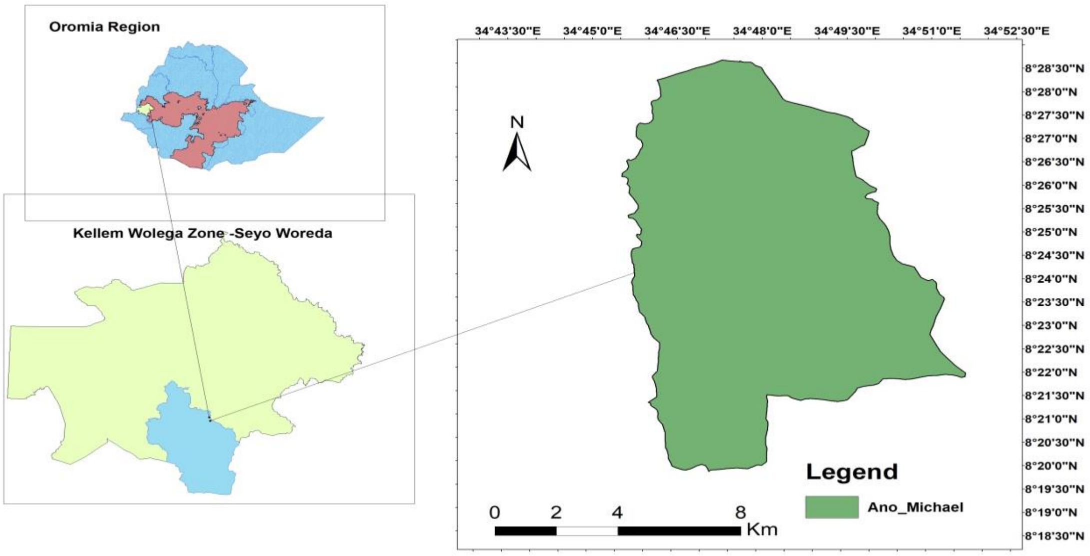

Fig.1: Map of the study area

Treatments and Experimental Design

Seeds of the multipurpose trees included in the trial (*Acacia Senegal, Pinus patula, Olea africana, Callistmon citrinus* and *Spathodea nilotica),* were obtained from forestry research centre. Seedlings were raised at Meti nursery sites with the recommendation of nursery activities. The experiment was laid out as in complete block design. Seedlings were out planted on a plot of 14m*14m for each species. The space between block were 3m, Spacing between row and within row were based on recommendation of each species.

Data Collection and Analysis

In order to fit the given objectives data were collected on the following parameters; Diameter (RCD or DBH), height and survival rate). RCD were collected only up to the tree reaches 1.3 meters in height where as DBH were measured for tree those have $\geq$ 1.3 meter in height while survival and Height were recorded up to the end of the trial. Finally, the data collected were analyzed using appropriate statistical package (SAS).

Results and Discussion

Survival

Survival data of the five species under the present investigation in average revealed that S. *nilotica* were highest (100%) followed by *O. africana* (98.7%), *A. Senegal* (98.0%) and *C. citrinus* (96.6%), while survival of P. *Patula* were the lowest (66 %). (Table 1).The poor survival and growth response were observed on *P. Patula,* This might be due to a response to the specific site condition of the study area.

Soil and below ground competition are also other factors that influence the growth and survival rate (Casper and Jackson, 1997)

Table 1. Mean survival of 5 years old multipurpose tree species tested in Meti site of Sayo district, West Oromia

Tree species	Survival (%)					Mean of 5 Years
	Year I	Year II	Year III	Year IV	Year V	
A.senegal	100	100	98.1	97.2	94.5	98
O.africana	100	98.4	98.4	98.4	98.4	98.7
C.citrinus	99	96	96	96	96	96.6
S.nilotica	100	100	100	100	100	100
P.patula	100	96.2	48.4	41.7	43.8	66

Height Growth

Among tree species planted in the study area *C. citrinus* gained the highest mean height during the first and third years of monitoring. In fourth and fifth years *S. nilotica* gained the highest mean height. *O. africana* attained highest mean height during the second year of assessment. Mean Height of 5 years indicated that *C. citrinus* attained maximum height followed by *S. nilotica.* But A. senegal gained the least mean height during monitoring (Figure 2).

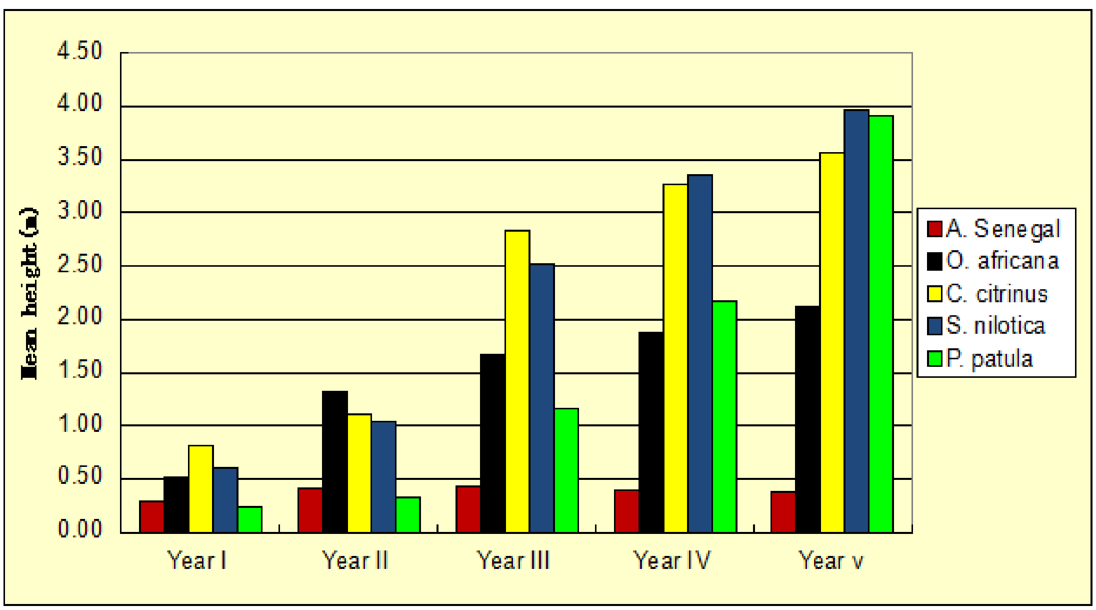

Figure 2. Mean height of 5 years old multipurpose tree species tested at Meti site of Sayo District, West Oromia.

Diameter Growth RCD and DBH

Mean RCD of 5 years indicated that S. Nilotica gained the highest followed by *O. Africana.* Whereas, *P. patula* gained the least mean RCD during monitoring of 5 years. (Table 2) Among tree species planted in the study area, *S. nilotica* gained the highest mean dbh during the second, third, fourth and fifth years of monitoring. The mean dbh was recorded only for *C. citrinus* during first year of monitoring. Mean dbh of 5 years also indicated that S. nilotica attained maximum dbh during the experiment. (Table 3)

Table 2. Mean RCD growth of 5 years old multipurpose tree species tested in Meti site.

Tree species	Year I RCD(cm)	Year II RCD(cm)	Year III RCD(cm)	Year IV RCD(cm)	Year V RCD(cm)	Mean of 5 Yrs.' RCD(cm)
A.senegal	0.567	0.915	1.002	1.141	0.923	0.995
O.africana	0.663	1.376	1.43	1.88	1.8	1.622
C.citrinus	0.867	1.5				1.184
S.nilotica	2.398	4.181	3.362	3.433		3.659
P.patula	0.47	0.644	0.898	0.873	1.411	0.957

Table 3. Mean DBH growth of 5 years old multipurpose tree species tested in Meti site.

Tree species	Year I	Year II	Year III	Year IV	Year V	Mean DBH(cm) of 5 Yrs.'
A.senegal						
O.africana		0.371	0.516	0.863	1.308	1.398
C.citrinus	0.412	0.785	1.377	1.957	2.676	1.163
S.nilotica		1.739	2.796	4.343	6.504	3.626
P.patula		1.3	2.361	3.241	5.107	2.679

Conclusion and Recommendation

The result revealed that the Survival rate of *S.nilotica* were the highest followed by *O.africana* and *A.senegal*. While *P.patula* were shown poor survival rate. The height data recorded by the end of the experiment revealed that there were highly significant differences among the species ($p<0.000$). *C. citrinus* gained maximum height followed by *S. nilotica.* A. senegal gained the least mean height during monitoring. Similarly, the High mean value of root collar diameter was recorded for *S. nilotica*, *O.africana* while it was low in *P.patula*. The survival result also showed, *S. nilotica* were higher (100%) followed by *O.africana* (987%), *A.senegal* (98%), and C.citrnus (96.6%), while survival of P. *patula* were the lowest (66.6 %).

Good performed tree species *(S.nilotica*, *A.senegal* and *O.africana*) were recommended for planting in area for soil conservation, timber production, shading purpose, and in general for multifunction purposes.

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Analysis of Past and Future Intra-Seasonal Climate Variability in the West Harerghe Zone, Oromia, Eastern Ethiopia

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Abstruct

Climate change and variability is already imposing a significant challenge to Ethiopia by deterring the struggle to reduce poverty and sustainable development efforts. Accurate estimation of the spatio-temporal distribution of rainfall and temperature; and observing its trends are crucial input parameters for securing sustainable agricultural production. Thus this study was aimed to characterize, test for variability and trends of rainfall and temperature variables in the west Harerghe Zone. Obseved climate data of five weather stations found at: Mechara, Hirna, Mieso, Bedesa and Chiro woreda were collected from National Meteorology Agency of Ethiopia.While, future climate data were downscaled under composite of 5 models for RCP 4.5 in MARKSIM DSSAT model. The study has reviled high variation in spatial intra- seasonal rainfall amount distribution and also inters- seasonal (temporal) distribution. Trend of observed Belg and annual rainfall amount was spatially inconsistent, but Kiremt and Bega rainfall amount had showed non-significant positive trend at all stations. Almost at all stations; the variability of onset date of Belg rain was more variable and less stable than Kiremt onset and cessation date(less variable). Thus, high variability and less stability of Belg onset date have indicated that the patterns could not be easily understood and decisions concerning crop planting and related activities are made with high risk. This study reported the non-significant late onset date of Belg rain at all stations. The observed mean annual maximum and minimum temperature had showed worming trend at all stations except mean minimum annual temperature that showed cooling trend at Hirna. The result of projection have notified that: expected spatially inconsistent trend of Belg rainfall amount. Kiremt rainfall amount had indicated significant reduction at all stations except at Hirna that indicated non-significant increasing trend. In contrary, Bega rainfall amount is expected to increase significantly at all stations. In general annual mean rainfall amount is expected to decrease significantly at Chiro, Mieso, Mechara and badesa whereas, non-significant reduction at Hirna to the end of 21 century. Moreover, all months and seasonal maximum and minimum temperature are expected to experience the worming trend at all stations till the end of 21Century.Thus, the author has forwarded the following recommendations: awareness should be created for each characterized climate variables spatially independently for community and concerned stakeholder, due attention should be paid to use meteorological forecast and early warning system, Projected climate change and variability impacts and possible adaptation strategies among different stakeholders has to communicated.

Key words: **Rainfall and Temperature Variability, Trend, Observed, Projection**,

Introduction

In Africa, precipitation amounts are likely to decrease for most parts of Sub-Saharan Africa (SSA) while rainfall variability is expected to increase (IPCC, 2014). World Bank (2010) argued that Africa is expected to experience mainly negative climate change impacts, in terms of an increase in the already high temperatures and a decrease in the largely erratic rainfall in its context of widespread poverty and low development. Africa, due to low adaptive capacity and high sensitivity of socio-economic systems, is one of the most vulnerable regions highly affected and to be affected by the impacts of climate change (IPCC, 2014). Current climate variability is already imposing a significant challenge to Ethiopia by deterring the struggle to reduce poverty and sustainable development efforts (NMA, 2007). World Bank (2010) has ranked Ethiopia among the most vulnerable countries in the world to the adverse effects of climate change; mainly due to its high dependence on rain fed agriculture, low adaptive capacity and a higher reliance on natural resources base for livelihood, among others (NMA, 2007; World Bank, 2010; EPCC, 2015).

Cheung et al. (2008) emphasized that in countries where their economy is heavily dependent on low-productivity rain fed agriculture, rainfall trends and variability are frequently mentioned factors in explaining various socioeconomic problems such as food insecurity. As a result, investigating the spatio-temporal dynamics of these meteorological variables is very crucial so as to provide input for policymakers and practitioners that help to make informed decisions. Riddle and Cook (2008) pointed out that since agricultural calendars in most parts of Africa are closely tied to the timing of local rainfall, improved forecasts of rainy season onset and termination would greatly benefit particularly for smallholder farmers. The implication here is therefore, quantification of climate change is necessary in order to detect the change that has already occurred and this will be further helpful to make predictions and for better preparedness. Tabari and Talaee (2011) have noted that trend analysis of climatic variables has received a great deal of consideration from scholars recently. Characterization of the intra-and inter-annual spatio-temporal trend of meteorological variables in the context of a changing climate is vital to assess climate-induced changes and suggest feasible adaptation strategies and agricultural practices.

In terms of rainfall occurrence, there are three seasons in Ethiopia, namely Bega (dry season) which extends from October–January, Belg (short rainy season) which extends from February–May and Kiremt or meher (long rainy season) which lasts from June–September (NMA, 2007). Rainfall in the short rainy season (Belg) is caused by moist easterly and south-easterly winds from the Indian Ocean, while in the main rainy season (Kiremt) is a result of convergence in low-pressure systems and the Intertropical Convergence Zone (Daniel, 2011; Tabari et al., 2015).

Sea surface temperature changes and El-Ni~no Southern Oscillation (ENSO) episodes in the Atlantic and Indian Oceans do have remarkable implication in the timing and amount of rainfall in Ethiopia (Shanko and Camberlin, 1998; NMA, 2007; Daniel, 2011; Kassa, 2015). Haile (1988) particularly underscored that, drought events in Ethiopia are caused by ENSO along with sea surface temperature (SST) anomalies in the Southern Atlantic and Indian Oceans combined which is exacerbated with anthropogenic activities. Rainfall distribution in Ethiopia affected by ENSO events and SST anomalies by displacing and weakening the rain-producing air masses. Kiremt rain account for 50–80% of annual rainfall totals in Ethiopia, which has high contribution to agricultural productivity and major water reservoirs. Thus, the most severe droughts in Ethiopia are usually related to a failure of the Kiremt rainfall to meet the agricultural and water resource needs (Diriba and Barnston, 2007; Kassa, 2015).

In a highly agrarian community like Ethiopia, where the livelihood of the population and the gross domestic product of the country are almost entirely dependent upon rain-fed agricultural production, analysis of precipitation and temperature patterns has paramount importance to cope with impacts on crop yields, animal breeding, power production and ecosystem management. Considering the history of recurrent drought and rainfall variability in Ethiopia, conducting long-term trend and variability studies with robust methods to obtain important information on what has been changing in the past few decades has a vital contribution (Daniel et al., 2014). As a result, accurate estimation of the spatio-temporal distribution of rainfall; and observing its trends are crucial input parameters for securing sustainable agricultural production (Dereje et al., 2012). Different trend analysis studies have been conducted in Ethiopia at different spatio-temporal scales and came up with mixed results. A study by Daniel et al. (2014) revealed a mixed trend for rainfall over the upper Blue Nile river basin of Ethiopia. Seifu and Abdulkarim (2006) had tried to cover relatively wider spatial coverage and disclosed no significant trend of Belg rainfall totals while, Kiremt rainfall exhibited a significant decreasing trend. Understanding the nature of past and future climate variability is important for increasing crop productivity and buffering situations where increased stresses are likely to occur (Sarr, 2012; Kassie et al., 2014). This study was, therefore designed with the objectives of:

To characterize rainfall and temperature variables in West Harerghe zone

To analyze variability of past and future intra- seasonal temperature and rainfall characteristics in West Harerghe zone

To examine the trends of past and future temperature and rainfall characteristics in West Harerghe zone

Materials and Methods

Description of the Study Area

The study was carried out in West Harerghe zone, Oromia Regional State, Eastern Ethiopia. The rainfall and temperature data of five weather stations found at: Mechara, Hirna, Mieso, Bedesa and Chiro *woreda* were used.

Table 1. Study site information

Woreda name	Station name	Altitude (m)	Longitude (0)	Latitude (0)	Mean Annual rainfall (mm)	Mean annual temperature(^{0}C)
Chiro	Chiro/Asebe Teferi	1792	40.87	9.07	876	20.00
Tullo	Hirna	1763	41.10	9.20	995	18.87
Mieso	Mieso	1332	40.75	9.23	761	23.10
Oda Bultum	Bedesa	1703	40.77	8.91	1053	20.20
Daro Lebu	Mechara	1780	40.32	8.60	1120	21.00

Data and Source

Observed climate data were collected from National Meteorology Agency of Ethiopia. Future climate data were downscaled under composite of; GFDL-ESM2M, BCC-CSM1-1, NorESM1-M, SIRO-Mk3-6-0 and miroc 5 models for RCP 4.5 in MARKSIM DSSAT model.

Tables 2. Used parameters and their Periods

	Observed				Projected	
Woreda name	Station name	Variables	Year interval	year	Year interval	year
Chiro	Asebe Teferi	Rainfall	1987- 2018	32	2025-2094	70
		Temperature	1987-2018	32	2025-2094	70
Oda Bultum	Bedesa	Rainfall	1967-2018	52	2025-2094	70
		Temperature	1983-2018	36	2025-2094	70
Mieso	Mieso	Rainfall	1970-2018	49	2025-2094	70
		Temperature	1991-2018	28	2025-2094	70
Tulo	Hirna	Rainfall	1971-2018	48	2025-2094	70
		Temperature	1983-2018	36	2025-2094	70
Daro Lebu	Mechara	Rainfall	1995-2019	25	2025-2094	70
		Temperature			2025-2094	70

Data Quality Control

Rainfall missing values in the data series were filled by using Markov chain first order simulation models. This is because of the fact that first order doesn't exaggerate the result and, moreover, it gives an accurate model estimates (NMSA, 1996 and Stern *et al*, 2006). Additionally, 4 point level moving average was used for filling missed temperature data. Data outlier detection test of rainfall and temperature data for studied station was carried out using XLStat software.

Analysis of Historical Rainfall Variability and Trend

In order to examine the rainfall and temperature variables variability statistical tools like mean, standard deviation and coefficient of variability were used. Coefficient of variability (CV) was used to classify the degree of variability of rainfall events as less, moderate and high. When CV < 20% it is less variable, CV from 20% to 30% is moderately variable, and CV > 30% is highly variable. Areas with CV >30% are said to be vulnerable to drought (Gebremichael *et al.*, 2014). Scientifically, it is computed using the following formula:

$$CV = \frac{SD}{\underline{X}} * 100 ----------------------------equation\ (1)$$

Where CV is Coefficient of variation, SD is the standard deviation and $\underline{X}$ is mean. According to Reddy (1990), the stability of rainfall is examined as follows: when standard deviation < 10 as very high stability, 10-20 as high stability, and 20-40 as moderate stability and > 40 as less stability. Where SD can be computed as:

$$SD = \sqrt{\left[\sum_{i=1}^{n} \quad \frac{(xi-\underline{x})^2}{n}\right]} ------------------------- equation\ (2)$$

Standardized Anomaly Index (SAI): Moreover, SAI was used to detect the variability and nature of the trend. It is determined as:

$$Z = \frac{X - \underline{X}}{SD} ----------------------------- equation\ \ (3)$$

Where, Z is number of standard deviation of the observation deviated from the normal, x is an observed rainfall value and $\underline{X}$ is mean rainfall and SD is the standard deviation. This statistics are enable us to determine the dry (-ve values) and wet (+ve values) years in the observation. Trend test was carried out using the non-parametric Mann-Kendall's trend test which is less sensitive to outliers and test for a trend in a time series without specifying whether the trend is linear or non-linear (Partal and Kahya, 2006; Yenigun *et al.,* 2008; Hadgu *et al.,*2013).The Mann-Kendall's test statistic is given as:

$$S = \sum_{i=1}^{N-1} \quad * \sum_{j=i+1}^{N} \quad sgn(x_j - x_i) ----------------------equation\ (1)$$

Where S is the Mann-Kendal's test statistics;x_i and x_j are the sequential data values of the time series in the years *j and I*(*j* >*i*) and *N* is the length of the time series. A positive *S* value indicates an increasing trend and a negative value indicates a decreasing trend in the data series. The sign function is given as

$$sgn(x_{j-}x_x) = \{+1\ if\ (x_{j-}x_i)\ > 0 \quad 0\ \ if\ (x_j - x_i)\ = 0\ -1\ \ if\ (x_{j-}x_i)\ < 1\} ----------------equation\ (2)$$

The variance of *S*, for the situation where there may be ties (i.e., equal values) in the *x* values:

$$var(S) = -------------------------------- equation\ (3)$$

Where, *m* is the number of tied groups in the data set and $t_i$is the number of data points in the i^{th}tied group. For n larger than 10, Z_{MK} approximates the standard normal distribution (Partal and Kahya, 2006; Yenigun *et al*., 2008) and computed as follows:

$$Z_{MK} = ---------------------------------equation\ \ (4)$$

The presence of significant trend is evaluated using the Z_{MK} value. In a two-sided test for trend, the null hypothesis *Ho* should be accepted if $Z_{MK} < Z_{1-\alpha/2}$ at a given level of significance. $Z_{1-\alpha/2}$ is the critical value of Z_{MK} from the standard normal table.

Results and Discussions

Table 3. Chiro monthly, seasonal and annual rainfall amount descriptive statistics and trend

Variables	Mean (mm)	Min. (mm)	Max. (mm)	SD (mm)	CV %	Sen's slope	p-value
January	14	0	105	23	164	-0.23	0.16
February	17	0	107	27	158	-1.92	0.12
March	89	0	227	73	82	-1.5	0.29
April	107	0	285	68	63	-0.42	0.81
May	87	0	344	76	87	0.78	0.2
June	52	10	121	31	60	-0.19	0.97
July	137	27	354	73	54	2.3	0.14
August	162	59	413	74	46	-0.44	0.77
September	127	3	290	71	56	0	0.96
October	56	0	273	73	131	0.08	0.32
November	14	0	70	19	131	0	0.65
December	14	0	73	19	138	0	0.79
Belg	300	81	653	61	98	-7.49	0.04
Kiremt	477	164	861	62	54	2.25	0.41
Bega	98	0	369	34	141	0.27	0.81
Annual	876	444	1264	52	97	-2.23	0.62

Table 4 .Bedesa monthly, seasonal and annual rainfall amount descriptive statistics and trend

Variables	Mean (mm)	Min. (mm)	Max. (mm)	SD (mm)	CV%	Sen's slope	p-value
January	12	0	92	20	177	0	0.54
February	26	0	181	41	160	-0.17	0.01
March	68	0	202	58	86	0.3	0.44
April	137	19	311	69	50	-0.06	0.91
May	126	0	335	72	57	0	1
June	99	15	304	60	60	-0.4	0.53
July	145	0	279	59	41	0.71	0.28
August	165	31	276	56	34	-0.39	0.49
September	158	0	367	72	46	1.1	0.09
October	76	0	306	67	89	0.28	0.6
November	32	0	232	48	148	0	0.63
December	10	0	72	18	184	0	0.1
Belg	356	110	902	60	88	-1.57	0.24
Kiremt	567	182	976	62	45	1.43	0.27
Bega	130	8	446	38	149	0.02	0.95
Annual	1053	673	1649	53	94	1.38	0.55

Table 5. Hirna monthly, seasonal and annual rainfall amount descriptive statistics and trend

Variables	Mean (mm)	Min. (mm)	Max. (mm)	SD (mm)	CV%	Sen's slope	p-value
January	14	0	146	26	192	0	0.8
February	19	0	98	24	126	-0.31	0.02
March	77	3	223	51	67	-0.67	0.15
April	125	18	349	74	60	0.14	0.72
May	90	5	214	61	68	1.07	0.17
June	81	10	236	51	63	0	0.99
July	166	43	459	81	49	1.2	0.16
August	217	0	367	85	39	0.17	0.89
September	149	7	404	78	53	0.41	0.64
October	40	0	191	44	110	0.45	0.21
November	12	0	71	16	130	0.07	0.12
December	6	0	55	11	163	0	0.83
Belg	311	116	659	53	80	-0.32	0.85
Kiremt	612	228	1331	74	51	2.22	0.18
Bega	72	0	313	24	149	0.75	0.14
Annual	995	427	2302	50	93	1.62	0.39

Table 6. Mechara monthly, seasonal and annual rainfall amount descriptive statistics and trend

Variables	Mean	Min.	Max.	SD	CV%	Sens's slope	P Value
January	11	0	122	26	231	-0.02	0.04
February	26	0	169	50	196	0	0.53
March	90	0	253	67	74	-0.51	0.73
April	157	36	414	95	61	-1.51	0.5
May	128	23	265	69	59	4.29	0.05
June	101	29	190	42	42	-1.65	0.21
July	144	52	229	50	35	-1.27	0.39
August	158	73	266	59	37	2.17	0.34
September	127	64	243	49	39	1.93	0.07
October	102	0	337	80	79	-0.01	0.98
November	58	0	161	52	89	1.86	0.06
December	19	0	110	26	140	0	0.76
Belg	400	173	730	70	97	2.95	0.53
Kiremt	530	315	706	50	38	2.29	0.63
Bega	190	38	475	46	135	0.05	0.98
Annual	1120	700	1494	55	90	3.57	0.66

Table 7. Mieso monthly, seasonal and annual rainfall amount descriptive statistics and trend

Variables	Mean	Min.	Max.	SD	CV%	Sen's slope	p-value
January	20	0	150	33	163	0.00	0.70
February	33	0	239	47	144	-0.03	0.51
March	69	0	247	63	92	-1.04	0.05
April	103	0	371	72	70	0.25	0.72
May	64	0	230	55	86	0.31	0.53
June	47	5	110	27	57	0.38	0.09
July	137	0	267	65	48	0.98	0.22
August	138	19	296	64	46	-0.96	0.18
September	88	0	168	41	47	0.61	0.08
October	34	0	361	62	185	-0.02	0.82
November	18	0	97	26	140	0.22	0.00
December	10	0	100	19	184	0.00	0.21
Belg	269	11	771	59	98	-1.42	0.18
Kiremt	410	75	645	49	50	0.66	0.50
Bega	82	0	439	35	168	0.17	0.73
Annual	761	282	1172	48	105	-1.28	0.43

Spatial and Temporal Variability of Rainfall

As shown in Table 3-7 listed above, the average annual rainfall of Chiro , Bedesa, Hirna, Mechara and Mieso were observed as 876 mm, 1053 mm, 995 mm, 1120 mm and 761mm with CV of 97%, 94%, 93%, 90% and 105% and SD of 52 mm, 53 mm, 50 mm, 55 mm, and 49 mm respectively. Similarly, the average Belg rainfall amounts of Chiro, Bedesa, Hirna, Mechara and Mieso weather stations were happened to be 300, 356, 311, 400 and 269 mm with less stability (all station SD > 40) and high variability (CV > 30) at all stations. Similarly, the average Kiremt rainfall amounts Chiro, Bedesa, Hirna, Mechara and Mieso were 477, 567, 612, 530 and 410 mm with less stability and high variability at all stations. High CV was observed in Belg rainfall amount than Kiremt in all stations. Similarly, all month's rainfall amount had reviled high variation at all studied stations. From the result it was clear that, the study area was vulnerable to drought (CV > 30%). This is consistent with the recent studies (Mekasha and Duncan 2014; Duhan and Pandey 2013), which identified a strong variability and unpredictability of the seasonal and annual trends of climate in Ethiopia.

Linear Trend Analysis of Annual and Seasonal Rainfall

As showed in the Table 3-7listed above, March non-significant decreasing trend at all stations except Bedesa that showed non- significant increasing trend. Similarly, April non-significant decreasing trend at all stations except Hirna and Mieso that showed non- significant increasing trend. May rainfall amount had showed significant increasing trend at on average by amount of 4.29 mm per year while non-significant increasing trends at Chiro, Hirna and Mieso. June non-significant decreasing trend at all stations except Mieso that showed non-significant increasing trend. July all stations non-significant increasing trend except Mechara that showed non-significant decreasing trend. August rainfall amount showed non-significant decreasing trend at Chiro, Bedesa and Mieso while non-significant increasing trend at Hirna and Mechara. September non-significant increasing trend at Bedesa, Hirna, mieso and Mechara While, no trend at Chiro. Belg rainfall amount showed significant decreasing trend by -7.49 mm per year at Chiro and non-significant decreasing trend at Bedesa and Hirna station but non-significant increasing trend at Mechara and Mieso. *Kiremt* and *Bega* rainfall amount had showed non-significant increasing trends at all stations. Similarly, annual rainfall amount have shown non-significant increasing trends at Bedesa, Hirna and Mechara but, non-significant decreasing trend at Chiro and Mieso.

The result is consistent with the findings by Belay et al., (2021) in Southern Ethiopia using time series analysis for the period 1983–2016 and noted that the seasonal trends of rainfall amount for Belg, Kiremt, and Bega seasons was -1.935 mm/year, 1.841 mm/year and 0.568 mm/year respectively. Whereas the declining trend of Belg season was statistically significant. The Belg season rainfall is crucial for the farmers as the season determines the preparation and planting activities of the farmers in the study area. The observed decreasing trend of the Belg rainfall might be caused by the atmospheric– oceanic processes that influence rainfall in the region. Moreover the current study is consistent with the findings of other studies that observed non-significant change in annual and Kiremt rainfall over Ethiopia (Matewos, 2019, Wagesho et al., 2013, De Luis et al., 2000, Mengistu et al., 2014).The rate of change of the annual rainfall variability was recorded as 0.474mm/year while the trend of annual rainfall was found to be statistically insignificant. These results are in agreement with the findings made by Benti and Abara (2019) who examined the trends of annual rainfall distribution in southern Ethiopia and noted that the annual rainfall had a statistically insignificant increasing trend since 1995–2014.

Observed Mean Maximum and Minimum Temperature Variability and Trend

Table 8. Chiro Monthly, seasonal and annual maximum temperature variability and trend

Variables	Mean	Min.	Max.	SD	CV%	Sen's slope	p-value
January	26.78	23.85	30.85	1.53	5.7	-0.03	0.33
February	28.32	25.37	35.32	2.20	7.8	-0.03	0.47
March	28.51	25.66	31.18	1.54	5.4	0.01	0.77
April	28.4	25.98	31.23	1.28	4.5	0.03	0.45
May	28.96	25.89	31.82	1.22	4.2	-0.03	0.09
June	28.95	27.24	31.62	1.20	4.1	0.02	0.49
July	28.12	25.99	31.32	1.24	4.4	0.04	0.10
August	27.53	24.21	31.35	1.33	4.8	-0.03	0.20
September	27.72	24.47	32	1.34	4.8	-0.02	0.45
October	27.84	25.16	31.38	1.34	4.8	-0.04	0.10
November	27.63	25.65	31.77	1.33	4.8	-0.03	0.11
December	26.49	24.7	30.57	1.66	6.2	-0.03	0.27
Belg	28.55	25.98	31.49	1.26	4.4	0.00	0.89
Kiremt	28.08	26.58	31.57	1.07	3.8	0.01	0.29
Bega	27.18	25.66	30.22	1.19	4.4	-0.03	0.13
Annual	27.94	26.7	30.89	0.99	3.5	-0.01	0.83

Chiro 9. Monthly, seasonal and annual minimum temperature variability and trend

Variables	Mean	Min.	Max.	SD	CV%	Sen's slope	p-value
January	11.73	7.65	16.58	2.48	21.2	0.15	0.0036
February	12.47	8.35	17.91	2.76	22.1	0.19	< 0.0001
March	13.33	8.07	16.95	2.61	19.6	0.23	< 0.0001
April	13.91	8.18	17.38	2.76	19.8	0.22	< 0.0001
May	14.37	8.59	17.55	2.80	19.5	0.24	< 0.0001
June	14.87	8.94	18.15	2.52	16.9	0.20	< 0.0001
July	14.3	9.68	17.12	2.26	15.8	0.18	< 0.0001
August	14.05	9.38	16.21	2.49	17.7	0.18	< 0.0001
September	13.93	9.63	16.85	2.53	18.1	0.20	< 0.0001
October	13.15	9.56	17.02	2.24	17	0.18	< 0.0001
November	11.91	8.61	15.73	2.43	20.4	0.17	0.0003
December	11.08	7.86	15.85	2.23	20.1	0.08	0.0389
Belg	13.52	8.30	16.31	3.0	20.0	0.23	< 0.0001
Kiremt	14.29	9.56	16.95	2.0	17.0	0.21	< 0.0001
Bega	11.97	8.81	15.78	2.1	20.0	0.14	< 0.0001
Annual	13.26	8.89	16.05	3.0	19.0	0.20	< 0.0001

Table 10. Bedesa Monthly, seasonal and annual maximum temperature variability and trend

Variables	Mean	Min.	Max.	SD	CV%	Sen's slope	p-value
January	27.99	24.41	29.63	1.007	3.6	0.01	0.5250
February	29.26	27.53	30.83	0.81	2.8	0.04	0.0005
March	28.81	25.98	31.44	1.59	5.5	0.08	0.0067
April	27.91	25.56	31.43	1.62	5.8	0.06	0.0255
May	27.99	24.02	30.21	1.11	4	0.03	0.0498
June	27.98	25.87	29.43	0.91	3.2	0.01	0.7853
July	27.14	23.31	29.43	1.27	4.7	-0.01	0.6951
August	26.94	22.29	29.13	1.22	4.5	0.00	0.9677
September	26.98	22.27	29.26	1.11	4.1	0.01	0.4787
October	27.65	23.44	29.63	1.18	4.3	-0.02	0.2880
November	27.8	24.08	29.86	1.25	4.5	0.01	0.6239
December	27.39	22.05	29.31	1.26	4.6	0.01	0.6169
Belg	28.5	27.05	30.34	1.28	4.5	0.06	0.0001
Kiremt	27.26	23.65	28.98	1.13	4.1	0.00	0.9032
Bega	27.71	24.17	29.34	1.17	4.3	0.00	0.9461
Annual	27.82	25.43	29.02	1.19	4.3	0.02	0.0448

Table 12. Bedesa Monthly, seasonal and annual minimum temperature variability and trend

Variables	Mean (mm)	Min. (mm)	Max. (mm)	SD (mm)	CV%	Sen's slope	p-value
January	10.83	6.31	17.88	2.08	19.2	-0.02	0.543
February	11.49	6.907	14.5	1.83	15.9	-0.03	0.227
March	12.9	6.543	15.59	2.09	16.2	0.02	0.425
April	13.54	10.02	16.63	1.54	11.3	0.07	0.002
May	13.33	9.206	18.8	2.04	15.3	0.10	0.001
June	13.75	9.288	18.99	1.94	14.1	0.07	0.007
July	14.15	10.68	18.13	1.29	9.1	0.07	< 0.0001
August	14.1	10.57	18.65	1.54	10.9	0.07	0.001
September	13.61	10.26	18.2	1.37	10.1	0.05	0.008
October	11.78	7.423	17.58	2.04	17.3	0.04	0.261
November	10.35	4.873	17.58	2.61	25.2	-0.03	0.350
December	10.34	2.835	14.11	2.48	23.9	-0.07	0.034
Belg	12.81	9.626	15.1	1.8	14.7	0.05	0.021
Kiremt	13.9	11.41	18.49	1.5	11.1	0.07	0.000
Bega	10.83	5.36	16.12	2.3	21.1	-0.02	0.227
Annual	12.51	9.513	16.1	1.9	15.7	0.03	0.054

Tabble 13. Tulo Monthly, seasonal and annual maximum temperature variability and trend

Variables	Mean	Min.	Max.	SD	CV%	Sen's slope	p-value
January	26.25	22.9	29.09	1.50	5.7	0.10	< 0.0001
February	27.71	23.36	29.96	1.58	5.7	0.10	< 0.0001
March	27.51	23.61	30.17	1.58	5.8	0.10	< 0.0001
April	26.79	23.54	29.63	1.76	6.6	0.11	0.0002
May	27.48	24.35	30.48	1.83	6.7	0.10	0.005
June	27.43	24.63	30.63	1.69	6.2	0.11	< 0.0001
July	26.79	24.13	29.47	1.38	5.1	0.06	0.012
August	25.96	23.79	27.97	1.11	4.3	0.05	0.001
September	26.02	24.51	27.85	0.99	3.8	0.04	0.010
October	26.47	22.34	29.4	1.66	6.3	0.07	0.007
November	26.73	22.81	29.52	1.44	5.4	0.06	0.001
December	26.07	23.45	29.52	1.20	4.6	0.04	0.015
Belg	27.37	24.33	29.27	1.7	6.2	0.10	< 0.0001
Kiremt	26.55	24.26	28.13	1.3	4.9	0.06	0.026
Bega	26.38	23.04	28.39	1.5	5.5	0.06	0.0003
Annual	26.77	24.18	28.49	1.5	5.5	0.08	0.0004

Table 14. Hirna Monthly, seasonal and annual minimum temperature variability and trend

Variables	Mean	Min.	Max.	SD	CV%	Sen's slope	p-value
January	8.27	2.38	16.61	3.26	39.4	-0.22	< 0.0001
February	9.35	2.38	16.42	3.28	35	-0.22	0.0002
March	11.10	4.20	14.76	3.00	27.1	-0.24	< 0.0001
April	11.93	7.08	14.57	2.43	20.4	-0.08	0.02
May	12.05	7.50	14.76	2.39	19.8	-0.09	0.03
June	12.68	7.20	15.36	2.17	17.1	-0.08	0.001
July	13.25	7.95	15.33	1.94	14.6	-0.07	0.003
August	13.09	7.74	15.11	1.97	15	-0.01	0.560
September	12.69	7.13	14.9	2.13	16.8	-0.02	0.293
October	11.14	2.71	15.02	2.56	22.9	0.04	0.217
November	8.41	1.05	13.71	2.73	32.5	-0.07	0.213
December	7.64	1.01	15.65	2.81	36.7	-0.12	0.000
Belg	11.11	5.92	14.58	2.8	25.6	-0.16	< 0.0001
Kiremt	12.93	7.67	14.79	2.1	15.9	-0.05	0.02
Bega	8.86	2.61	13.72	2.8	32.9	-0.06	0.01
Annual	10.97	5.75	13.98	2.6	24.8	-0.12	< 0.0001

Table 15. Miesso monthly, seasonal and annual maximum temperature variability and trend

Variables	Mean	Min.	Max.	SD	CV%	Sen's slope	p-value
January	28.22	26.86	29.81	0.88	3.10	-0.01	0.429
February	29.62	25.27	32.18	1.60	5.40	0.02	0.323
March	30.80	27.55	33.11	1.25	4.10	0.02	0.252
April	31.70	29.04	33.33	1.40	4.40	0.10	< 0.01
May	33.44	30.11	35.07	1.34	4.00	0.08	0.001
June	33.57	31.11	35.06	0.81	2.40	0.03	0.192
July	31.74	29.70	33.72	1.07	3.40	0.09	< 0.01
August	30.40	28.69	31.82	0.86	2.80	0.04	0.010
September	30.86	28.60	33.41	1.08	3.50	0.08	0.001
October	30.92	27.59	32.40	1.18	3.80	0.07	0.011
November	29.17	27.68	31.68	1.08	3.70	-0.05	0.022
December	28.15	26.73	29.15	0.66	2.40	0.02	0.0003
Belg	31.39	28.86	32.57	1.4	4.5	0.05	< 0.01
Kiremt	31.64	30.15	32.88	1.0	3.0	0.06	0.363
Bega	29.12	28.15	30.12	0.9	3.3	0.01	< 0.01
Annual	30.72	29.51	31.63	1.1	3.6	0.04	0.323

Table 16. Miesso monthly, seasonal and annual minimum temperature variability and trend

Variables	Mean	Min.	Max.	SD	CV%	Sen's slope	p-value
January	12.07	8.50	14.28	1.44	11.90	0.05	0.05
February	13.23	8.38	15.34	1.69	12.70	0.02	0.61
March	15.28	11.60	16.69	1.16	7.60	0.01	0.72
April	17.32	15.02	19.35	1.34	7.70	0.13	< 0.01
May	18.17	16.17	20.65	1.56	8.60	0.15	< 0.01
June	18.46	16.04	20.64	1.44	7.80	0.16	< 0.01
July	17.80	15.00	18.79	1.06	5.90	0.08	< 0.01
August	17.49	13.93	18.48	0.88	5.00	0.04	< 0.01
September	17.41	15.37	19.83	1.49	8.60	0.14	< 0.01
October	14.89	12.25	17.63	1.78	12.00	0.15	0.0002
November	11.25	7.30	13.92	1.17	10.40	0.01	0.24
December	11.35	8.07	15.08	2.19	19.30	0.12	0.03
Belg	16.00	14.33	17.50	1.43	9.15	0.08	0.0002
Kiremt	17.79	15.08	19.29	1.22	6.83	0.12	< 0.01
Bega	12.39	10.75	13.84	1.64	13.40	0.09	0.001
Annual	15.39	14.05	16.88	1.43	9.79	0.10	< 0.01

Observed Mean Maximum and Minimum Temperature Descriptive Statistics

The results showed in the Table 8-16 listed above revealed that, the mean annual maximum and minimum temperature at Chiro was 26.7ºC and 13.26ºC. At Chiro the minimum temperature was showed more variability than maximum temperature. At bedesa maximum temperature ranged 25.43–29.02 ºC and average of 27.82ºC while, annual minimum temperature ranged 9.5–16 ºC and average of 12.5ºC with stable degree of hotness (SD 2.4). At Hirna mean maximum temperature ranged 24.18– 28.49ºC and average of 26.38ºC while annual minimum temperature ranged 5.75–13.98ºC and average of 10.97ºC and both maximum and minimum temperature had showed stable degree of hotness. At Mieso mean annual maximum temperature ranged 29.51–31.63ºC and average of 30.72ºC while mean annual minimum temperature ranged 14.05–16.88ºC and average of 15.39ºC and both maximum and minimum temperature had showed stable degree of hotness.

Trends of Observed Mean Maximum and Minimum Temperature

The results showed in the Table 8-16 listed above revealed that, At Chiro March, April, June, July, mean maximum temperature had showed non-significant warming trend while, the remaining months had showed non-significant cooling trend. Belg and Kiremt season showed non-significant warming trend while, Bega and annual showed non-significant cooling trend. Moreover, at Chiro all month's/seasonal minimum temperature had showed significant upward trend. At Bedesa seasonal and annual maximum and minimum temperature showed warming trend except Bega minimum temperature that showed cooling trend. At Hirna all months/seasonal maximum temperature had showed significant warming trend. In contrary, all months/seasonal minimum temperature had showed significant cooling trend. At Mieso Belg and Kiremt maximum temperature showed significant increasing warming trend whereas Bega and annual maximum temperature showed non-significant warming trend. Moreover, at Mieso all seasonal/ annual minimum temperature showed significant warming trend.

Observed Rainfall Events (Belg Onset Date, Kiremt Onset and Cessation Date and Length of Growing Period (LGP) Belg to Kiremt

Table 17.Discriptive Statistics and Trends of Observed Rainfall Events

Station name	Variables	Mean	Min.	Max.	SD	CV%	S/slope	p-value
Chiro/Asebe Teferi	Belg onset	97	37	197	41	42	0.33	0.56
	Kiremt onset	173	153	223	20	12	-0.57	0.05
	K/Cessation	294	245	333	23	8	0.20	0.67
	LGP (B-K)	198	84	270	51	26		
Bedesa	Belg onset	86	34	130	21	24	0.12	0.58
	Kiremt onset	164	153	204	15	9	0.00	0.68
	K/Cessation	312	245	363	24	8	0.08	0.64
	LGP(B-K)	226	131	317	34	15		
Hirna	Belg onset	69	34	150	23	34	0.08	0.76
	Kiremt onset	164	153	186	10	6	0.10	0.25
	K/Cessation	305	245	351	17	5	0.32	0.05
	LGP(B-K)	236	141	291	31	13		
Mieso	Belg onset	96	34	260	47	49	0.50	0.30
	Kiremt onset	177	153	260	20	11	-0.50	0.00
	K/Cessation	260	245	298	15	6	0.00	0.70
	LGP(B-K)	168	55	249	41	24		
Mechara	Belg onset	94	39	141	27	29	0.29	0.66
	Kiremt onset	171	154	219	16	10	0.00	0.94
	K/Cessation	284	245	328	26	9	0.54	0.36
	LGP(B-K)	113	27	165	33	29	0.82	0.29

Kiremt season rainfall onset date were ranged 153 – 223, 153 – 204, 153- 186, 163- 260,154 - 219 DOY with respective mean 173, 164, 164, 177, and 171 DOY at Chiro, Bedesa, Hirna, Mieso, and Mechara respectively. Kiremt length of growing period was ranged; 60 – 177, 100 – 210, 80 – 198, 15 – 133, 27 – 165 days at Chiro , Bedesa, Hirna, Mieso, and Mechara respectively (Table 17).

Belg rainfall onset date were ranged 37 – 197, 34 – 130, 34- 150, 34 - 260, 39 – 141 DOY with respective mean of; 97, 86, 69, 96 and 94 DOY at Chiro , bedesa, hirna, mieso, and mechara respectively with their respective SD; 41, 21, 23, 47, 27 DOY and CV of; 42, 24, 34, 49 and 29%(Table 17). From the result Chiro and mieso have been experienced high variability and less stability on Belg rainfall onset while, other stations Belg rain onset were moderately variable. In general, almost at all stations; the variability of onset date of Belg season was more variable and less stable than Kiremt onset and cessation date. Thus, high variability and less stability of Belg onset date have indicated that the patterns could not be easily understood and decisions concerning crop planting and related activities are made with high risk. In line with the present result, Wasihun et al. (2019) also found DOY 88 (March 28) with CV of 26%, as average onset date of Belg rainy season at Galemso station, West Hararge Zone of Oromia Regional State.

Kiremt season rainfall onset date were ranged 153 – 223, 153 – 204, 153- 186, 163- 260,154 - 219 DOY with respective mean 173, 164, 164, 177, and 171 DOY at Chiro , bedesa, hirna, mieso, and mechara respectively with their respective SD of; 20, 15, 10, 20, 16 DOY and CV of; 12, 9, 6, 11, 10%(Table 17). This indicated Kiremt rain onset in the study area has been experienced less variability and high stability at all stations. The Kiremt rain cessation date were ranged 245 – 333, 245 – 363, 245 – 351, 245 – 298, 245 – 328 at Chiro, Bedesa, Hirna, Mieso and Mechara with their respective mean of; 294, 312, 305, 260, 284 and SD of ; 23, 24, 17, 15, 26 DOY and CV of; 8, 8, 5, 6, 9%. This has indicated that Kiremt cessation date was moderately variable at Chiro, Bedesa, Mechara and high stability and Hirna and Mieso station. Current results in line with other previous study conducted by Wasihun et al. (2019) at Galemso station, West Hararge Zone that reported the average cessation date of *Kiremt* rainfall for Gelemso station using 1988 - 2017 year data was 302 DOY (28 October) with SD 22 days and CV of 7%, which is moderately stable and less variable. The earliest date of cessation of the rainy season at Gelemso station was 248 DOY (4 September) while the latest cessation date was 342 DOY (7 December). Moreover, the study conducted on cessation of rainy season in north western of Ethiopia revealed that on average the *Kiremt* rain ends on 302, 304, 292, 302 and 317 DOY at Bahir Dar, Motta, Yetmen, Debre Markos and Dangla, respectively (Taye *et al*., 2013). And as Ayalew *et al*. (2012) indicated, the average date of cessation of rainy season ranged from September 2 (246 DOY) at Mahil Meda to October 30 (304 DOY) at Debark in Amhara region.

The average Kiremt length of growing period at Chiro, Bedesa, Hirna, Mieso and Mechara was; 121, 149, 141, 84, and 113 with their respective SD; 32, 24, 20, 24, 33 and CV of; 26, 16, 14, 28, and 29%.

Moreover, this study reported the non-significant late onset of Belg rain at all stations and non-significant late onset date of Kiremt rain at Bedesa, Hirna and Mechara while, non-significant early onset date of Kiremt rain at Chiro and significant early onset date of Kiremt rain at Mieso station. Additionally, Kiremt rain cessation date and keremt length of growing period were experienced positive trends at all stations.

Projected Rainfall Amount

Table 18.Chiro monthly, seasonal and annual rainfall amount descriptive statistics and trend

Variables	Mean	Min.	Max.	SD	Sen's slope	p-value
January	26	20	36	5	0.15	0.004
February	26	18	36	5	0.17	< 0.0001
March	43	29	60	9	-0.20	0.042
April	77	67	104	9	-0.17	< 0.0001
May	197	126	254	37	0.69	0.000
June	98	71	133	18	-0.57	< 0.0001
July	306	252	381	35	0.03	0.696
August	131	106	189	19	0.16	0.001
September	106	86	125	10	-0.15	0.484
October	19	7	24	3	0.04	< 0.0001
November	34	12	43	11	-0.04	0.019
December	8	6	14	3	0.03	< 0.0001
Belg	343	278	392	15	0.44	0.060
Kiremt	640	602	717	21	-0.49	< 0.0001
Bega	87	49	102	6	0.10	0.009
Annual	1070	981	1142	14	-0.84	0.049

Table 19.Hirna monthly, seasonal and annual rainfall amount descriptive statistics and trend

Variable	Mean	Min.	Max.	SD	Sen's slope	p-value
January	24	15	31	7	0.027	0.003
February	26	25	26	0	0.004	0.000
March	28	26	31	2	-0.012	0.244
April	82	64	96	15	-0.012	0.105
May	244	213	289	32	0.033	0.887
June	92	71	106	9	-0.250	< 0.0001
July	316	274	345	20	0.489	< 0.0001
August	138	116	164	21	-0.189	< 0.0001
September	89	88	90	1	-0.023	< 0.0001
October	8	7	8	0	0.000	0.100
November	24	8	33	10	-0.027	0.000
December	14	9	17	4	0.000	0.428
Belg	380	361	410	12	0.085	0.224
Kiremt	635	611	663	13	0.059	0.693
Bega	70	45	88	4	0.000	0.976
Annual	1085	1059	1102	10	-0.100	0.278

Table 20. Mieso monthly, seasonal and annual rainfall amount descriptive statistics and trend

Variables	Mean	Min.	Max.	SD	Sens’s slope	P Value
January	23	10	39	10	0.28	< 0.0001
February	32	19	44	7	0.15	< 0.0001
March	31	13	59	10	-0.02	0.179
April	57	41	100	14	-0.05	0.273
May	128	94	181	27	-0.73	< 0.0001
June	76	44	97	13	-0.26	0.002
July	179	149	214	18	0.33	< 0.0001
August	77	45	104	12	-0.06	0.0001
September	130	90	147	16	-0.28	< 0.0001
October	12	8	15	2	0.00	0.953
November	32	15	43	10	0.08	0.002
December	8	0	19	7	-0.04	0.023
Belg	247	211	321	14	-0.41	< 0.0001
Kiremt	463	417	511	15	-0.46	0.0003
Bega	75	55	96	7	0.38	< 0.0001
Annual	785	722	864	12	-0.85	< 0.0001

Table 21.Mechara monthly, seasonal and annual rainfall amount descriptive statistics and trend

Variable	Mean	Min.	Max.	SD	Sen's slope	p-value
January	21	3	31	8	0.13	< 0.0001
February	24	15	33	6	-0.08	< 0.0001
March	50	22	75	16	0.02	0.30
April	90	61	115	22	-0.32	< 0.0001
May	189	117	229	27	-1.07	< 0.0001
June	95	60	140	23	-0.36	0.02
July	255	249	278	5	-0.11	< 0.0001
August	176	132	187	6	0.14	< 0.0001
September	108	99	131	10	0.05	0.56
October	24	22	30	1	0.00	0.57
November	35	24	42	5	-0.02	0.17
December	8	5	18	4	-0.01	< 0.0001
Belg	352	264	419	18	-1.58	< 0.0001
Kiremt	634	583	690	11	-0.48	0.01
Bega	89	75	100	4	0.12	0.04
Annual	1076	984	1171	11	-2.40	< 0.0001

Table 22.Bedesa monthly, seasonal and annual rainfall amount descriptive statistics and trend

Variable	Mean	Min.	Max.	SD	Sen's slope	p-value
January	24	20	39	5	-0.02	0.06
February	23	14	34	6	-0.19	< 0.0001
March	47	33	71	12	-0.07	0.07
April	82	68	115	17	0.02	0.17
May	192	124	240	38	-1.39	< 0.0001
June	85	69	103	13	-0.06	0.45
July	278	241	290	10	-0.07	0.11
August	125	111	183	14	0.14	< 0.0001
September	111	104	123	6	-0.04	0.59
October	21	7	51	7	-0.02	0.00
November	42	36	46	3	0.10	< 0.0001
December	7	6	10	1	-0.02	< 0.0001
Belg	344	278	457	18	-1.75	< 0.0001
Kiremt	599	582	626	11	-0.03	0.48
Bega	93	80	124	4	0.08	0.07
Annual	1036	948	1137	11	-2.43	< 0.0001

The mean Belg rainfall amount is expected to be ranged 278 – 392, 361 – 410, 211 – 321, 264- 419, 278-457 mm with respective mean 343, 380, 247, 352 and 344 mm at Chiro , hirna, mieso, Mechara and Bedesa respectively. Kiremt mean minimum and maximum rainfall amount ranged 602 – 717, 611 - 663, 417 – 511, 583 – 690, 582 – 626 mm with respective mean 640, 635, 443, 634 and 599 mm at Chiro , Hirna, Mieso, Mechara and bedesa respectively. Moreover, mean annual rainfall amount expected at Chiro, Hirna, Mieso, Mechara and Bedesa were 1070, 1085, 785, 1076 and 1036 mm respectively (Table 18- 22 listed above).

Moreover, the temporal and spatial distribution of Belg Kiremt and annual rainfall amount is expected to be highly stable (SD < 20) for some consecutive years then followed by abrupt change in amount that persist for meanwhile and so on table ….This indicated that, the meanwhile persistence in amount then followed by meanwhile abrupt change in amount have vegetative consequence on sustainable environmental and agricultural production unless, it is intentionally followed by meteorological forecast, early warning and any required adaptive technology.

February significant decreasing trend at Mechara and Bedesa while, significant increasing trend at Chiro, Hirna and Mieso. March significant increasing trend at Chiro, non-significant decreasing trend Bieso and Bedesa while non-significant increasing trend at Hirna and Mechara. april significant increasing trend at Chiro and Mechara, non-significant decreasing trend at Mirna and Mieso while non-significant increasing trend at Bedesa. May rainfall amount significant decreasing trend at Mieso, Mechara and Bedesa while significant increasing trend at Chiro and non- significant increasing trend at Hirna. June significant increasing trend at all stations except Bedesa that showed non-significant increasing trend. July Significant increasing trend at Hirna and Mieso and non-significant increasing trend Chiro while, significant reduction at Mechara and Bedesa. August rainfall amount is expected show significant increment at Chiro, Mieso and Bedesa. September significant reduction was expected at Hirna and Mieso and non-significant increasing trend at Chiro and Bedesa but, non-significant increment at Mechara. The results of projection have indicated that, Belg mean rainfall amount had indicated significant increasing trend at Chiro and non-significant increasing trend at Hirna, while, significant decreasing trend at Mechara and Bedesa. Kiremt rainfall amount had indicated significant reduction at all stations except at Hirna that indicated non-significant increasing trend. In contrary, Bega rainfall amount is expected to increase significantly at all stations. In general annual mean rainfall amount is expected to decrease significantly at Chiro , Mieso, Mechara and badesa whereas, non-significant reduction at Hirna stations 2025-2092 intervals.

Projected Temperature

Table 23. Chiro monthly, seasonal and annual maximum temperature variability and trend

Variable	Mean	Min.	Max.	SD	Sen's slope	p-value
January	25.4	24.56	25.95	0.45	0.025	< 0.0001
February	27.36	26.36	28.14	0.60	0.031	< 0.0001
March	28.9	27.95	29.75	0.58	0.029	< 0.0001
April	30.38	29.34	31.2	0.57	0.029	< 0.0001
May	33	31.95	33.79	0.56	0.030	< 0.0001
June	30.88	29.42	31.91	0.61	0.029	< 0.0001
July	29.41	28.5	30.16	0.49	0.025	< 0.0001
August	29.69	28.93	30.4	0.37	0.018	< 0.0001
September	28.86	27.96	29.51	0.49	0.026	< 0.0001
October	29.64	28.83	30.4	0.46	0.024	< 0.0001
November	24.95	23.99	25.76	0.59	0.029	< 0.0001
December	28.15	27.26	28.82	0.43	0.024	< 0.0001
Belg	29.91	28.91	30.58	0.57	0.031	< 0.0001
Kiremt	29.71	28.72	30.33	0.47	0.023	< 0.0001
Bega	27.04	26.16	27.66	0.47	0.026	< 0.0001
Annual	28.89	27.95	29.49	0.50	0.027	< 0.0001

Table 24. Chiro monthly, seasonal and annual minimum temperature variability and trend

Variable	Mean	Min.	Max.	SD	Sen's slope	p-value
January	10.49	9.66	11.28	0.53	0.15	0.004
February	13.18	12.12	14.16	0.64	0.17	< 0.0001
March	14.19	13.18	15.01	0.58	-0.20	0.042
April	16.72	15.96	17.30	0.44	-0.17	< 0.0001
May	18.97	18.31	19.52	0.39	0.69	0.0005
June	17.82	16.83	18.79	0.52	-0.57	< 0.0001
July	15.74	14.98	16.50	0.47	0.03	0.70
August	16.68	15.85	17.27	0.34	0.16	0.001
September	17.37	16.59	17.93	0.43	-0.15	0.484
October	15.91	14.96	16.86	0.43	0.04	< 0.0001
November	9.65	8.78	10.37	0.54	-0.04	0.019
December	13.49	12.79	14.06	0.39	0.03	< 0.0001
Belg	15.76	14.91	16.39	0.51	0.44	0.06
Kiremt	16.90	16.11	17.49	0.43	-0.49	< 0.0001
Bega	12.38	11.61	12.98	0.46	0.10	0.01
Annual	15.02	14.21	15.60	0.47	-0.84	0.05

Table 25. Bedesa monthly, seasonal and annual maximum temperature variability and trend

Variable	Mean	Min.	Max.	SD	Sen's slope	p-value
January	26.06	25.19	26.84	0.45	0.024	< 0.0001
February	28.06	27.03	29.03	0.62	0.031	< 0.0001
March	29.53	28.46	30.21	0.54	0.028	< 0.0001
April	31.03	30.04	31.75	0.52	0.027	< 0.0001
May	33.53	32.42	34.36	0.66	0.033	< 0.0001
June	31.58	30.25	32.46	0.60	0.027	< 0.0001
July	30.02	29.15	30.79	0.45	0.023	< 0.0001
August	29.98	29.25	30.59	0.33	0.016	< 0.0001
September	29.46	28.63	30.13	0.44	0.022	< 0.0001
October	30.07	29.17	30.57	0.47	0.025	< 0.0001
November	25.41	24.52	26.05	0.52	0.026	< 0.0001
December	28.63	27.76	29.3	0.45	0.023	< 0.0001
Belg	30.54	29.49	31.21	0.58	0.030	< 0.0001
Kiremt	30.26	29.32	30.9	0.45	0.021	< 0.0001
Bega	27.54	26.66	28.1	0.47	0.025	< 0.0001
Annual	29.45	28.49	30.03	0.50	0.026	< 0.0001

Table 26. Bedesa monthly, seasonal and annual minimum temperature variability and trend

Variable	Mean	Min.	Max.	SD	Sen's slope	p-value
January	10.83	10.05	11.98	0.55	0.028	< 0.0001
February	13.36	12.29	14.30	0.64	0.032	< 0.0001
March	14.50	13.47	15.45	0.58	0.031	< 0.0001
April	17.12	16.41	17.91	0.44	0.023	< 0.0001
May	19.20	18.52	19.75	0.39	0.021	< 0.0001
June	18.32	17.38	19.16	0.51	0.025	< 0.0001
July	16.29	15.54	17.00	0.46	0.023	< 0.0001
August	17.00	16.21	17.65	0.37	0.018	< 0.0001
September	17.82	17.11	18.54	0.42	0.022	< 0.0001
October	16.01	15.15	16.81	0.43	0.021	< 0.0001
November	9.98	9.14	10.65	0.54	0.028	< 0.0001
December	13.73	13.02	14.33	0.41	0.021	< 0.0001
Belg	16.05	15.17	16.77	0.51	0.027	< 0.0001
Kiremt	17.36	16.56	17.94	0.43	0.022	< 0.0001
Bega	12.64	11.84	13.32	0.47	0.025	< 0.0001
Annual	15.35	14.52	16.01	0.47	0.025	< 0.0001

Table 27. Hirna monthly, seasonal and annual maximum temperature variability and trend

Variable	Mean	Min.	Max.	SD	Sen's slope	p-value
January	24.63	23.80	25.28	0.51	0.02	< 0.0001
February	26.55	25.48	27.30	0.59	0.03	< 0.0001
March	28.35	27.28	29.07	0.55	0.03	< 0.0001
April	29.93	28.94	30.59	0.49	0.02	< 0.0001
May	31.69	30.63	32.62	0.63	0.03	< 0.0001
June	30.23	28.93	31.38	0.59	0.03	< 0.0001
July	28.73	28.02	29.21	0.32	0.02	< 0.0001
August	28.94	28.23	29.65	0.44	0.02	< 0.0001
September	28.52	27.60	29.03	0.42	0.02	< 0.0001
October	29.21	28.31	30.04	0.44	0.02	< 0.0001
November	24.46	23.50	25.24	0.52	0.03	< 0.0001
December	27.56	26.79	28.24	0.50	0.03	< 0.0001
Belg	29.13	28.08	29.80	0.56	0.03	< 0.0001
Kiremt	29.11	28.22	29.59	0.43	0.02	< 0.0001
Bega	26.47	25.63	27.03	0.47	0.02	< 0.0001
Annual	28.23	27.31	28.79	0.49	0.03	< 0.0001

Table 28. Hirna monthly, seasonal and annual minimum temperature variability and trend

Variable	Mean	Min.	Max.	SD	Sen's slope	p-value
January	10.11	9.25	10.89	0.56	0.03	< 0.0001
February	13.31	12.25	14.14	0.60	0.03	< 0.0001
March	13.92	12.82	14.78	0.58	0.03	< 0.0001
April	16.47	15.76	17.04	0.42	0.02	< 0.0001
May	18.59	17.91	19.23	0.44	0.02	< 0.0001
June	17.68	16.64	18.56	0.50	0.02	< 0.0001
July	15.67	14.95	16.20	0.43	0.02	< 0.0001
August	16.09	15.45	16.61	0.40	0.02	< 0.0001
September	17.02	16.24	17.54	0.39	0.02	< 0.0001
October	15.94	15.12	17.11	0.46	0.02	< 0.0001
November	9.53	8.60	10.26	0.53	0.03	< 0.0001
December	13.63	13.03	14.21	0.41	0.02	< 0.0001
Belg	15.57	14.70	16.19	0.50	0.03	< 0.0001
Kiremt	16.62	15.82	17.15	0.42	0.02	< 0.0001
Bega	49.22	46.08	51.55	1.92	0.10	< 0.0001
Annual	14.83	14.01	15.40	0.47	0.02	< 0.0001

Table 29. Mechara monthly, seasonal and annual maximum temperature variability and trend

Variable	Mean	Min.	Max.	SD	Sen's slope	p-value
January	25.84	25.03	26.38	0.45	0.022	< 0.0001
February	27.86	26.89	28.6	0.57	0.028	< 0.0001
March	29.59	28.67	30.3	0.50	0.023	< 0.0001
April	30.96	30.12	31.54	0.45	0.021	< 0.0001
May	32.84	31.71	33.89	0.67	0.032	< 0.0001
June	31.54	30.26	32.52	0.65	0.030	< 0.0001
July	29.56	28.81	30.04	0.39	0.020	< 0.0001
August	29.5	28.81	30.3	0.42	0.019	< 0.0001
September	29.16	28.42	29.72	0.41	0.019	< 0.0001
October	29.87	28.99	30.55	0.47	0.021	< 0.0001
November	25.11	24.17	25.84	0.53	0.026	< 0.0001
December	28.07	27.37	28.72	0.46	0.023	< 0.0001
Belg	30.31	29.35	30.94	0.54	0.027	< 0.0001
Kiremt	29.84	23.12	30.46	0.92	0.022	< 0.0001
Bega	27.22	26.39	27.77	0.46	0.023	< 0.0001
Annual	29.16	28.27	29.72	0.48	0.025	< 0.0001

Table 30. Mechara monthly, seasonal and annual minimum temperature variability and trend

Variable	Mean	Min.	Max.	SD	Sen's slope	p-value
January	9.761	8.848	10.77	0.56	0.028	< 0.0001
February	13.01	12	14.27	0.64	0.030	< 0.0001
March	14.05	12.94	15.2	0.60	0.029	< 0.0001
April	16.41	15.75	17.18	0.43	0.018	< 0.0001
May	18.52	17.78	19.5	0.44	0.021	< 0.0001
June	18.07	17.16	18.94	0.49	0.023	< 0.0001
July	15.82	15.08	16.41	0.42	0.020	< 0.0001
August	16.77	16.07	17.41	0.40	0.019	< 0.0001
September	17.36	16.67	17.82	0.38	0.018	< 0.0001
October	15.72	14.88	16.95	0.49	0.022	< 0.0001
November	8.844	7.893	9.677	0.53	0.026	< 0.0001
December	12.87	12.18	13.66	0.44	0.020	< 0.0001
Belg	15.5	14.62	16.39	0.51	0.024	< 0.0001
Kiremt	17	16.24	17.56	0.42	0.021	< 0.0001
Bega	11.8	10.96	12.65	0.49	0.024	< 0.0001
Annual	14.77	13.94	15.53	0.47	0.023	< 0.0001

Table 31. Mieso monthly, seasonal and annual maximum temperature variability and trend

Variable	Mean	Min.	Max.	SD	Sen's slope	p-value
January	28.6	27.48	29.19	0.47	0.024	< 0.0001
February	30.38	29.21	31.22	0.61	0.032	< 0.0001
March	31.99	30.61	32.75	0.57	0.028	< 0.0001
April	34.17	33.16	34.81	0.51	0.026	< 0.0001
May	36.26	34.4	37.27	0.66	0.030	< 0.0001
June	35.14	33.55	35.88	0.64	0.031	< 0.0001
July	33.72	32.82	34.37	0.44	0.023	< 0.0001
August	32.52	30.73	33.8	0.52	0.021	< 0.0001
September	32.7	31.78	33.43	0.51	0.027	< 0.0001
October	33.31	31.83	33.94	0.48	0.024	< 0.0001
November	28.4	27.57	29.28	0.58	0.028	< 0.0001
December	30.14	28.6	31.3	0.56	0.026	< 0.0001
Belg	33.2	31.85	33.91	0.58	0.031	< 0.0001
Kiremt	33.52	32.23	34.17	0.50	0.024	< 0.0001
Bega	30.11	28.99	30.7	0.50	0.026	< 0.0001
Annual	32.28	31.02	32.89	0.52	0.027	< 0.0001

Table 32. Mieso monthly, seasonal and annual minimum temperature variability and trend

Variable	Mean	Min.	Max.	SD	Sen's slope	p-value
January	13	13	14	0.56	0.03	< 0.0001
February	15	14	16	0.64	0.03	< 0.0001
March	17	16	18	0.59	0.03	< 0.0001
April	20	19	21	0.46	0.02	< 0.0001
May	22	21	22	0.44	0.02	< 0.0001
June	22	21	22	0.50	0.03	< 0.0001
July	20	19	20	0.44	0.02	< 0.0001
August	19	18	20	0.50	0.02	< 0.0001
September	21	20	21	0.42	0.02	< 0.0001
October	19	17	19	0.43	0.02	< 0.0001
November	12	11	13	0.55	0.03	< 0.0001
December	15	13	16	0.48	0.02	< 0.0001
Belg	18	17	19	0.53	0.03	< 0.0001
Kiremt	20	19	21	0.45	0.02	< 0.0001
Bega	15	14	15	0.49	0.03	< 0.0001
Annual	18	17	18	0.49	0.03	< 0.0001

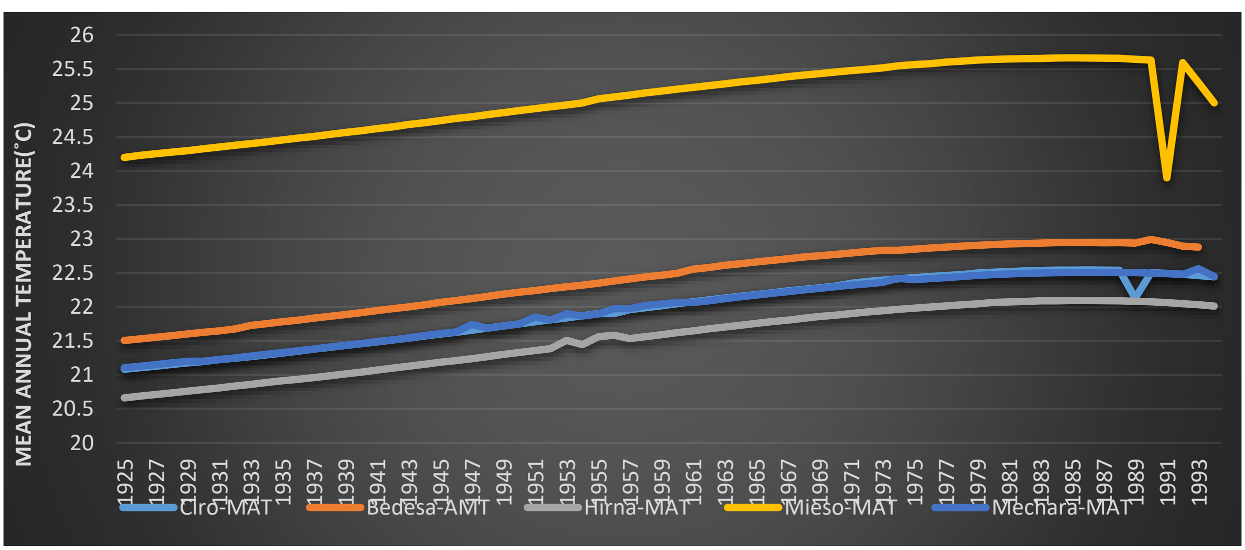

Figure 1. Trend of Mean Annual Temperature

As shown in Table 23-32 listed and Figure 1 above, all months and seasonal projected mean Maximum and minimum temperature had showed less variability and high stability at all studied stations. Moreover, all months and seasonal maximum and minimum temperature are expected to experience the worming trend at all stations till the end of 21Century.

Summary

The study has reviled high variation in spatial intra- seasonal rainfall amount distribution and also inters-seasonal (temporal) distribution. Trend of observed Belg and annual rainfall amount was spatially inconsistent, but Kiremt and Bega rainfall amount had showed non-significant positive trend at all stations. Both mean annual maximum and minimum temperature had showed stable degree of hotness and less variability at all stations. In general, both mean annual maximum and minimum temperature had showed worming trend at all stations except mean minimum annual temperature that showed cooling trend at Hirna

Almost at all stations; the variability of onset date of Belg rain was more variable and less stable than Kiremt onset and cessation date(less variable). Thus, high variability and less stability of Belg onset date have indicated that the patterns could not be easily understood and decisions concerning crop planting and related activities are made with high risk. This study reported the non-significant late onset date of Belg rain at all stations.

Belg rainfall amount Expected to be experienced spatially inconsistent trend of in west Harerghe. Kiremt rainfall amount had indicated significant reduction at all stations except at Hirna that indicated non-significant increasing trend. In contrary, Bega rainfall amount is expected to increase significantly at all stations. In general annual mean rainfall amount is expected to decrease significantly at Chiro, Mieso, Mechara and Bedesa whereas, non-significant reduction at Hirna to the end of 21 century. In general, The result of projection have notified that: West Harerghe is expected to experience both unusual dry and wet years than the climatological condition in the future.

Recommendations

- Awareness should be created for each characterized climate variables spatially independently for community and concerned stakeholder.
- Due attention should be paid to use meteorological forecast and early warning system
- Projected climate change and variability impacts and possible adaptation strategies among different stakeholders has to communicated

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Assessment of Existing agroforestry practices in West Hararghe Zone of Oromia Region, Ethiopia

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Abstract:

A study was conducted in west Hararghe zone, on three districts, in six peasant associations with the intention to identify and assess potentials, constraints, opportunities and farmers' perception on the existing agro-forestry practices of the study areas. The study was multistage sampling methods in which 121 households were selected using random sampling technique. Qualitative data generated by conducting household survey interviews, focus group discussions, key informant interview, and direct field observations in order to fit intention of the study. The collected Data was manipulated using suitable analytical software packages (SPSS, V.20) to calculate percentage and frequency of events through descriptive statistics. Based on the respondents idea across the districts, an average value of home garden agroforestry practices with 86% increasing and 11.5% decreasing and 2.5% no change trends were observed; while alley cropping of agroforestry practice during the past ten years ago with 89.3% increasing and 10.7% decreasing trend was observed (Table 4). Almost all in both Hararghe zones; alley cropping system is the most familiar than other existing agroforestry practices. For instance; an average value across the districts, Kchat plantation in alley cropping practice during the past ten years ago with 97.5% increasing and 2.5% decreasing trend was recorded (Table 4). In the result, the three top and the highest percentage observation of woody species have been retaining and planting in farmland across districts with the specific uses were Catha Edulis with (64.2%), Coffea with (49.9%) and Cordia Africana with (36.7%) could be observed (Table 2). The three top constraints of agroforestry practices were shortage of farm land with (43.8%), lack of understanding with (24.8%) and nutrient competition with (20.7%) observed. Basically, agroforestry practices needs optimum farm land size with related extent in order to compensate the observed constraints. On the contrary, the three top opportunities of agroforestry practices were Multipurpose Utilities with (26.1%), provision of shading with (14.3%) and Climate Balance with (6.7%) observed .It was also found that multipurpose trees shrubs play various traditional roles to local community. Generally; retention and planting of trees/shrubs in farm lands are used for fuel, construction, food, medicine, folder, and aesthetic *value, shading values, windbreak, soil conservation and soil fertility improvement, bee forage and other uses in advance.*

Keywords: Existing Agroforestry practices, Multidimensional utilizes of Trees/shrubs, Woody Species

Introduction

Agroforestry is defined as "an ecologically based natural resource management system that integrates trees (for fiber, food and energy) with crop and/or animal on the same land units, while maintaining ecosystem service" (6;15). Worldwide deem that agroforestry give various ecosystem services through providing diversification of household need in addition to cultural service such as agro-tourism, aesthetic value, demonstration and education. Principally, agroforestry afford amendable service such as soil conservation, watershed management, pest control and carbon sinks. In so doing that, it gives higher contributing to the mitigation of global climate change (7).

In developing countries especially Africa, rapid population growth, decline in per capita food production and environmental degradation are the main problems. Consequently, the need for intensification of agricultural production coupled with population growth. Then the farmers force to expand their cultivation to hilly and marginal areas (3). This aggravates the degradation and unsustainability of natural resource. In relation to this, agroforestry practice can be the only option to condense pressure on leftover natural forest as off deforestation and sustain biodiversity (8; 4).

The tropical region has many traditional agroforestry practices such as scattered trees on crop field, homestead tree planting and multistory home garden (12). There are three common classification of agroforestry system (forms, structures and arrangements). Under the forms of agroforestry system classification are agro-silvo-cultural (crops + trees), silvo-pasture (trees + animals) and agro-silvo-pastoral (crop + trees + animals) systems (11). Under the structure of agroforestry system classification are crop under tree cover and multi-strata agroforestry. Under the arrangement of agroforestry system classification are animal agroforestry, sequential agroforestry and minor agroforestry techniques. Agroforestry practice in the tropic and sub-tropic is probably as old as agriculture itself (14; 9).

In Ethiopia, the integration of trees and shrubs into agriculture emerged many years ago (Edmond *et al.* 2000). In ancient time, the cultivation of domesticated and wild fruit tree was concentrated in monasteries and isolated churches as major source of food for the nuns, monks, hermits and warriors (4). The historical development of farming in the country followed the human settlement time past and thus is much older in northern Ethiopia than the other parts. Various agroforestry systems are practiced in different part of the country. One of the oldest indigenous agroforestry system is the retention of scattered trees (*Faidherbia albida)* on farmland of rift valley and highland of eastern Ethiopia. Farmers in southern Ethiopia retain *Cordia africana* and *Millettia ferruginea* for maintaining soil fertility on Enset-coffee based agroforestry practice (1;3). Coffee in agroforestry system can be referred as a good example in the Arsi zone Gololcha and Shenen Kolu districts, which are cultivated under the shade of vestige native trees, such as *Cordia africana, Erythrina abyssinica* and *Acacia abyssinica* (2).

Most part of Ethiopian arable land is degraded because of soil erosion dominance. This might be due to no vegetation cover and topography of area thus usually prone to soil erosion. Therefore, agroforestry is the only solutions to reverse the situation in order to meet the multiple demands of forest and tree in sustain form to safe the remaining forest resource and renovate land degradation. Generally, integration of trees in to the farm have to be adapted as biological soil and water conservation for livelihood diversification to meet multiple demands of farmer through agro-forestry practice thereby to mitigate global climate change (13). Now a day to resilience global climate changes that implementation of the desire agroforestry practices are to be as a mono option. So assessment of traditional information of indigenous people is significant. Understanding of the prevailing agriculture scheme is the starting point for development of farming system. The interventions of agricultural development in the past failed due to giving inadequate consideration to traditional knowledge [10]. Therefore; the recommended agroforestry practices have to be informed on the way for researchers, farmers and policymakers to understand the effectiveness of the trees/shrubs on the existing agroforestry practices. Even though the study could be implemented in west Hararghe zone on three districts; would not provide adequate information with evenly understanding of traditional agroforestry practices.

There are several customary agroforestry practices in different agro-ecological region of west Hararghe zone, but they are not well studied and documented based on the report of (5). Assessing of information as well as identifying of constraint and opportunity on the existing agroforestry practices is essential for agroforestry research and advance work in the study areas. In so doing that the study aimed to assess the indigenous agro-forestry practice in the study area and to highlight opportunities and constraints of the agro-forestry practice for sustainable agricultural production alternatively. Furthermore, to assess potential of agro-forestry practices through examining the existing practices with the context of identifying the best practices in the farming system providing to be positive harmony for similar agroecology of the study area.

General Objective

To assess the existing agroforestry practices in West Hararghe Zone, Oromia Region, Ethiopia

Specific Objectives of the Study

- To assess and identify the potentials, constraint, opportunity, perception of farmers as well as preference of tree /shrub species in the existing agro-forestry practices.

Materials and Methods

Description of the Study Area

Oda Bultum woreda is found in West Hararghe Zone, Oromiya Regional State. It is located in the eastern part of the country, 362km from Addis Ababa and 37km from Chiro. Bedessa town serves as the main administrative center of Oda Bultum woreda. Livelihoods in the woreda mainly center on rain fed agriculture, with mixed farming constituting 90% and agro-pastoralism estimated at 10%. Maize, sorghum, teff, wheat and barley are the major food crops while chat, coffee and pepper are the most important cash crops. The mean annual rainfall is 950mm-1053mm, with maximum and minimum temperature is 28.82^0c and 12.51^0c, respectively.

Boke district is one of the districts of West Hararghe zone. The dominant cash crops are coffee and Kchat production. It is located at 391 km East of Addis Ababa and about 69 km south of Chiro, capital town of the zone. The district receives an average annual rainfall of 850 mm and average temperature is 20°C. It shares borders with Chiro district in the west and north, Oda Bultum district in the south and Shenen dhugo district in the East. The district is found within 1300 to 2400 m above sea level. Similarly; Hancar district is one of the districts found in West Hararghe zone. It is located in the eastern part of the country, 352km from Addis Ababa and about 100km from Chiro. Altitude range of Hancar district is 1400-3000m aslv. Mean annual rainfall is 800mmto 2000mm, and with maximum and minimum temperature of the district is about 29.5^0c and 10^0c, respectively (Oromia livelihood profile, 2006).

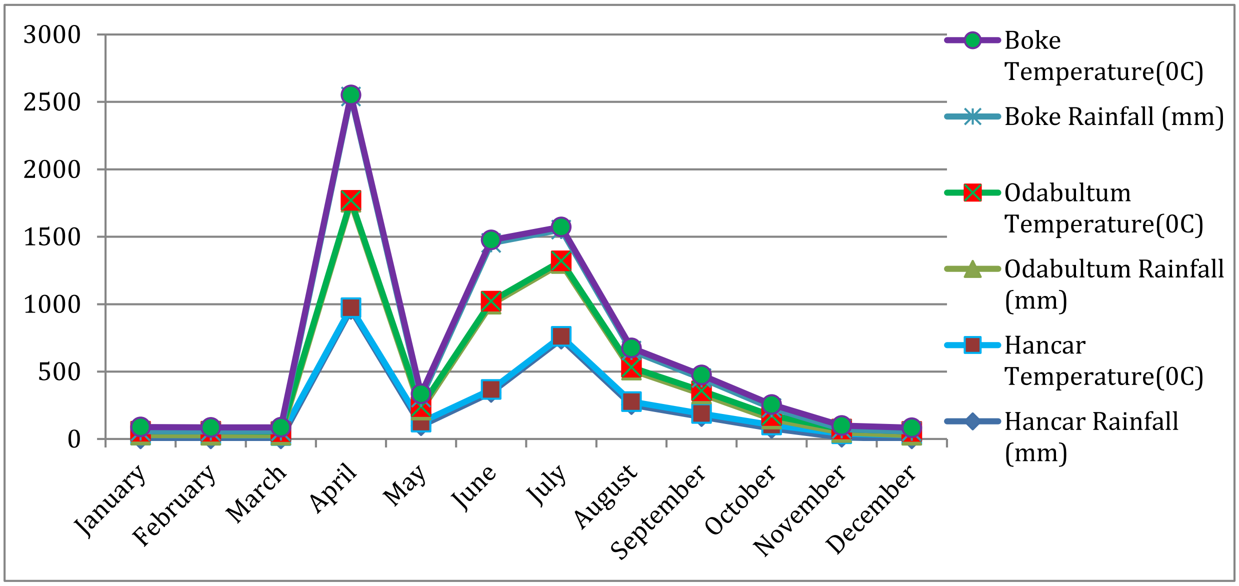

Figure 1-Data of average Temperature and annual mean Rainfall of Hancar, Odabultum and Boke districts, 2020.

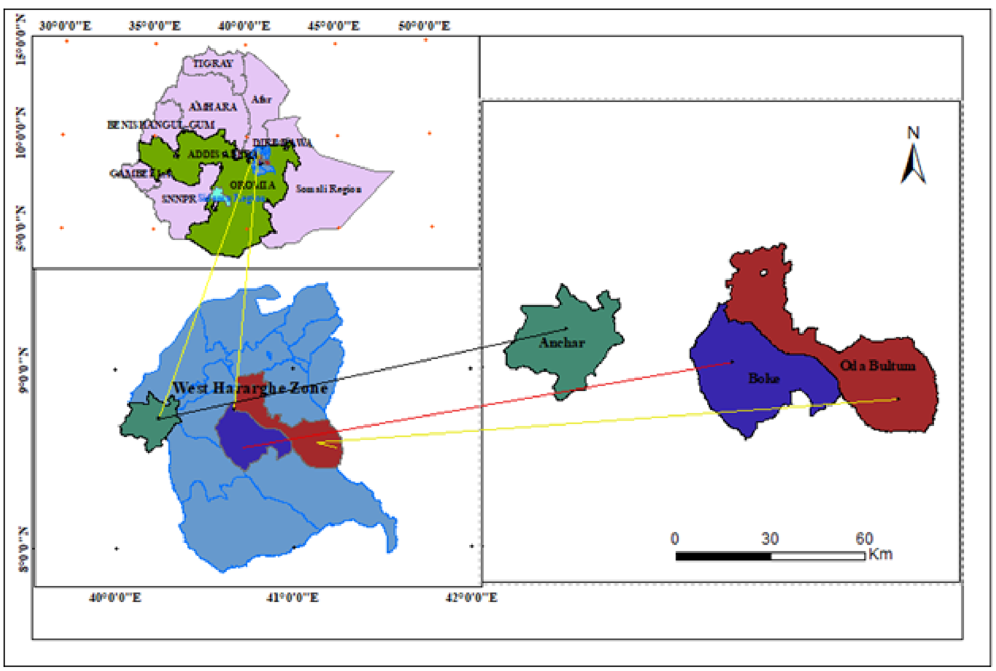

Figure 2; Map of the study districts

Selection of the Study Area

For the intended purpose, three districts, three kebele from each district and fourteen farmers from each kebele were selected to conduct the survey based on agro ecology and altitude range that from low land, mid land and highland of agro ecologies zones. The data was collected based on household survey carried out in districts of the West Hararghe zone in Oromia region, Ethiopia.

Sampling Procedures and Sample Size

The survey was carried out in Western Hararghe Zone. To select district and Kebele, a purposive sampling method was applied based on the objectives of the activity. Accordingly, three districts were selected purposefully based on their exposure to agro-forestry practices, having considerable diversity in terms of agro-ecological zones and their experiences of agro-forestry practices. Then, from each district, three kebele were chosen randomly, based on similar criteria as mentioned above. The farm households for interview were selected randomly from the sample kebele.

Finally, from each kebele of one district that fourteen farmers were selected randomly and a total of 121 households for the intended purpose. Fruit full data was collected from 121 households with semi-structured questionnaires concerning to consistent of agroforestry practice by individual farmers' interview. The inquiry guide checklist was supplied for each individuals and focus group discussions to capture the data from semi-structured questionnaires including farming characteristics of the study area, which are mainly serving in agroforestry practice.

Method of Data Collection

Semi-structured interviews from the selected individual farmers, focus group discussions and personal observations was implemented to generate primary data pertaining to the existing agro-forestry systems and practices in the study area. The survey from household was implemented to collect data on general socio-economic characteristics of sample households and to know facts about the household, their experience in agro-forestry practice, reasons for their participation in agro-forestry practices, indigenous knowledge on agroforestry practice and constraints and opportunities they faced.

The major source of data was gained from sample households and focus group discussions to get preliminary information about the agro-forestry practices, prevailing opportunities and constraints in implementing agro-forestry practices with key informants (DAs, community leaders), elders and experienced farmers using guide checklist questions so as to explore information pertaining with agro-forestry practices in the study area.

The Collected Data

The input of all inquiries from each individual and focus group checklists' data/ feedback, including the plant species occurs that were mainly serving in agroforestry system, perception of farmers on agroforestry utilities, opportunities and constraints, and also the types of agroforestry practices in the study area were collected for further analysis.

Method of Data Analysis

The collected data was coded and entered in to the computer. Quantitative data was analyzed by using descriptive statistics such as frequency and percentages in order to describe the event as it was. On the other hand, qualitative data was analyzed through narration and description.

Finally, the available data was compiled using Statistical Package for Social Science (SPSS) version 20 software. Qualitative data that obtains from interview and discussion was analyzed and described through concepts and opinions, by sorting out, grouping and organizing in the field that to supplement the survey result. In general, the data was managed and analyzed by descriptive analysis and narration.

Result and Discussion

Characteristics of Sample Households

Result of this study indicated that the existing agroforestry practices are mostly done by men due to cultural value of the country. Thus; out of the total respondents, 121 (96.3%) of them were male; while the rest 4 (3.3%) of them were female. The survey result showed that only 43% of the respondents were educated; while 57% were uneducated. With regards to the experience of farming status that below 25 years of the respondents were 11.6%; while above 25 years of the respondents were 88.4% (Table 1). This means that the respondents were native to the study area. The idea reflected nativness of respondent was 98.3%; while 0.8% new comers to the study area. The eminences to main problem of farm Land were soil erosion, soil fertility, drought, disease and water logging that with 13.2%, 33.1%, 28.1%, 11.6 % and 6.6 % observed, respectively. The other standing points of main problem of the respondents on farming system were shortage of farm land with 71.1%, capita with 8.3 %, labor with 2.5% and input problem with 16.5% observed (Table 1). Agro ecological zone of the study areas are high land of Hancar district with 33.1 % coverage, midland of Odabultum district with 33.9% coverage and low land of Boke district with 33.1% coverage perceived (Table 1).

Table 1: Descriptive Statistics of Socio-economic characteristics of Respondents

No	Variables	Values		
		Indicator	Frequency	Percentage (%)
1	Gender of house hold	➢ Male	117	96.7
		➢ Female	4	3.3
		Total	121	100
2	Education level of house hold	➢ Educated	69	57
		➢ Un educated	52	43
		Total	121	100
3	Experience of farming system	➢ Below 25 years	14	11.6
		➢ Above 25 years	107	88.4
		Total	121	100
4	Presences	➢ Native	119	98.3
		➢ New comers	1	0.8
		Total	121	100
5	Main Problem of Farm Land	➢ Soil erosion	16	13.2
		➢ Soil fertility	40	33.1

		➢	Drought	34	28.1
		➢	Weed	7	5.8
		➢	Disease	14	11.6
		➢	Waterlogging	8	6.6
			Total	121	100
6	Main Problem of Farming system	➢	Land size	26	71.1
		➢	Capital	10	8.3
		➢	Labor	3	2.5
		➢	Input	20	16.5
			Total	121	100
7	Respondents with Districts	➢	Hancar	40	33.1
		➢	Odabultum	41	33.9
		➢	Boke	40	33.1
			Total	121	100
8	Respondents with Agro ecological zone	➢	Lowland (<1500)	40	33.1
		➢	Midland(1500-2300)	41	33.9
			Total	121	100

Source: Survey Result, 2020/21

Reason of Farmer Implementing Agroforestry Practices

Small holder farmers in the study area have a great awareness about the benefit of traditional agroforestry practice. Most of the respondents believed that traditional agroforestry practices had a vital role to enhance the overall productivity of farmlands. The major reason and benefit of planting and retention of woody species in farm land as agroforestry practices in the study area used for household consumption, environmental services and ecological balance through multidimensional delivery. Additionally, the use and service of woody species in farmlands are: as food, feed, fuel, income, construction, shade and soil fertility improvement. So the farmers in the study area have been adapting diversified uses and services from retained and planted trees/shrubs species in their farm lands.

In the results, the three top and the highest percentage observation of woody species that have been retaining and planting in farmland across districts with the specific uses are *Catha Edulis*, *Coffea* and *Cordia Africana* (Table 2). The result of this study in line with the findings of [5], that asserted trees/shrubs species were deliberately retained and/or planted in farmlands have served the people for supplying food, fodder, income generation, wood, shade and environmental services.

Generally, the study had reflected that smallholder farmers of western Hararghe zone have well perceived and identified the implementation and value of trees/shrubs species from the existing agroforestry practices. Thus, each of the tree/shrub species had own benefits to sustain livelihood of the societies.

Perception of Farmers about Agroforestry

Table 2 : **The Type of Trees/Shrubs and their uses in Agroforestry practices across districts**

Districts	**Scientific name**	**Local Name**	**uses of trees/shrubs for:**	Frqncy.	(%.)
Boke	***1-Catha Edulis***	**Jima**	**Chewing/Feed/Income/Fuel**	**37**	14.2
	2- Coffea	**Buna**	**Drinking/Income**	**37**	14.2
	3- Cordia Africana	**Weddessa**	**Shade/Timber/Income/Fuel**	**28**	10.7
	4- Mangifera Indica	Maango	Food/Income/Shade	24	9.2
	5-Papaya	Paapaayyaa	Food/Income/Shade	16	6.1
	6-Moringa	Shiferaw	Food/Feed/Medicinal Plant	12	4.6
	7-Ficus Sycomorus	Harbu	Shade/Timber/Fuel	11	4.2
	8-Terminalia Brownie	Berensa,	Shade/Timber/Fuel	11	4.2
	9-Acaciaalbida	Garbi	Shade/Timber/Fuel	10	3.8
	10-Olia Africana	Ejarsa	Shade/Fuel	9	3.4
	11-Sesbania Sesban	Enchini, Harcha	Shade/Feed/Fuel	9	3.4
	12-Vernonia Amygdalina	Ebicha	Feed/Fuel/Medicinal Plant	9	3.4
	13-Ziziphus Mucronata	Qurqura	Shade/Feed/Fuel	9	3.4
	14-Shugerken	Shankora	Food/feed/Income	7	2.7
	15-Maesa Lanceolata	Abayi	Shade/Fuel	6	2.3
	16-Otostegia Integrifolia	Tingiti	Medicinal Plant	6	2.3
	17-Podocarpus Falcatus	Bibirsaa	Shade/Timber	4	1.5
	18-Melia Azedarach	Muka Kinin	Shade/Feed/Fuel	3	1.1
	19-Musa Acuminate	Werqe	Shade/Food/Feed	3	1.1
	20--Orange	Birtukana	Food/Shade	3	1.1

	21-Mimusops Kummel	Mito	Shade/Food/Fuel	3	1.1
	22-Sitress Limen	Xuxxo	Food/Shade	2	0.8
	23-Tamarindus Indica	Roka	Shade/Fuel	2	0.8
Sub-total				**261**	**100.**
Hancar	***1-Catha Edulis***	**Jima**	**Chewing/Feed/Income/Fuel**	**50**	20.4
	2-Cordia Africana	**Waddesa**	**Shade/Timber/Income/Fuel**	**40**	16.3
	3-Coffea	**Buna**	**Drinking/Income**	**33**	13.5
	4-Acacia albida	Garbi	Shade/Timber/Fuel	30	12.2
	5-Casimiroa Edulis	Kasamiro	Food/Shade/Fuel	18	7.3
	6-Mangifera Indica	Maango	Food/Income/Shade	17	6.9
	7- Caesarian Cunninghamiana	Shewshawe	Shade /Fuel	10	4.1
	8-Persea Americana	Avocado	Shade/Food/Fuel	9	3.7
	9- Shugerken	shankora	Food/feed/Income	7	2.9
	10-Albizia Schimpeiana	Muka Arba	Shade/Fuel	6	2.4
	11-Annona Senegalensis	Komate,Gishxa	Shade/Food/Fuel	6	2.4
	12-Casuarina Equisetifolia	Shuwshuwe	Shade/Timber/Fuel	5	2.0
	13-Combretum Molle	Bika	Shade/ Food/Feed/Fuel	5	2.0
	14-Acacia Senegal	Saphensa, Garbi Dima	Shade/Fuel	3	1.2
	15-Acacia Tortolis	Tedecha	Shade/Fuel	2	0.8
	16-Cactus	Tinii	Food/Feed	2	0.8
	17--Melia Azedarach	Muka Kinin	Shade/Feed/Fuel	2	0.8
Sub-total				**245**	**100**
Odabultum	***1-Catha Edulis***	**Jima**	**Chewing/Feed/Income/Fuel**	**90**	29.6
	2-Coffea	**Buna**	**Drinking/Income**	**59**	19.4
	3-- Cordia Africana	**Waddesa**	**Shade/Timber/Income/Fuel**	**38**	12.5
	4- Acacia albida	Garbi	Shade/Fuel	30	9.9
	5- Eucalyptus	Bahargamo	Constriction/Income/Fuel	18	5.9
	6--Gravilia Robusta	Gravilia	Shade/Timber/Income/Fuel	18	5.9

	7-Erythrina Abyssinica	Walensu	Shade/Feed/Fuel	10	3.3
	8--Juniperus Procera	gaantra	Shade/Timber/Fuel	9	3.0
	9-Balanites Aegyptiaca	Bedena, Baddano	Shade/Timber/Fuel	8	2.6
	10--Ehretia Cymosa	Ulaga,	Shade/Fuel	6	2.0
	11-Elephant Grass	Shankora Hori	Feed	6	2.0
	12-Croton Macrostachyus	Bakanisa	Shade/Fuel	5	1.6
	13-Mangifera Indica	maango	Food/Income/Shade	2	0.7
	14-Rhus Natalensis	Debobosso	Shade/Fuel	2	0.7
	15-Tamarindus Indica	Roka	Shade/Fuel	2	0.7
	16-Ziziphus Mucronata	qurqura	Shade/Feed/Fuel	1	0.3
Sub-total				304	100
Grand Total				810	**100.**

The current practices of smallholder farmers' on the existing agroforestry practices into their farm plots were recorded through informant interviews. Of 121 respondents; 70 informants with (57.9%) replied "strongly agree"; while 2 informants with (1.7%) replied "Neural "perception that "an agroforestry practice increase farm income" (Table 3). So, the proportion of smallholder farmers with a positive attitude to existing agroforestry practices on their farm land is significantly higher than those who were not clearly and openly optimistic (Table 3). Similarly, 76 informants with 62.8% replayed "agree": that "agroforestry practices reduce the chance of completely crop faille" (Table 3). This response reflected that agroforestry practice help farmers to meet their basic need and minimize the risk of the production system's total failure. The result of this study in line with (ICRAF, {15}) that, Agroforestry practice has reduced the chances of complete crop failure. Based the respondents idea; they had awareness and positive attitude based on a given arrogances inquiry of the existing agroforestry practices (Table 3). Generally, the farmers had positive perception on agroforestry practices in the study area and they know very well on its utilities for income diversification, improvement of soil quality, fuel, construction materials, food, and feed, provision of shade, accessibility and ecological value etc, could be understood from the given inquiry parameters (Table 3).

Source: Survey Result, 2020/21

Trends of Agroforestry practices

The major trends of agro forestry practice involved in the study area were identified (Table 4). Similar to other parts of Ethiopia, the following existing agroforestry system and the special practices of the study areas were identified. The result of the study revealed that, among the different existing traditional of agroforestry practices; the trend of parkland agroforestry practice in the past 10 years duration across the districts was indicated increasing scenario. So over all in average increasing with 83.5%, decreasing with 12.4% and no change with 4.1% were recorded (Table 4).

Trend of home garden agroforestry practice was observed in Hancar with 87.5% increasing, 5% decreasing and 7.5% no change; whereas in Odabultum district 82,2% increasing, 17.5% decreasing and 0% no change,

Table:3:- Perception of farmers on Existing Agroforestry Practices

Attitude of respondents to Agroforestry practices		Perception value of respondents across district								
		Degree of perception	Ancar		Odabultum		Boke		Grand Total	
			Freq uency	Perc. (%)	Freq uency	Perc. (%)	Freq uency	Perc. (%)	Freq Uency	Perc. (%)
1	Does an agroforestry practice increase farm income	-Strongly Agree	24	60.0	20	48.8	26	65	**70**	**57.9**
		-Agree	16	40.0	21	51.2	12	30	**49**	**40.4**
		-Neutral	0	0.0	0	0.0	2	5	**2**	**1.7**
		-Disagree	0	0.0	0	0.0	0	0	**0**	**0.0**
		-Strongly Disagree	0	0.0	0	0.0	0	0	**0**	**0.0**
		-Total	**40**	**100**	**41**	**100**	**40**	**100**	**121**	**100.0**
2	Does an agroforestry practice improve soil fertility and soil and water conserve	-Strongly Agree	4	10	20	48.8	17	42.5	**41**	**33.8**
		-Agree	1	2.5	17	41.5	22	55.0	**40**	**33.0**
		-Neutral	15	37.5	2	4.9	0	0.0	**17**	**14.1**
		-Disagree	19	47.5	1	2.4	1	2.5	**21**	**17.5**
		-Strongly Disagree	1	2.5	1	2.4	0	0.0	**2**	**1.6**
		-Total	**40**	**100**	**41**	**100**	**40**	**100**	**121**	**100**
3	Does an agroforestry practice reduce the chance of completely crop faille	-Strongly Agree	14	35	9	22.0	15	37.5	**38**	**31.5**
		-Agree	26	65	27	65.9	23	57.5	**76**	**62.8**
		-Neutral	0	0	5	12.2	2	5	**7**	**5.7**
		-Disagree	0	0	0	0.0	0	0	**0**	**0.0**
		-Strongly Disagree	0	0	0	0.0	0	0	**0**	**0.0**
		-Total	**40**	**100.0**	**41**	**100**	**40**	**100**	**121**	**100**
4	Does agroforestry practice save time on	-Strongly Agree	5	12.5	9	22.0	15	37.5	**29**	**24.0**
		-Agree	30	75.0	27	65.9	20	50	**77**	**63.6**
		-Neutral	1	2.5	5	12.2	2	5	**8**	**6.6**
		-Disagree	0	0.0	0	0.0	0	0	**0**	**0.0**

while 87.5% increasing, 12.5% decreasing and 5% no change was recorded in Boke district that with an

	collecting fodder and fuel wood	-Strongly Disagree	0	0.0	0	0.0	0	0	**0**	**0.0**
		-Total	**40**	**100.0**	**41**	**100**	**40**	**100**	**121**	**100**
5	Does an agroforestry practice take a long time to get income	-Strongly Agree	7	17.5	8	19.5	14	35	**29**	**24.0**
		-Agree	26	65.0	25	61.0	21	52.5	**72**	**59.5**
		-Neutral	2	5.0	3	7.3	2	5	**7**	**5.8**
		-Disagree	1	2.5	1	2.4	1	2.5	**3**	**2.5**
		-Strongly Disagree	0	0.0	0	0.0	0	0	**0**	**0.0**
		-Total	**40**	**100.0**	**41**	**100**	**40**	**100**	**121**	**100.0**
6	Does an agroforestry practice maintain weather condition	-Strongly Agree	18	45	13	31.7	17	42.5	**48**	**39.7**
		-Agree	22	55	22	53.7	18	45	**62**	**51.2**
		-Neutral	0	0	1	2.4	1	2.5	**2**	**1.6**
		-Disagree	0	0	1	2.4	1	2.5	**2**	**1.6**
		-Strongly Disagree	0	0	0	0.0	1	2.5	**1**	**0.8**
		-Total	**40**	**100.0**	**41**	**100**	**40**	**100**	**121**	**100.0**
7	Does an agroforestry practice sustain bio-diversities conservation	-Strongly Agree	12	30	9	22.0	12	30	**33**	**27.3**
		-Agree	24	60	29	70.7	23	57.5	**76**	**62.7**
		-Neutral	4	10	2	4.9	5	12.5	**11**	**9.1**
		-Disagree	0	0	1	2.4	0	0	**1**	**0.8**
		-Strongly Disagree	0	0	0	0.0	0	0	**0**	**0.0**
		-Total	**40**	**100.0**	**41**	**100**	**40**	**100**	**121**	**100.0**
8	Does an agroforestry practice sustain hydrologic cycling	-Strongly Agree	13	32.5	11	26.8	15	37.5	**39**	**32.3**
		-Agree	20	50	22	53.7	21	52.5	**63**	**52.1**
		-Neutral	3	7.5	5	12.2	2	5	**10**	**8.2**
		-Disagree	0	0	0	0.0	0	0	**0**	**0.0**
		-Strongly Disagree	0	0	3	7.3	0	0	**3**	**2.4**
		-Total	**40**	**100.0**	**41**	**100**	**40**	**100**	**121**	**100.0**
9	Does an agroforestry practice the	-Strongly Agree	19	47.5	17	41.5	21	52.5	**57**	**47.2**
		-Agree	16	40	18	43.9	16	40	**50**	**41.3**
		-Neutral	1	2.5	1	2.4	1	2.5	**3**	**2.5**

	option to save deforestation	-Disagree	0	0	0	0.0	0	0	**0**	**0.0**
		-Strongly Disagree	0	0	1	2.4	0	0	**1**	**0.8**
		-Total	**40**	**100.0**	**41**	**100**	**40**	**100**	**121**	**100.0**
10	Do you think tree production in farm land minimize deforestation	-Strongly Agree	34	85	33	80.5	34	85	**101**	**83.5**
		-Agree	3	7.5	5	12.2	3	7.5	**11**	**9.1**
		-Neutral	3	7.5	3	7.3	3	7.5	**9**	**7.4**
		-Disagree	0	0	0	0.0	0	0	**0**	**0.0**
		-Strongly Disagree	0	0	0	0.0	0	0	**0**	**0.0**
		-Total	**40**	**100**	**41**	**100**	**40**	**100**	**121**	**100.0**

average value of 86% increasing and 11.5% decreasing observed (Table 4). Trends of alley cropping agroforestry practice in Hancar inquired 97.5% increasing, 2.5% decreasing and 0% no change, and in Odabultum district 82.9% increasing, 17.1% decreasing and 0% no change; while in Boke district 87.5% increasing, 12.5% decreasing and 0% no change was recorded and also with an average value was 89.3% increasing and 10.7% decreasing was observed (Table 4). Almost all in both Hararghe zones; alley cropping practice is the most familiar than other existing Agroforestry practices. For instance; Trends of Kchat plantation in alley practice was 97.5% increasing, 2.5% decreasing and 0% no change was recorded in Hancar district, while 85.4% was increase, 14.6% decrease and no change was 0% recorded in Odabultum district; whereas 92.5% was increasing, 7.5% was decreasing and 0% was no change recorded in Boke district; and with an average value of districts for Kchat plantation was 91.8% increasing, 8.2% was decreasing was observed (Table 4).

On the other side, in alley practice; the trend of coffee plantation was contrary of Kchat plantation across the district that means Kchat plantation is dominating and replacing Coffee plantation almost in all Hararghe districts surprisingly (Table 4). However, it makes subjective imperfection of human mind; Hararghe farmers are very sensitive to Kchat plantation for their livelihood dependency thereby used for soil and water conservation purpose. Generally; the study result implies that domination of Kchat plantation across the districts is increasing scenarios extremely.

Opportunities and Constraints of Existing Agroforestry Practice for the Farmers

Table 4: Trend values of Existing Agroforestry Practices across the districts in the past 10 years

Trend of Existing Agroforestry Practices in	Trend value of respondents across district								
the last 10 years	Degree of Trends	Hancar		Odabultum		Boke		Grand total	
		Freq	Perce	Freq	Perce	Freq	Perce	Freq	Perce

			uency	(%)	uency	(%)	uency	(%)	uency	(%)
1	Trend of tree planting in the last 10 years	Increasing	35	87.5	27	65.9	33	82.5	95	78.6
		Decreasing	4	10	9	22.0	5	12.5	18	14.8
		No change	1	2.5	6	14.6	2	5	9	7.4
		Total	40	100	41	100	40	100	121	100.0
2	Trend of home garden agroforestry practice in the last 10 years	Increasing	35	87.5	34	82.9	35	87.5	104	86.0
		Decreasing	2	5.0	7	17.1	5	12.5	14	11.5
		No change	3	7.5	0	0.0	0	0	3	2.5
		Total	40	100	41	100	40	100	121	100.0
3	Trend of parkland agroforestry practice in the last 10 years	Increasing	33	82.5	33	80.5	35	87.5	101	83.5
		Decreasing	7	17.5	3	7.3	5	12.5	15	12.4
		No change	0	0.0	5	12.2	0	0	5	4.1
		Total	40	100	41	100	40	100	121	100.0
4	Trend of woodlot in the last 10 years	Increasing	16	40.0	14	34.1	21	52.5	51	42.2
		Decreasing	12	30.0	27	65.9	19	47.5	58	47.8
		No change	12	30.0	0	0.0	0	0	12	10.0
		Total	40	100	41	100	40	100	121	100.0
5	Trend of alley croping in the last 10 years	Increasing	39	97.5	34	82.9	35	87.5	108	89.3
		Decreasing	1	2.5	7	17.1	5	12.5	13	10.7
		No change	0.0	0.0	0	0.0	0	0	0	0.0
		Total	40	100	41	100	40	100	121	100.0
	➢ *Trend of coffee production in the last 10 years*	*Increasing*	*10*	*25.0*	*8*	*19.5*	*3*	*7.5*	21	17.3
		Decreasing	*23*	*57.5*	*25*	*61.0*	*30*	*75*	78	64.5
		No change	*7*	*17.5*	*8*	*19.5*	*7*	*17.5*	22	18.2
		Total	*40*	*100*	*41*	*100*	*40*	*100*	121	100.0
	➢ *Trend of kchat production in the last 10 year*	Increasing	*39*	*97.5*	*35*	*85.4*	*37*	*92.5*	111	91.8
		Decreasing	*1*	*2.5*	*6*	*14.6*	*3*	*7.5*	10	8.2
		No change	*0*	*0*	*0*	*0.0*	*0*	*0*	0	0.0

		Total	40	100	41	100	40	100	121	100.0
6	Trend of animal diversity in the last 10 year	Increasing	29	72.5	7	17.1	38	95	74	61.5
		Decreasing	11	27.5	34	82.9	2	5	47	38.5
		No change	0	0.0	0	0.0	0	0	0	0.0
		Total	40	100	41	100	40	100	121	100.0
7	Trend of honey production in the last 10 years	Increasing	1	2.5	1	2.4	1	2.5	3	2.5
		Decreasing	38	95.0	40	97.6	37	92.5	115	95.0
		No change	1	2.5	0	0.0	2	5	3	2.5
		Total	40	100	41	100	40	100	121	100.0
8	Trend of animal feed usage in the last 10 years	Increasing	18	45	20	48.8	18	45	56	46.3
		Decreasing	10	25	12	29.3	11	27.5	33	27.3
		No change	12	30	9	22.0	11	27.5	32	26.5
		Total	40	100	41	100	40	100	121	100.0

The result showed that as the resource becomes scarce; farmers change their survival strategy either by migrating to productive areas or by diversifying agroforestry practices. Agroforestry practices such as fodder, fuel wood, livestock and crops on the same unite of lands. Therefore, excellent opportunities for introducing improved agroforestry practices so that there is a need to provide improved provenances of fruit and multipurpose trees/shrubs species. The farmers' plant/protect trees on farmland and appreciate their role in improving soil fertility. The farmers of the study areas have to be given appreciation and promotion for their bests is the best opportunity of the practice.

Major constraints and barrier to adapt agroforestry practices are shortage of farm land for silvicultural practices with 43.8%, lack of understanding with 24.8%, computation with crops with 20.7%, Hosts for arboreal animals with 4.1%, over shading problem with 2.5%, Computation available nutrients and moisture with 1.7% and Cause of disease with 2.5% were observed (Table 5). Agroforestry practices are needed optimum farm land size with related extent in order to compensate the observed constraints. On the contrary; the best opportunities of agroforestry practices are observed in the study that enable the farmers to be used multidimensional utilities was recorded by highest percentage of respondents' responses with (26.1%) followed by shade delivery values with (14.3%) was indicated (Table 5).

Generally, necessary to inspire the wisely implementation of agroforestry practices enable to convince and engage in the opposite of the constraints on existing agroforestry practices.

Table 5: Major constraints and opportunities of the study area in Agroforestry practices

Major opportunity of agroforestry practice in the study areas		
Lists of opportunities	Frequency	Percent (%)
Multipurpose Utilities	31	26.1
Shading value	17	14.3
Climate Balance	8	6.7
Wind break	8	6.7
Feed and food	7	5.9
Add Soil Fertility	6	5
Income diversification	5	4.2
Save Time To Collect	3	2.5
Soil and Water Conservation	3	2.5
Fuel	2	1.7
For construction	2	1.7
Seedling source	2	1.7
Environmental Wall Fare	1	0.8
Wood accessibility from farm	1	0.8
Total	119	100.0

Major Constraints of agroforestry practice in the study areas		
Lists of constraints	Frequency	Percent (%)
Shortage of farm land	53	43.8
Lack of understanding	30	24.8
Competition With Crops	25	20.7
Hosts for arboreal animals	5	4.1
Over Shading problem	3	2.5
Computation available nutrients and moisture	2	1.7
Couse of Disease	3	2.5
Total	121	100.00

Conclusion and Recommendations

Conclusion

The active involvement of farmers on traditional agroforestry practices showed that they have to be given awareness creation on their traditional practices for their livelihood progress. The traditional knowledge on agroforestry system and practice management being applied in the study site should have to get recognition and promotion. Farmers identified and used the number of multipurpose trees/shrubs species with consideration of various degree values. Therefore, traditional, agroforestry practice could be the best option to improve small farmer's livelihood in study site based on multidimensional utilities could be mentioned in the above tables. Among the major concerning point of existing traditional of agroforestry practices, "trends of parkland agroforestry practice, Trends of home garden agroforestry practice and Trends of alley cropping agroforestry practice within the past 10 years ago indicated increasing scenario in all of the study districts. Nevertheless; Kchat makes subjective imperfection of human mind, it has been increasing alarming rate that in the Trends of alley cropping agroforestry practice. This indicated that the increment of trend of Kchat plantation caused distraction of coffee plantation within the past 10 years ago across districts had been observed from the study areas.

Recommendations

Existing traditional agroforestry practices were observed and identified. However; improving, existing and introducing new agroforestry systems is needed. Research should explore the local species that could be of interest to the farmers and needs bringing new technologies with expected awareness creation in addition to the existing agroforestry practices. The best existing practices such as usefulness of botanical, ecological knowledge and management practices should be promoted for other interested farmers.

Generally, as a recommendation; farmers need to be provided with the opposite of their constraints and encouraged their opportunities in agroforestry practices to be implemented on farms progressively. Agroforestry practices are needed optimum farm land size with the related extent in order to compensate the observed constraints. Therefore; appropriate planting of improved multipurpose trees/shrubs with identified usage and management techniques need to be developed and extended to farmers through trained of training for more progressive desire.

However; same agroforestry practices of the study area observed improper value of human mind, whereas proper value of income to the societies. For instance, increment and domination of Kchat instead of coffee; makes subjective imperfection of human mind; but it has highest income charge for the societies and this is consequently contradiction values. So for this kind of contradiction value; to be made socially acceptable and economically assuredeble; the farmers should be given training and awareness creation though compare and contrast of negative and positive effect of Kchat plantation based on consideration of social, economic and ecological values.

Hence it is necessary to carryout agroforestry trials in relation to intercropping designs, spacing, planting techniques, improved multipurpose trees/shrubs species and awareness creation should be given for farmers though training. The study suggested that the dominant woody species effect on crop productivity didn't seen. Therefore, the existing agroforestry practices' effect on crop productivity of per plot has to be observed for the way forward.

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Evaluation of Legumes Multipurpose Trees Species Alley Cropping on Maize Yield and Soil Fertility at Abaya District, Southern Oromia, Ethiopia

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Abstract

Agroforestry as a dynamic ecologically-based natural resources management system that through the integration of trees on farms and in the agricultural landscape diversifies and sustains production for increased socio-economic and environmental benefits. Among those, alley cropping is one of the agroforestry practices which is growing food crops between hedgerows of planted shrubs and trees, preferably leguminous species. A study was conducted to evaluate the contribution of alley cropping for improving maize yield and to evaluate the role of alley cropping for soil fertility improvement in the study area. Sesbania sesban and Cajanus cajan trees/shrubs were selected for their potential to improve soil fertility (nitrogen fixing) and have other uses such as fodder. The experiment was designed with four treatments and laid out in randomized complete block design with three replication (block) along the slop gradient. The size of a sampling units (a plot) for each treatments were 20m x 13m and the distance between treatments (plots) was 2m, while; the distance between blocks were 3m. Alley crop was designed in doubled alley per study plot and the size of an alley crop was 20m x 5m. The selected variety of maize (Gibe 2) was sown between alleys of trees/shrubs with recommended spacing of 25cm and 75cm between plant and rows of maize respectively. Soil samples were collected and analyzed to evaluate the change made to soil fertility improvement. As a result, a significant difference among arrangements of maize alley cropping in grain yield was observed at (P<0.001). The highest total grain yield was obtained from maize sown with recommended fertilizer (5.16 ton/ha) in 2018 cropping season and maize grown in between alley of Cajanus cajan (4.33 ton/ha) in 2011 cropping season. The soil chemical properties under the alleys plots improved compared to control plots. Positive changes in the soil fertility in terms of soil organic C, total N, soil pH, available K, and exchangeable Ca, Mg and CEC of the top soil layer were detected in alley cropping system. Between the tree species Cajanus cajan seemed to be better than L. leucocephala in improving soil health. Accordingly, it is recommended to grown maize with recommended application of fertilizer and in between alleys of Cajanus cajan tree/shrub species as it has multipurpose importance.

Key words: Alley crop, soil fertility, yield

Introduction

Agroforestry, growing of multipurpose trees along with agricultural crops and rearing of animals has been an important soil conservation practice. Thus, agroforestry systems are believed to increase or at least maintain the organic matter level of soils mainly through litter fall (Young, 1989). Cultivation of trees and agricultural crops in intimate combination with one another is an ancient practice that farmers have used throughout the world. Traditional agroforestry systems are common and major features of land use systems in the tropics. Particularly in sub-Saharan countries farmers consider trees as an integral part of agriculture, which helps them to overcome many land use problems and constraints (Nair, 1993). Current thinking places Agroforestry as a dynamic ecologically-based natural resources management system that through the integration of trees on farms and in the agricultural landscape diversifies and sustains production for increased socio-economic and environmental benefits (Garrity *et al*., 2006).

The major components of agroforestry systems are trees or shrubs (woody perennials, including bamboos) deliberately retained or planted on the farmland; agricultural crops, including food and 'cash' crops (some of which are herbaceous annuals or perennials); and livestock. In an Agroforestry system, the trees and shrubs provide a variety of products, some of which are consumed by the farming family or sold for cash, and a variety of services that benefit the crops, livestock or the landscape (Garrity *et al*., 2006). In this way, integration of trees and shrubs in crop and livestock production systems can transform the rural landscape, and also improves farmers' livelihood. Among those, alley cropping is one of the agroforestry practices which have paramount advantages.

Alley cropping is broadly defined as the planting of two or more sets of single or multiple rows of trees or shrubs at wide spacing's, creating alleys within which agricultural, horticultural or forage crops are cultivated (Gold *et al*., 2013). This approach is sometimes called intercropping and multi-cropping. Alley cropping provides the opportunity to grow wood or other tree products while providing an annual income through the production of the companion crops. Generally, Alley cropping diversifies farm enterprises by providing short-term cash flow from annual crops while also providing medium to long term products from the woody components; reducing soil erosion from wind and water; reducing erosion on slopping cropland; improving crop production by slowing wind speed and reducing wind erosion; modifying the crop microclimate with similar effects to that of windbreaks; reducing damage from insect pests by reducing crop visibility, diluting pest hosts due to plant diversity, interfering with pest movement, and creating habitat more favorable to beneficial insects and enhancing wild life habitat and aesthetics (Gold *et. al*., 2013).

Alley cropping is a promising agroforestry technology for the humid and sub humid tropics, which is growing food crops between hedgerows of planted shrubs and trees, preferably leguminous species (Nair, 1992). The hedges are pruned periodically during the crop's growth to provide biomass (which, when returned to the soil, enhances its nutrient status and physical properties) and to prevent shading of the growing crops. The underlying scientific principle of this technology is that, by continually retaining fast-growing, preferably nitrogen fixing, trees and shrubs on crop-producing fields, their soil-improving attributes (such as recycling nutrients, suppressing weeds, and controlling erosion on sloping land) will create soil conditions similar to those in the fallow phase of shifting cultivation (Atta-Krahetal, 1985). Which means, soil under alley cropping was higher in organic matter and nitrogen content than soil without trees. From An eight year alley cropping trial conducted in southern Nigeria on a sandy soil, using *Lucinia leucocephala* pruning's only, *maize* yield could be maintained at a "reasonable" level of 2t ha^{-1}, as against 0.66tha^{-1}without *Leucaenia* pruning's (Kang *et al*., 1981).

Nowadays, crop cultivation is undertaken in West Guji in which rainfall is erratic and soil erosion is common. Even though West Guji is highly degraded, currently different soil and water conservation activities has been practiced on degraded land. However, for the mid highland areas little attention has been given to improve the soil fertility of agricultural land. Therefore, alley cropping agroforestry practice is optional to reduce soil erosion so as to; improve soil fertility, improve crop production and improve trees/shrubs products simultaneously on agricultural land. Thus, this study was designed to evaluate the contribution of alley cropping for improving maize yield and to evaluate the role of alley cropping for soil fertility improvement in the study area.

Objectives

The objectives of the study were

- To evaluate the role of alley cropping for soil fertility improvement.
- To evaluate the contribution of alley cropping for improving maize yield.

Materials and Methods

Description of the study areas

The activity was conducted at Abaya sub-station of Yaballo Pastoral and dryland Agriculture Research Center, Abaya district of West Guji Zone for the last two years. Abaya is found in southern Ethiopian rift valley 365km away from Addis Ababa. The altitude of the site is 1492masl. Abaya receive annual rain fall ranging from700mm to 1000mm which reaches its pick in June.

Methods

Selection of Trees/shrubs and Crops

Sesbania sesban and *Cajanus cajan* were selected for the alley cropping study. These trees/shrubs were selected for their potential to improve soil fertility (nitrogen fixing) and have other uses such as fodder. Crop type which dominantly producing in the study area and suitable for alley cropping was selected. Accordingly, maize is the major crop produced in Abaya district of West Guji Zone (Borana Agricultural office, 2013). Based on this, the recommended pioneer Gibe 2 maize (*Zea maize*) varieties for Abaya was used. Accordingly, the selected alley crop *Zea maize* will be sown in between single species of Susbania sesban, Cajanus cajan, with recommended rate of fertilizer and plot with no tree/shrub (sole maize) which was used as control.

Treatments and Experimental Design

The experiment was designed with four treatments (Table 1). The treatments were *Sesbania Sesban* with maize alley cropping, *Cajanus cajan* with maize alley cropping, maize sowing with recommended rate of fertilizer and control/sole maize (maize sowing without inorganic fertilizer and fertilizer trees). The experiment was laid out in randomized complete block design with three replication (block) along the slop gradient. The size of a sampling units (a plot) for each treatments were 20m x 13m and the distance between treatments (plots) was 2m, while; the distance between blocks were 3m (Figure 1).

Table 1: Treatment combinations

Treatment code	Description of treatments
1	*Sesbania Sesban + Zea maize*
2	*Cajanus cajan + Zea maize*
4	Sole *Zea maize* (control)
5	*Zea maize* with recommended fertilizer

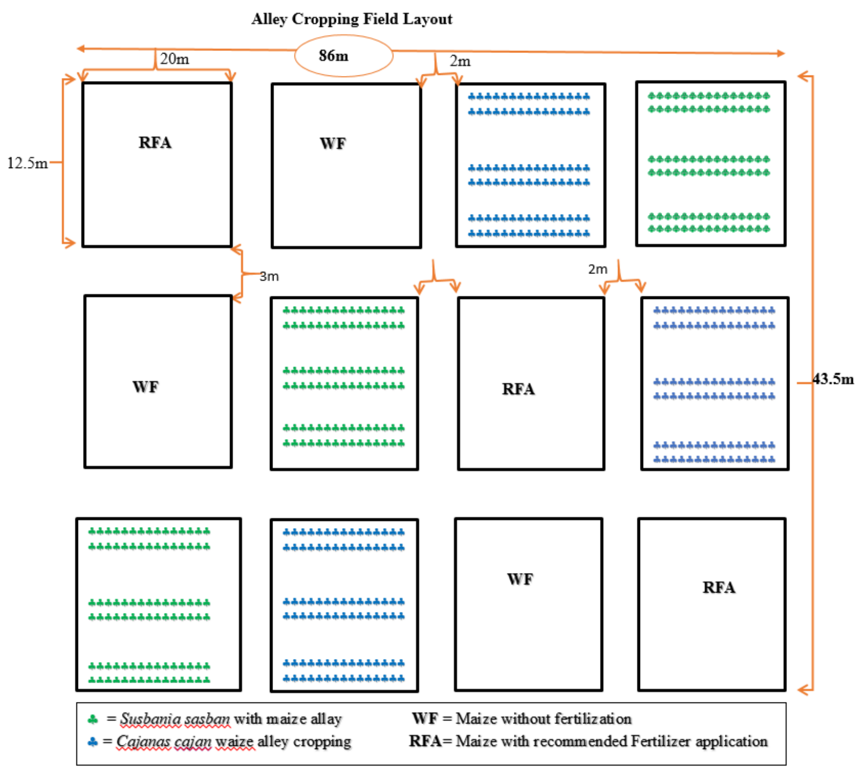

Figure 2: Design and field layout of the experiment

Establishment and Arrangement of Trees Rows

The selected alley trees/shrubs species were raised in nursery and transplanted in double rows in zigzag arrangements to the experimental area as double rows allow maximum utilization of space for companion crops (Gold *et. al.*, 2013). Spacing of 0.5m between plants and 1m between rows for *Sesbania Sesban and Cajanus cajan* while 5m spacing was used between each alleys of trees/shrubs. Throughout the study years trees/shrubs component was permanently kept and protected from wildlife and livestock interference and, maize was sown every year during main rainy seasons.

Alley Crop Arrangement

Land preparation was done using tractor before the establishment of the treatment and oxen plow after the establishment of the treatment. Alley crop was designed in doubled alley per study plot and the size of an alley crop was 20m x 5m. The selected variety of maize (Gibe 2) was sown between alleys of trees/shrubs with recommended spacing of 25cm and 75cm between plant and rows of maize respectively. In plots of recommended fertilizer and sole maize (non-fertilizer) treatments, maize was also sown in rows with the recommended spacing of 25cm and 75cm between plant and rows of maize respectively.

Soil Sampling Techniques and Laboratory Analysis

Soil samples was purposively taken from the four corners and center of each experimental plot 45 days after sowing the test crop by soil auger and core sampler and mixed to make a composite soil samples. Accordingly, the soil samples were collected from each treatment and replications separately. Then, the composite soil samples were prepared for laboratory analysis and sent to Batu Soil Research Center and analyzed using standard methods. Accordingly, the soil samples taken by core samplers was oven dried at 105^{o}C for 24 hours to calculate the soil bulk density and moisture content. EC was analyzed: in water suspension with soil to water ratio 1:25 by electro conductivity meter method, PH in water suspension with soil to water ratio 1:25 by PH meter, TN by Kjeldhal Method (1965), Av.P by Olsen *et al*, Av.K using Ammonium acetate (1MNH4OAC), CEC by Ammonium Acetate (1 M NH4OAC), Exch. Na & K using flame photometer, Exch.Ca & Mg using EDTA titration, OC using Walkley black and Texture was analyzed using Bouycos hydrometer method.

Management Practices

The trees/shrubs species were pruned periodically and mulched on alleys and necessary management techniques will be timely carried out.

Data to be Collected

Data recorded during the course of the experiment, agronomic data: (plant height, hundred seed weight, grain yield, cob diameter and cob height) and soil data (soil data (EC, pH, T.N, Av.p, Av.K, CEC, Ca, Mg, Ex.Na, Ex.K and OC) were collected.

Statistical Data Analysis

Data were subjected to analysis of variance following a procedure appropriate to the design of the experiment (N.R.DAS, 2008) using SAS statistical software. The treatment means that were significantly different at 5% level of significance were separated using Duncan and LSD tests.

The Model is:

$$Y_{ij} = \mu + \beta_i + \tau_j + \epsilon_{ij}$$

$$i = 1, 2, \ldots, n; \;\; j = 1, 2, \ldots, k$$

x_{ij} is a typical value from the overall population

μ is an unkwon constatnt

β_i represents a block effect reflecting the fact that the experimental unit fell in the ith block.

τ_i represents a treatment effect, reflecting the fact that the experimental unit recieved the jth treatment

ϵ_{ij} is a residual component representing all sources of variation other than treatments and blocks.

Results and Discussions

Plant height: The arrangements of different alley cropping system were found highly significant at (p<0.001) on mean plant height of maize. The tallest mean plant height (216.6 cm) of maize was observed from maize sown with recommended fertilizer rate while the lowest plant height was observed for maize sown in between alley of Susbania sesban (162.72 cm).

Hundred seed weight: no significant difference was observed for mean hundred seed weight among maize grown under different arrangements. However, the highest hundred seed weight was observed for maize sown with recommended fertilizer (31.83gm) while the lowest hundred seed weight was observed for sole maize cropping system (29.00gm).

Grain yield (GY): Combined analysis of variance over years showed a significant difference among arrangements of maize alley cropping in grain yield at (P<0.001). The highest grain yield was observed for a maize sown with a recommended fertilizer (4.22 ton/ha) while the lowest grain yield of maize was observed for maize grown in between alley of *Sesbania sesban* (1.55 ton/ha) (Table 2). The highest total grain yield was obtained from *maize* sown with recommended fertilizer (5.16 ton/ha) in 2018 cropping season and maize grown in between alley of Cajanus cajan (4.33 ton/ha) in 2019 cropping season while the lowest total grain yield was obtained from *maize* sown in between alley of *Sesbania sesban* (1.17 ton/ha) in 2018 and sole maize cropping (1.28 ton/ha) in 2011 cropping season (Table 3). Thus, the mean grain yield of maize sown with recommended fertilizer was decreased in 2019 as compared with grain yield of 2010 cropping season. This might be due to maize sown for a second cropping season in a row on the same plot which decreases soil micronutrients while the mean grain yield of maize was increased in 2019 for maize grown in between alleys of Cajanus cajan as it starts releasing soil nutrition's and biomass transfer of the shrubs to the experimental plots. That means, the yield increment was depend on the soil micronutrients that crops gains from the soil due to alley shrubs biomass transfer to the soil and/or application of recommended fertilizer.

Cob diameter: The analysis of combined variance data showed a significance difference among different arrangements of maize alley cropping at p<0.001 (Table 1). The highest cob diameter was recorded from maize sown with recommended fertilizer rate (5.03cm), while the lowest cob height was recorded from maize grown in alleys of *Sesbania sesban* (4.61cm) (Table 2).

Cob height: Analysis of variance showed a significance difference among treatments in cob height for both years at (p<0.001) (Table 1). The highest cob height was obtained from maize sown with recommended fertilizer (18.03 cm) while the lowest cob height was recorded from maize grown in alleys of *Sesbania sesban* (13.46cm) (Table 2). This implies that, the number of cob height of maize decreases as compared to sole maize and maize sown with recommended fertilizer. This might be due to the synergistic effect of the crops and alley shrubs was changed to compete for the limited availability of moisture in the area since moisture stress is the main problem in the study area.

Table 1: Mean square value of yield and yield related parameters of maize alley cropping from combined analyses of variance over two years at Abaya district in 2018 and 2019 EC.

Source of variations	DF	PH (cm)	GY (ton/ha)	HSW	CD (cm)	CH(cm)
Replications	2	46.34ns	0.11ns	6.45ns	0.02ns	5.55*
Treatment	3	3203.44**	12.37***	9.02ns	0.32***	46.56***
Year	1	3203.51*	0.05*	18.32*	0.014ns	0.23ns
Ttreatment*Year	3	270.76ns	3.29***	5.90ns	0.09*	4.34ns
Error	14	629.07	0.10	2.91	0.02	1.52
CV		13.61	12.08	5.64	2.94	8.35
Mean		184.30	2.66	30.28	4.82	14.77

Table 1: Mean value of yield and yield related parameters of maize alley cropping from combined analyses of variance over two years at Abaya district in 2019 and 2019 EC.

Treatments	PH	GY (ton/ha)	HSW	CD (cm)	CH(cm)
Zea maize with recommended Fertilizer	216.64a	4.22a	31.83a	5.03a	18.03a
Cajanus cajan + Zea maize	182.93b	3.54b	30.62ab	5.01a	15.91b
Sole *Zea maize (no fertilizer)*	174.93b	1.34c	29.00b	4.64b	11.67d
Sesbania Sesban + Zea maize	162.72b	1.55c	29.67ab	4.61b	13.46c
Mean	13.61	12.08	5.64	2.94	8.35
CV	184.30	2.66	30.28	4.82	14.77

Table 3: Mean value of yield and yield related parameters of maize alley cropping at Abaya district during 2010 and 2011 cropping season.

Treatments	Year	Mean ± Standard error				
		PH (cm)	GY (t/ha)	HSW (gm)	CD (cm)	CH (cm)
Cajanus cajan + Zea maize	2018	166.67±14.48^{cd}	2.75±0.19d	28.67±0.99g	4.91±0.08ab	14.76±0.71bcd
	2019	199.19±14.48^{abc}	4.33±0.19b	32.57±0.99abcd	5.11±0.08a	17.06±0.71a
Zea maize with recommended fertilizer	2018	210.67±14.48^{ab}	5.16±0.19a	30.34±0.99bcdefg	5.15±0.08a	18.53±0.71a
	2019	222.62±14.48^{a}	3.28±0.19cd	33.31±0.99a	4.91±0.08ab	17.53±0.71a
Sole Zea maize (no fertilizer)	2018	169.33±14.48^{bcd}	1.39±0.19fgh	28.93±0.99fg	4.67±0.08cde	12.35±0.71ef
	2019	180.52±14.48^{abcd}	1.28±0.19gh	29.07±0.99efg	4.61±0.08de	10.99±0.71f
Sesbania Sesban + Zea maize	2018	144.33±14.48^{d}	1.17±0.19h	29.68±0.99cdefg	4.46±0.08e	13.04±0.71def
	2019	181.1±14.48^{abcd}	1.94±0.19e	29.67±0.99defg	4.75±0.08bcd	13.87±0.71cde

Soil Properties

The results of the soil properties after the alley cropping experiment stablished are shown in Table 4 and Table 5. The soil organic carbon content from the *Susbania sesban* and Cajanas *cajan* and fertilizerd plots was significantly different from control plots. In non-fertilizer (control) plots the soil organic carbon content was lowest than others experimental plots. The average soil organic carbon content of *L. leucocephala*, *Cajanas cajan* and fertilized plots even though not statistically significantly different, it was greatest in *L. leucocephala* plots followed by *Cajanas cajan* plot (Table 4). The result obtained in this study agreed with the report of Atta-Krah (1986), that soils under alley cropping system were higher in organic matter and N than soils without hedgerow tree. The soil organic carbon content of experimental plots were not significantly different statistically, however it was increased with time in *L. leucocephala* and *Cajanas Cajan* plots, and it was decreased with time in fertilized and control non-fertilized (control) plots (Table 5). The result obtained agreed with a study found that the plant nutrients were gradually built up in the alley cropping system plots than in the fertilizer and control (Okonkwo *et al.*, 2009).

Table 4: Mean soil chemical properties of experimental plots

	%	%	ppm		pH	meq/ 100g soil				mmhos/
Treatments	**OC**	**TN**	**AvK**	**AvP**		**Ex. K**	**Ca**	**Mg**	**CEC**	**EC**
Cajanas cajan alley cropping	1.60 [a]	0.16[a]	299.72 [a]	2.01 [a]	6.03 [a]	1.045[a]	8.51 [a]	5.38 [a]	13.01 [a]	0.18[a]
Recommended fertilizer rate	1.53 [a]	0.14[a]	289.00 [a]	2.30 [a]	5.68 [b]	1.03[a]	7.59 [a]	3.96 [b]	12.74 [a]	0.15[ab]
Susbania sesban alley cropping	1.73 [a]	0.15[a]	288.22 [a]	2.26 [a]	5.83 [ab]	0.96[a]	7.13 [ab]	4.28 [b]	12.79 [a]	0.15[bc]
Non-fertilizer (control)	1.16 [b]	0.10[b]	229.78 [b]	1.73 [a]	5.82[ab]	0.91[a]	5.83 [b]	2.89 [c]	11.42 [a]	0.12[c]
LSD(0.05)	0.36	0.03	41.41	0.92	0.34	0.13	1.63	0.83	1.94	0.03
CV (%)	24.82	22.66	15.38	45.68	5.93	13.49	23.11	20.74	3.36	19.22

Similar to soil organic carbon content, the % of soil total nitrogen (TN) content of the treatments was significantly different. It was lowest in non-fertilized (control) plots compared to others experimental plots. The soil total nitrogen (TN) content of *Cajanas Cajan*, *L. leucocephala* and fertilized plots were not significantly different (Table 4). Despite the TN content of the experimental plots were not significantly different along study years, the *Cajanas Cajan* and *L. leucocephala* plots TN contents maintained improved compared to fertilized and non-fertilized (control) plots (Table 5). This result therefore, indicated that incorporated pruning of the legume trees alley cropping improved the total nitrogen contents of the soil. This finding agreed with a study by Okonkwo *et al.*, (2009) which showed that the total nitrogen (N) content increased in the alley plots over time with continuous addition of pruning from the hedgerow trees.

The level of available P was not significantly different both among treatments and along the study years statistically; however, it was lowest in non-fertilized (control) plots compared to other experimental plots (Table 4). This might be due to no variations in soil pH of the experimental plots Larsen (1995) reported that maximum phosphate availability is obtained when the soil pH is maintained in the range from 6 to 7. Low soil pH in found in fertilized plots. Continuous cultivation and long-term application of inorganic fertilizers led to low soil pH.

The available K was significantly different among the treatments; while the exchangeable K content was non-significant however it was lower in control treatment compared to other treatments (Table 4). The available K was lowest in non-fertilized (control) plots (229.78 ppm) compared to of *Cajanas Cajan*, *L. leucocephala* and fertilized plots. This finding related with the findings of Jannatul *et al.*, (2019) showed the exchangeable K content was lower in control treatment compared to agroforestry treatments. Crop removal and losses through runoff may be attributed the lowest exchangeable K in control plot moreover no K added to this plot through pruned materials, whereas, the increase in exchangeable K in plots with tree species was probably due to the return of K via tree pruning and leaf litter fall to the soil surface (Miah *et al.*, 1997). The available K was significantly different along the study years; it was showed significant increase in ally cropping and fertilized plots (Table 5).

There were significant different levels soil Mg and Ca contents among the treatments. The levels of soil Mg and Ca contents were lowest in non-fertilized (control) plots and were 20.74 and 23.11 meq/ 100g soil respectively. The Mg contents of soil showed an increasing trend in alley cropping agroforestry treatments and fertilized plots; whereas, Ca contents showed an irregular fashion (Table 5). The variations of CEC of the soil among the treatments were not so different, on the other hand the EC was significantly different and lowest in control treatment plots.

Table 5: Mean of Soil Properties of along the study years (2018, 2019, 2021)

Treatments	Study Year	% OC	% TN	mmhos/cm EC	ppm AvK	ppm Avp	pH	meq/ 100g soil CEC	Ca	Mg	Ex.K
Cajanas cajan alley cropping	Year I	1.39^{abcd}	0.16^{ab}	0.16^{abcd}	207.50^{cde}	1.72^{b}	5.58^{b}	12.33^{abc}	9.13^{a}	4.23^{bc}	0.77^{efg}
	Year II	1.60^{abcd}	0.16^{ab}	0.19^{a}	264.33^{bc}	2.43^{ab}	6.13^{ab}	15.23^{a}	8.50^{abc}	5.50^{ab}	0.95^{de}
	Year III	1.80^{ab}	0.16^{ab}	0.19^{a}	427.33^{a}	1.87^{ab}	6.38^{a}	11.47^{bc}	7.90^{abc}	6.40^{a}	1.43^{b}
Recommended fertilizer rate	Year I	1.58^{abcd}	0.14^{abcd}	0.15^{abcde}	164.17^{de}	2.57^{ab}	5.76^{b}	13.07^{ab}	8.80^{ab}	2.93^{cd}	0.59^{g}
	Year II	1.54^{abcd}	0.13^{abcd}	0.15^{abcde}	228.50^{bcde}	2.59^{ab}	5.54^{b}	13.07^{ab}	6.87^{abcd}	3.23^{cd}	0.83^{ef}
	Year III	1.47^{abcd}	0.16^{ab}	0.17^{abc}	474.33^{a}	1.74^{b}	5.75^{b}	12.10^{abc}	7.10^{abcd}	5.70^{a}	1.68^{a}
Susbania sesban alley cropping	Year I	1.48^{abcd}	0.13^{abcd}	0.12^{de}	222.50^{bcde}	3.46^{a}	5.67^{b}	11.97^{abc}	8.50^{abc}	3.57^{c}	0.68^{fg}
	Year II	1.74^{abc}	0.14^{abc}	0.18^{ab}	234.67^{bcd}	1.81^{b}	5.79^{b}	12.10^{abc}	6.20^{bcd}	3.90^{c}	0.89^{ef}
	Year III	1.98^{a}	0.18^{a}	0.15^{abcde}	407.50^{a}	1.51^{b}	6.02^{ab}	14.30^{ab}	6.70^{abcd}	5.38^{ab}	1.32^{bc}
Non-fertilizer (control)	Year I	1.34^{bcd}	0.11^{bcd}	0.10^{e}	158.17^{e}	1.79^{b}	5.85^{ab}	12.40^{abc}	6.83^{abcd}	2.00^{d}	0.70^{fg}
	Year II	1.16^{cd}	0.10^{cd}	0.14^{bcde}	248.83^{bc}	2.04^{ab}	5.74^{b}	12.53^{abc}	5.83^{cd}	3.00^{cd}	0.88^{ef}
	Year III	0.99^{d}	0.09^{d}	0.13^{cde}	282.33^{b}	1.35b	5.88^{ab}	9.34^{c}	4.83^{d}	3.68^{c}	1.16^{cd}
LSD(0.05)		0.63	0.05	0.05	71.72	1.60	0.58	3.35	2.83	1.44	0.22
CV (%)		24.82	22.66	19.22	15.38	45.68	5.93	15.95	23.11	20.74	13.49

OC= Organic carbon; T.N= Total Nitrogen, EC= Electro conductivity, Ex.K = Exchangeable Potassium, .Ca & Mg = Exchangeable Calcium & magnesium, Av. P = Available Phosphorus, CEC = Cation exchangeable capacity

Conclusions and Recommendations

This study concluded that, alley cropping system had significantly affected maize grain yield. Thus, a significant difference among arrangements of maize alley cropping in grain yield was observed at (P<0.001). Consequently, maize cropping with a recommended fertilizer had significantly higher grain yield at (P<0.001) than maize cropping between alleys of *Cajanus cajan*, *Susbania sesban* and sole maize cropping. Accordingly, the highest total grain yield was obtained from maize sown with recommended fertilizer (5.16 ton/ha) in 2018 cropping season and maize grown in between alley of *Cajanus cajan* (4.33 ton/ha) in 2019 cropping season. Based on this, the study confirmed that, growing crops with recommended fertilizer application and in between alley of *Cajanus cajan* was preferable than growing maize in between alleys of *Susbania sesban* and sole maize cropping. Even though, the maize yield grown in between alleys of *Cajanus cajan* was lower than maize sown with that of recommended fertilizer application, *Cajanus cajan* has many additional importance (uses for fodder, soil improving through recycling nutrients and controlling erosion on sloping land). From the soil chemical properties point of view it may be concluded that alley cropping practices high contribution in soil amendments. The pruning of the legume species incorporated into the soil and dead roots were gradually built up soil nutrients. Accordingly, it is recommended to grown maize with recommended rate of fertilizer application and in between alleys of *Cajanus cajan* trees/shrubs species as it has multipurpose benefits. Further study is need on combinations of fertilizer trees and inorganic fertilizers.

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Soil Fertility Management Research

Evaluation of Released Finger Millet Varieties for Yields and Acid Soil Tolerance at Bako, Gute and Diga, East Wellega Zone of Western Oromia

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Abstract

Many finger millet verities were released and grown in the sub humid areas of western Oromia; but the extent to which these varieties perform under acid soils was not studied. A field experiment consisted of two factors (nine finger millet verities and two lime rates) were laid out in factorial arrangement, Randomized Complete Block Design with three replications. The experiment was carried out at three locations (Bako, Diga and Gute) during 2019 and 2020 main cropping seasons to identify and recommend finger millet varieties better performing to acid soils of sub humid areas of western Oromia. The interaction effect of variety by lime for two years over three locations was significant for biomass weight and grain yield. Bako 09 produced significantly the highest mean biomass weight and produced increments of 10% biomass weight and 7% grain yield by application of lime compared to un- limed treatment. At Bako, Kumsa, Bako 09, Boneya and Addis 01 produced significantly the highest biomass weight and grain yield compared to others but not significantly different from each other and produced 4% to 12% yield advantage over all mean grain yield. At Diga and Gute, Bako 09 produced significantly high grain yield. Consequently, application of lime increased finger millet grain yield, soil pH, available P, organic carbon and total nitrogen. Considering higher grain yield, production of Bako 09 under limed condition is recommended for the sub-humid western Oromia. Besides lime application and varietal selection, cropping system managements like rotation, integrated use of organic and inorganic fertilizers, and split application of fine particle lime to acid soils require further research attention for sustainable crop production in acidic soils.

Key words: finger millet, released varieties, acid soils, lime

Introduction

Crop tolerance to low soil pH has become important in the agricultural development of humid tropics because so many of those soils have low pH while some plants are more tolerant than other to grow on soils with low pH (Maranville, *et al.*, 1994). These crops have their specific characters tolerating acid soils with low pH. Considerable tolerance of low Ca and high Al, requirement of low pH, high levels of toxic Al and Mn has the components of both tolerance (of the presence of toxic elements within the plant) and of avoidance (prevention of the toxic element from entering the plant) were tolerance mechanisms (Marschner, 1991). Varietal differences in tolerance of aluminum have been identified in rice, alfalfa, tomato, soybean, cotton, maize, sunflower, pea and sweet potato. Besides the high Al tolerance crops, maize and rice were found more tolerant of high soil Mn than soybean and barley while clover and oats are more tolerant than cowpea and sweet clover (Kamprath and Foy, 1985). Varietal tolerance has been reported in soybean, wheat and cotton. Tolerance of Mn in forage legumes appears to be a combination of prevention of Mn entry into the plant and greater internal tolerance. Rhizobia associated with most of the legumes fix N at pH of 6.3 to 7, while that associated with lupin function well at pH 4.0. Superior Mn tolerance in maize compared to peanut is believed to be due to reduced transport of Mn to the leaves (Yost, 2010).

Performance evaluation of ten acid tolerant soybean lines was tested for Genetic x Environment interaction on a pH of 4.3 in Indonesia. The result has shown G x E for characters like crop phenology, yield and yield components were significant. The yield difference between genotypes were observed (Kuswantoro and Zen, 2013). Aluminum tolerant wheat varieties have the capacity to excrete more malic acid than aluminum sensitive genotypes. Malic acid added to nutrient solutions was able to protect Al-sensitive seedlings from normally phytotoxic aluminum concentrations. Hence, Al-tolerant wheat species excreted about 4 times the total amount of malic acid initially present within the root apices; these wheat species encodes an Al-tolerance mechanism based on aluminum-stimulated excretion of malic acid (Delhaize, *et al*., 1993). Varietal screening of maize for Al-tolerant and P efficient, was successful, obtaining genotypes that restrict Al uptake in the transition zone near the apex. Induction callose formation is a sensitive injury from Al while genotypes resisted Al-toxicity excluded its uptake into the root apex by sequestration with exuded citrates. Lime application to acid soil in Brazil have been used to decrease toxic effects of Al to the roots, but practical mechanical methods for deep lime incorporation have not been developed (Horst, 2000). Therefore, the combination of liming practices for neutralization of soil acidity at the surface together with selection of more tolerant plant species to Al toxicity has been more economic approach.

The study by Hirpa *et al.,* (2003) has shown that out of 25 common bean varieties grown on acid soils (pH of 4.6), 5 of them produced similar yield both under lime and un-limed plots. Al-sensitive and Al-tolerant genotypes were identified through root growth measurement and haematoxilyne staining methods. From the tested 28 tef genotypes, some of them have tolerated Al toxicity (Ermias, 2015). The author justified exclusion of Al from roots by organic acids may operate as a tolerance mechanism by tef. Application of 12 t ha^{-1} biochar and 2 t ha^{-1} lime reduced exchangeable acidity, increased CEC, increased soil OC, TN and also raised soil pH from 5.38 to 6.17 and 5.9; available P from 12.75 ppm to 18,92 ppm and 17.50 ppm, respectively. Tef biomass yield was increased by 35% and 23% while grain yield was increased by 46% and 41% by application of 12 t ha^{-1} and 2 ton ha^{-1} lime, respectively (Anteneh, *et al.,* 2014).

In Ethiopia in general and western Oromia in particular, finger millet is considered acid tolerant because it is grown and perform better in areas where others do not grow well. There is views and thoughts that finger millet thrives well in acidic soils. However, there is no research finding indicating tolerance of the crop to soil acidity. Bako agricultural research center released about 10 finger millet varieties which are well adapted to Diga and Gute areas of East Wellega zone of western Oromia. No matter these varieties have differences in yield potential, the extent to which they perform under acidic soil condition is not well studied. The objective of this study was to identify and recommend finger millet variety (varieties) better performing to acid soils of the sub-humid areas of western Oromia.

Materials and Methods

The experiment was carried out at Bako Agricultural Research Center, Diga Farmers' Training Center and Gute Agricultural Research Sub-site on acid soil with pH of 5.26, 4.80 and 4.43, respectively. Available P, organic carbon, and total nitrogen of all test sites were rated as medium/moderate. Metrological data were available only for Bako. The area has a warm-humid climate, mean annual rainfall of 1237 mm that varies between 887 mm (year 2012) to as high as 1605 mm (year 2020) with maximum precipitation occurring from May to August. Annual mean minimum and mean maximum air temperatures of area ranges between 13.5 ^{0}C and 29.7 ^{0}C with a mean annual relative humidity of 52.15%.

A total of 9 regionally and nationally released finger millet varieties and two limed and un-limed treatments were tested in factorial arrangement laid out in Randomized Complete Block Design with three replications. Lime was applied a month before planting based on exchangeable acidity at the rates of 2.63, 6.43 and 8.33 t/ha for Bako, Diga and Gute, respectively. A plot area of 3.2 m (8 rows) x 3 m (9.6 m^2) was considered at 40 cm x 10 cm spacing between rows and plants, respectively according to the recommendation of seed rate of 15 kg/ha. A total of 6 rows (7.2 m^2) was used for data collection and harvesting. Fertilizer was applied at the recommended rate for the crop.

Data Collection and Measurements

Crop

Biomass weight and grain yield adjusted to 12.5% moisture content standard

Soils

Composite soil sample before planting and samples from each plot after crop harvest was collected at the depth of 20 cm from each experimental site. The soil samples were air dried, sieved to pass through 2 mm and grinded to smaller particles. The sample was analyzed for soil pH, available P using Bray and Kurtz, 1945, total N using Kejeldal, 1983 while Walkley-Black method was used to obtain organic carbon.

Results and Discussion

Overall limed mean biomass weight and grain yield were 7839 kg ha^{-1} and 2186 kg ha^{-1} compared to 6726 kg ha^{-1} and 2015 kg ha^{-1}, respectively for un-limed treatments. Both overall mean biomass weight and grain yield were higher by 6% during year 1 compared to year 2, might have attributed due to the fine lime particle which could show complete mix up with the soil during application, very high rainfall, as high as 1605 mm during 2020 and monocropping of finger millet that might have utilized the same soil nutrients. The result agree with lime application to acid soils could be used to decrease toxic effects of Al to the roots, but practical mechanical methods for deep lime incorporation were not occasionally applicable (Horst, 2000).

The interaction effect of variety by lime for two years over three locations was significant for biomass weight and grain yield. Finger millet variety, Bako 09 produced significantly the highest mean biomass weight (9428 kg ha^{-1}) and the highest grain yield (2728 kg ha^{-1}) under limed condition. This variety produced increments of 10% biomass weight and 7% grain yield by application of lime compared to un- limed treatment. Variety, Kumsa also produced the highest biomass weight which was not significantly different from Bako 09 under limed condition. It also produced the second highest grain yield (2505 kg ha^{-1}) under lime application (Table 1).

Table 1 Interaction of finger millet variety by lime over three locations and two years

No	Varieties	Biomass weight kg/ha		Grain yield kg/ha	
		With lime	Without lime	With lime	Without lime
1	Kumsa	8867^{ab}	7129^{fgh}	2505^{b}	2087^{efgh}
2	Bako 09	9428^{a}	8489^{bc}	2728^{a}	2532^{b}
3	Diga 1	7717de	6771^{ghi}	2211^{def}	2014^{hi}
4	Adis 01	8597^{bc}	7056^{fgh}	2465^{bc}	2064^{efgh}
5	Gudetu	7801de	6583^{hi}	2190^{defg}	1950hi
6	Gute	7445^{ef}	6603^{hi}	2111^{efgh}	1967^{hi}
7	Bereda	7074^{fgh}	6361^{i}	1999^{hi}	1888^{i}
8	Wama	7256^{efg}	6811^{ghi}	2042^{fghi}	2025^{ghi}
9	Boneya	8036^{cd}	7457^{ef}	2329^{cd}	2235de
	LSD (5%)	578.77		174.03	
	CV %	11.72		12.14	

The mean biomass weight and grain yield of finger millet were influenced by the main effects of variety and lime at Bako during 2019 and 2020 main cropping seasons. As a result, verities, Kumsa, Bako 09, Boneya and Addis 01 produced significantly the highest biomass weight and grain yield but not significantly different from each other to other. These four high yielder varieties produced 13% to 20% mean grain yield advantage over the lowest yielder finger millet variety, Wama and 4% to 12% yield advantage over all mean grain yield (Table 2). Application of lime also significantly increased finger millet mean biomass weight and mean grain yield during 2019 and 20202 main cropping seasons. Subsequently, application of lime increased mean grain yield of finger millet by 8% which might have attributed due to P availability for better crop phenology in lime reclaimed acid soils compared to un-limed ones. Findings by Iqbal (2012) confirmed crops grown in acid soils, extend their roots down to the sub soil and spreading the lateral roots at the surface, are exposed to various concentrations of higher P and lower Al at different depths in the soil profile.

Mean biomass weight and mean grain yield at Diga were significantly higher for finger millet variety, Bako 09 (8902 kg ha^{-1}) and (2606 kg ha^{-1}), respectively and followed by Kumsa with mean biomass weight of 7846 kg ha^{-1} and mean grain yield of 2279 kg ha^{-1}. Similar to the mean yields, Bako 09 significantly out yielded other varieties during both, 2019 and 2020 cropping seasons (Table 3). Effects due to lime was also significant whereby application of lime showed mean yield increment of 9% compared to un-limed treatments.

At Gute, similar to Bako and Diga, mean grain yield for Bako 09 was significantly highest (2906 kg ha^{-1}) followed by Addis 09 (2438 kg ha^{-1}). Similar work on soybean verities in Indonesia by Kuswantoro and Zen (2013) identified varietal difference of tolerating low pH of 4.3. At Gute, similar to varietal effect, lime application also increased grain yield of finger millet by 10% compared to un-limed treatments (Table 4).

Table 2 Biomass weight and grain yield of finger millet as influenced by the main effects of variety and liming at Bako during 2019 and 2020 main cropping seasons

	Mean yields (kg/ha)		Biomass weight (kg/ha)		Grain yield (kg/ha)	
Varieties	Biomass weight	Grain yield	2019	2020	2019	2020
Kumsa	8294[a]	2399[a]	8588[a]	8001[a]	2454[a]	2344[a]
Bako 09	8192[ab]	2379[a]	8542[a]	7842[a]	2479[a]	2278[ab]
Diga1	6854[c]	1994[c]	7138[bc]	6569[bc]	2071[bc]	1917[cd]
Addis 01	7645[b]	2193[b]	8048[ab]	7242[ab]	2321[ab]	2066[bc]
Gudetu	6841[c]	1956[c]	7043[bc]	6638[bc]	2012[c]	1901[cd]
Gute	6737[c]	1942[c]	6822[c]	6653[bc]	1984[c]	1900[cd]
Bereda	6426[c]	1841[c]	6464[c]	6389[c]	1893[c]	1789[d]
Wama	6644[c]	1905[c]	6899[c]	6383[c]	1983[c]	1828[d]
Boneya	7906[ab]	2296[ab]	8025[ab]	7788[a]	2308[ab]	2284[ab]
LSD (5%)	639.66	177.58	1038.20	800.71	292.24	235.57
Lime						
With lime	7839[a]	2186[a]	8061[a]	7617[a]	2250[a]	2122[a]
Without lime	6726[b]	2015[b]	6954[b]	6497[b]	2084[b]	1946[b]
LSD (5%)	301.54	83.71	489.42	377.46	137.76	111.05
CV (%)	10.83	10.42	11.79	9.67	11.49	9.87

Table 3 Biomass weight and grain yield of finger millet as influenced by the main effects of variety and liming at Diga during 2019 and 2020 main cropping seasons

	Mean yields (kg/ha)		Biomass weight (kg/ha)		Grain yield (kg/ha)	
Varieties	Biomass weight	Grain yield	2019	2020	2019	2020
Kumsa	7846[b]	2279[b]	8337[ab]	7356[b]	2437[b]	2121[ab]
Bako 09	8902[a]	2606[a]	9568[a]	8235[a]	2930[a]	2283[a]
Diga1	7388[bc]	2162[b]	7803[b]	6973[bc]	2319[b]	2005[bc]
Addis 01	7465[bc]	2163[b]	7651[b]	7279[b]	2222[b]	2103[b]
Gudetu	7487[bc]	2201[b]	8164[b]	6810[bcd]	2419[b]	1983[bc]
Gute	6945[c]	2057[b]	7457[b]	6432[cd]	2231[b]	1883[cd]
Bereda	6967[c]	2040[b]	7643[b]	6292[d]	2288[b]	1793[d]
Wama	7152[bc]	2103[b]	7436[b]	6867[bcd]	2218[b]	1989[bc]
Boneya	7793[b]	2287[b]	8201[b]	7384[b]	2439[b]	2134[ab]
LSD (5%)	806.6	251.25	1290.9	676.37	371.31	171.32
Lime						
With lime	8009[a]	2309[a]	8483[a]	7534[a]	2495[a]	2124[a]
Without lime	7090[b]	2112[b]	7575[b]	6605[b]	2283[b]	1941[b]
LSD (5%)	380.23	118.44	608.54	318.84	175.04	80.75
CV (%)	13.18	14.02	13.80	8.21	13.34	7.23

Table 4 Biomass weight and grain yield of finger millet as influenced by the main effects of variety and liming at Gute during 2019 and 2020 main cropping seasons

	Mean yields (kg/ha)		Biomass weight (kg/ha)		Grain yield (kg/ha)	
Varieties	Biomass weight	Grain yield	2019	2020	2019	2020
Kumsa	7845^{bc}	2209^{bc}	7732^{c}	7958b	2206^{c}	2212^{bcd}
Bako 09	9848^{a}	2906^{a}	10599^{a}	9998^{a}	3241^{a}	2571^{a}
Diga1	7516^{c}	2181^{cd}	7922^{bc}	7110^{cde}	2293^{bc}	2069^{cde}
Addis 01	8437^{b}	2438^{b}	8994^{b}	7880^{bc}	2656^{b}	2221^{bc}
Gudetu	7250^{cd}	2052^{cd}	7355^{c}	7146^{cde}	2117^{c}	1986^{e}
Gute	7366^{cd}	2118^{cd}	7638^{c}	7094de	2214^{c}	2021de
Bereda	6708^{d}	1949^{d}	6769^{c}	6646^{e}	2008^{c}	1890^{e}
Wama	7289^{cd}	2092^{cd}	7621^{c}	6956^{e}	2217^{c}	1967^{e}
Boneya	7656^{c}	2264^{bc}	7494^{c}	7817^{bcd}	2224^{c}	2304^{b}
LSD (5%)	728.06	242.72	1186.5	772.78	399.69	193.99
Lime						
With lime	8356^{a}	2364^{a}	8601^{a}	8111^{a}	2475^{a}	2253^{a}
Without lime	7181^{b}	2127^{b}	7426^{b}	6935^{b}	2231^{b}	2023^{b}
LSD (5%)	343.21	114.42	559.32	364.29	188.42	91.45
CV (%)	11.57	13.34	12.71	8.82	14.58	7.79

Soil pH and Available P

Initial soil pH was extremely acidic (4.43), very strongly acidic (4.80) and strongly acidic (5.26) for Gute, Diga and Bako, respectively. Moderate initial Av. P, 7.33 for Bako and 6.72 for Gute were recorded but relatively adequate initial Av. P, 10.96 was recorded for Diga. Application of lime significantly increased spoil pH (from strongly acidic to acidic) at Bako. Remarkable increase for soil pH at Diga and Gute were also recorded by application of lime whereby the increase of soil available P was also recorded with the increase of soil pH (Table 5). The result is supported by the work of Kannen, *et al.,* (2012), liming of the top soil reduces soil acidity if it doesn't drive from below the tillage layer.

Soil Organic Carbon and Total Nitrogen

Initial soil organic carbon for all locations was rated medium/moderate, 2.37 (Bako), 2.51 (Diga) and 2.13 (Gute). Medium initial total nitrogen was also recoded for all locations; 0.22, 0.24 and 0.19 for Bako, Diga and Gute respectively. Compared to initial content, soil organic carbon and total nitrogen increase was recorded for all locations and both years. However, there was no significant increase but remained in similar critical range category (Table 6). Increasing organic carbon and total nitrogen trend was achieved improving by cereal legume intercropping, using organic fertilizer (vermicompost) and application of lime (Shiferaw and Zerihun, 2019).

Table 5 Soil pH and available P as influenced by lime application over three location and two growing seasons

Location	Lime	pH			AVP		
		Initial	2019	2020	Initial	2019	2020
Bako	Without lime	5.26	5.17	5.04	7.33	7.35	7.56
	With lime	5.26	5.71	5.61	7.33	8.67	8.50
Diga	Without lime	4.8	4.96	4.85	10.96	10.54	10.52
	With lime	4.8	5.33	5.17	10.96	12.11	11.92
Gute	Without lime	4.43	4.63	4.57	6.72	6.84	6.86
	With lime	4.43	5.01	5.58	6.72	7.61	8.62

Table 6 Soil OC and TN as influenced by lime application over three location and two growing seasons

Location	Lime	Organic Carbon			Total Nitrogen		
		Initial	2019	2020	Initial	2019	2020
Bako	Without lime	2.37	2.51	2.47	0.22	0.25	0.23
	With lime	2.37	2.72	2.63	0.22	0.29	0.26
Diga	Without lime	2.51	2.77	2.68	0.24	0.26	0.24
	With lime	2.51	2.82	2.75	0.24	0.28	0.26
Gute	Without lime	2.13	2.63	2.54	0.19	0.23	0.22
	With lime	2.13	2.73	2.63	0.19	0.24	0.24

Conclusion and Recommendation

Varietal tolerance to low soil pH across locations was attained by Bako 09. The overall mean grain yield of two years and three locations for Bako 09 was the highest both under lime and un-limed treatments. Hence, Bako 09 is recommended across the three locations (Bako, Diga and Gute). As far as site specific recommendation is concerned, Kumsa, Bako 09 and Boneya produced the highest grain yields which were not significantly different from each other and recommended for strongly acidic soils of Bako area. Bako 09 is again produced the highest grain yields and recommended for Diga and Gute areas (very strongly acidic to extremely acidic soils). Application of lime on acidic soils increased soil pH and increased finger millet yields. Hence, lime application is critical for soils with low pH (< 5.5). Single technology, only lime application, might have temporary influence on soil reaction and soil chemical properties. Varietal selection for acid soils is the cheapest method and the technique to be considered at initial stage of screening. Cropping system managements, integrated use of organic and inorganic fertilizers and split application of fine particle lime require further research attention for sustainable crop and land productivity.

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Soil Test Based Crop Response Phosphorus Calibration Study for bread wheat Production in Sinana District of Bale Zone, Southeastern Ethiopia

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Abstract

Soil fertility decline as results of different factors and blanket fertilizer application throughout the country without considering soil types and agro-ecological are among the bottleneck to obtain sustainable desired yield. Therefore, this calls for site-specific soil nutrients managements and soil test based crop response fertilizer recommendations. Accordingly, soil test based crop response P calibration study for bread wheat production was conducted from 2011-2013 at Sinana district. The objective of the experiment was to determine economically optimum N, and to determine Phosphorus critical (Pc) and Phosphorus requirement factor for bread wheat production at Sinana district. A field trial were conducted in factorial combination of four levels of N (0, 23, 46 and 69 Kg/ha) and Six levels of P (0, 10, 20, 30,40 and 50 Kg /ha) chemical fertilizer laid out in randomized complete block design with three replications on plot size 3 m x 3 m (9 m^2). Bread wheat (Sanate variety) with a seed rate of 150 kg/ha which had been recommended for area was used. Composite soil sample before plating and intensive soil samples after 21 days of sowing were taken from each plot then subjected to air-dried, prepared and analyzed for selected physicochemical properties following standard laboratory procedures. Phosphorus critical level (Pc) determination was done using C'ate-Nelson diagram method. Agronomic data such as plant height; tiller, seed per spike, biomass, grain yield and thousand kernel weight were collected then subjected to two way factorial analysis of variance (ANOVA) using R software while the partial budget analysis was done using CIMMYT (1998).The results revealed that both N and combined NP fertilizer rates significantly different among agronomic data taken for bread wheat. Accordingly; the optimum nitrogen rate (46 N kg/ha); the critical P (Pc) concentrations (5.24 ppm) and P (Pf) requirement factors (22) for bread wheat production have been determined, at Sinana District. Therefore, application of 46 N kg/ha fertilizer advisable for bread wheat productions in Sinana District as well as other areas having the same soil conditions and agro-ecology. In the feature works; farther verification of the values of Pc and Pf on farm field could be a pre request before disseminating the technology to the end user.

Keywords: Optimum N, Calibration, Critical P Concentration, P requirement factor,

Introduction

Crop production is controlled by numerous complex interacting factors which include soil fertility, pests and diseases, climate, and farmers' resourcefulness (Altieri, 2018). Soil fertility decline is one of the principal factors contributing to low crop production and agricultural productivity in which this lead food insecurity in Ethiopia (Wogene and Agena, 2017). Soil fertility declines due to removal through crop harvest, leaching, soil erosion by water in the form of surface runoff and cereal based monocropping are among several restricting factors responsible for low crop yields and agricultural productivity.

Furthermore, Ethiopia is also one of the largest wheat producers in Sub-Saharan Africa in which approximately 80% of the wheat area is covered by bread wheat production (Assefa *et al*. 2015). Bread wheat (*Triticum aestivum*L.) is one of the most of the world and particularly in Sub-Saharan Africa like Ethiopia (Minot *et al*. 2015). It is one of the major cereal crops grown that covers an estimated area of 1.69 million hector and production of about 4.5 million tons (CSA, 2017). Wheat is main staple crops in terms of both production and consumption in Ethiopia. It is one of the most important cereals cultivated in Ethiopia (Jemal *et al*., 2015). Ethiopia is the second largest wheat (*Triticum aestivum L*.) producer in sub-Saharan Africa, after South Africa (FAO, 2019). However; these current wheat production is inadequate to fill Ethiopia's needs due to low soil fertility; limited management practices and other factors (Minot *et al*., 2015). Soil fertility degradation has been described as the most bottlenecks to food security in most countries, this indicated without maintaining soil fertility, it is impossible to obtained sustainable yield increment.

Nitrogen (N) and phosphorus (P) are considered as the most deficient nutrients in soils of Ethiopia (Alemu *et al*., 2019). Likewise, application of a large amount of N fertilizer has been a method of increasing yield which is costly and can cause environmental pollution (Fresew *et al*., 2018) Diammonium phosphate (DAP) and urea have been most of the chemical fertilizers used for crop production with initial understanding that nitrogen and phosphorus are the major limiting nutrients of Ethiopian soils in the form of blanket application. Phosphorus calibration is the way establishing a relationship between a given soil test value and the yield response from adding nutrients to the soil as fertilizer (Abdurrahman *et al*., 2021**)**. The calibrations study is specific for each crop type, soil type, soil pH, climate; plant species, and crop variety (Agegneh and Lakew, 2013).

Soil test based site specific nutrient management curtail role to overcome the traditional blacken fertilizer application that not considers soil types, crop response and agro. Currently, in Oromia Agricultural Research Institute across Oromia by different centers under soil fertility improvement research team the calibrations study were conducted particularly for major crops such as maize; teff; wheat; food barely to brought our farming community towards site specific fertilizer recommendation. In the study area the blanket recommendations applications rather than exposing farmers to increased production costs cannot contribute toward improve the depletion soils plant nutrients and crop productions in sustainable manners. This calls for site-specific soil test based Crop Response Phosphorus Calibration Study in Sinana District of Bale Zone, Southeastern Ethiopia. Supported with this idea Kefyalew *et al* (2017) stated that site specific sound full soil test calibration is essential for successful fertilizer program and crop production. Based on this concept, soil test calibration study was conducted on bread wheat production at Sinana district from 2011 – 2013 with the objectives; to determine optimum N fertilizer, P-critical and P-requirement factor values for bread wheat production and develop soil test based P-recommendation guidelines for bread wheat productions in the Sinana districts.

Materials and Method

Descriptions of the Study Area

The study was conducted in Sinana District which is one of the Bale highlands Oromia Regional State, Southeastern Ethiopia. This District is bordered by Goro District in the east, Dinsho District in west, Agarfa and Gassera in the north and northeast and Goba District. Sinana district is located about 460 km from the capital city of Addis Ababa. Geographically, Sinana District is located at 6^0 40' 0"to 7^0 20' 0" N and 45^0 55' 0" to 46^0 25' 0" E. Topographically, the area consists of gently undulating plain with average slope gradient of 7%. It extends from 1700 to 3100 mean above sea level (masl).

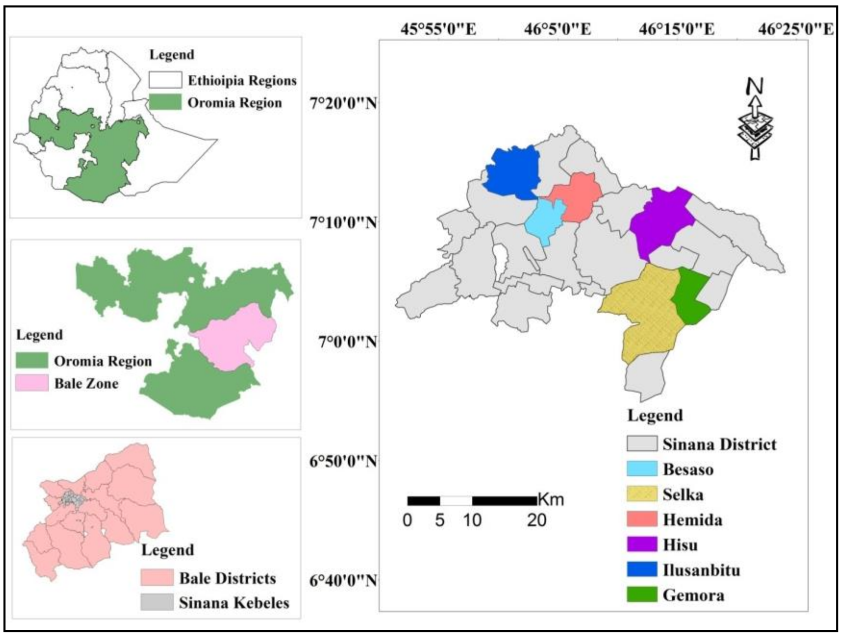

Figure 1.Map the study site

Climate and Agro-ecology

Rainfall climatologically patterns of the area follow a bimodal distribution having SH2 (humid sub humid to cool mild highland) agro ecology. The area is characterized by seasonal mean monthly rainfall varies from 8 to 160 mm, annual rainfall totals of between 452.7 mm and 1129.5 mm and mean temperature maximum ranged from 21.9 to 23.5 °C while minimum varied from 6.8 to 10.1 °C. Agriculture is the main economic practices in the district, from which the major sources of their livelihood income mainly from crop cultivation. Major crops grow in the district include wheat, barley, faba bean, field pea and others.

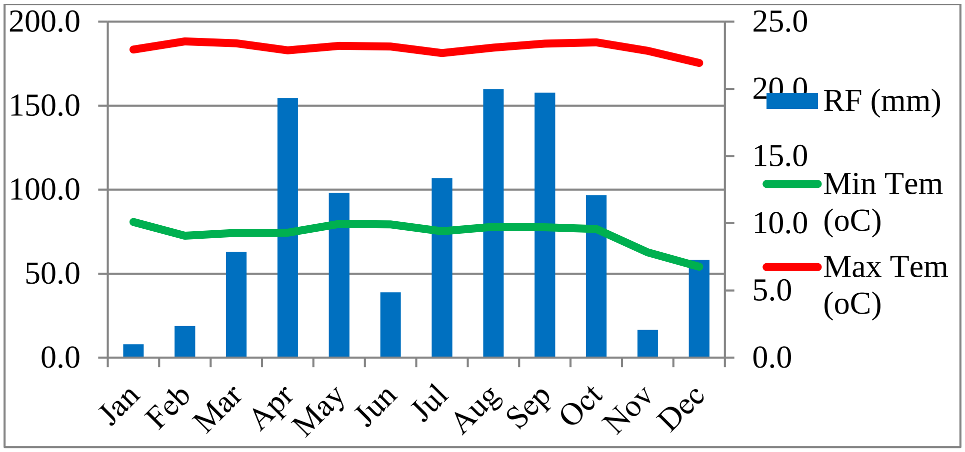

Figure 2. Mean monthly rain fall (mm), Max and Min Temperature (^{O}C) of three years (2018 to 2020) of Sinana District.

Site Selection, Experimental Treatments, Design and Procedures

To obtained representative for experimental sites composite soil samples were collected from 22 farmers' fields in Sinana district, where bread wheat is a dominant crop. Based on available soil P values determined by the Olsen method, fields were categorized into very low, low, and moderate available soil P contents. Based on this classification, sites with low or below critical available P were selected for the experiment in the district. On-farm field experiments were conducted in Sinana District for the three consecutive year during the main cropping seasons under rainfed (July to December) from 2011 to 2013 E.C In the first year factorial combination of four levels of N rates (0, 23, 46 and 69 Kgha^{-1}) and six rates of P (0, 10, 20, 30, 40 and 50 Kgha^{-1}) to determine optimum N rate as indicated was conducted at six locations as indicated Table 1. In the second and third years single six rates of P (0, 10, 20, 30, 40 and 50 Kg/ha) with recommended N rate (46 Kg/ha) were used to determine Pc and Pf.

Treatments laid out in RCBD with three replications, plot size 3 m x 3 m (9 m^2) using bread wheat (Senate variety) as test crop, N source urea , P source TSP and DAP both in first and second year were used. Land preparation were done both using tractors and oxen while others agronomic managements seed rate (150 kg/ha), hand weeding, herbicide, disease/pest control and row planting in 20 cm according to the recommendations were applied.

Table 1. Discriptions of treatments in the first year

Treatments	**Treatments**	**Treatments**	**Treatments**
N: P (Kg/ha)	**N: P (Kg/ha)**	**N: P (Kg/ha)**	**N: P (Kg/ha)**
T1 = 0 : 0	T7 = 23 : 0	T13 = 46 : 0	T19 = 69 : 0
T2 = 0 : 10	T8 = 23 : 10	T14 = 46 : 10	T20 = 69 : 10
T3 = 0 : 20	T9 = 23 : 20	T15 = 46 : 20	T21 = 69 : 20
T4 = 0 : 30	T10 = 23 : 30	T16 = 46 : 30	T22 = 69 : 30
T5 = 0 : 40	T11 = 23 : 40	T17 = 46 : 40	T23 = 69 : 40
T6 = 0 : 50	T12 = 23 : 50	T18 = 46 : 50	T24 = 69 : 50

Soil Sampling, Preparation and laboratory Analysis

Soil samples of the experimental sites before and after twenty one (21) days after planting at 0-20 cm soil depth were taken from five (5) different auger sampling points then composite soil samples were prepared for each sites and plots. The composite soil samples were labeled with necessary information then air dried, finally crushed using a mortar and pestle to passed through a 2 mm mesh sieve for most soil physicochemical properties except organic carbon and total nitrogen for which the samples further crushed to pass through a 0.5 mm mesh sieve. The analyses were conducted following standard laboratory procedures at Sinana and Melkasa Agricultural Research Center and Haramaya University Soil Laboratory.

Particle size distribution was determined using the Bouyoucos hydrometer method (Bouyoucos, 1962). Finally, the textural class of the soil was assigned using USDA textural triangle classification system (USDA, 1987).The pH of the soil was measured in the supernatant suspension of a 1:2.5 soil to water ratio using a pH meter (Rhoades, 1982). Walkley and Black (1934) used for the determination of organic carbon. Total nitrogen was determined using the Kjeldahl method as described by Bremner and Mulvaney (1982). Available P was determined following the Olsen method (Olsen, 1954) using ascorbic acid as reducing agent.

Total exchangeable bases (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were extracted after leaching the soils with 1N neutral ammonium acetate (NH_4OAc) solution. Exchangeable Ca^{2+} and Mg^{2+} were determined by atomic absorption spectrometry (*AAS*) while K^+ and Na^+ were determined by flame photometer (Okalebo *et al.,* 2002*)*. Cation exchange capacity (CEC) was determined for the soil samples which were first leached with 1 M ammonium acetate (NH_4OAc), washed with ethanol and the adsorbed ammonium was replaced by Na (Chapman, 1965). Then, the CEC was measured titrimetrically by distillation of ammonia that was displaced by Na. Percent base saturation (PBS) was calculated as follows;

$$\textbf{PBS (\%)} = \frac{Ca^{+2} + Mg^{+2} + K^{+} + Na^{+}}{CEC} * 100$$

The available micronutrients (Fe, Mn, Cu and Zn) were extracted by diethylenetriaminepenta acetic acid (DTPA). Finally, their contents were quantified using AAS at their wave lengths as described by (Lindsay and Norvell, 1978).

Agronomic Data Collection

Agronomic data related to yield and yield components such as plant height, numbers of productive tillers, seed per spike, above ground biomass yield; grain yield and thousand kernel weight were taken then finally subjected to standard statistical analysis.

Statistical Analysis

The collected bread wheat yield and yield component data was subjected to analyses of variance (ANOVA) using R-software computer software 4.0.3. Significant differences among treatments means were separated by least significant differences (LSD) at 5% level of probability and using linear correlation coefficient matrix. Interpretations were made following the procedure described by Gomez (1984).

Partial Budget Analysis

On the other hand, partial budget analysis was performed to investigate the economic feasibility of the treatments. Partial budget, dominance, marginal and rate of marginal return analyses were used. The average yield was adjusted downwards to reflect the difference between the experimental plot yield and the yield farmers will expect from the same treatment. The average grain yield also adjusted by reducing 10% to minimize the over estimation of yield when yield of small plot converted to hectare basis. The average open market price (Birr/kg) of bread wheat, urea (N) and DAP (P) fertilizers were considered for analysis. The minimum acceptable rate of return (MARR) should be 100% (CIMMYT, 1988), which is suggested to be realistic. This enables to make farmer recommendations from marginal analysis.

Determination of Critical P concentration

The critical P concentration (Pc) value was determined by the Cate-Nelson diagram method (Nelson and Aderson, 1977). Where soil test P put on the X-axis and relative yield on the Y-axis based on values obtained trials conducted at 22 sites of Sinana District. A pair of perpendicular lines drawn on it to produce four quadrants displayed the relative yield. The diagram of the results is divided into four quadrants that maximize the number of points in the positive quadrants and minimize the number of points in the negative quadrants.

The observations in the upper left quadrant overestimate the fertilizer P requirement while the observations in the lower right quadrant underestimate the fertilizer requirement. The optimum is indicated by the point where the vertical line crosses the x-axis and critical P value was determined using relative grain yield against the soil test values at different rates of applied phosphorous fertilizer for a given of nutrient rate. The relationship between grain yield response to nutrient rates and soil test P values, relative grain yields in percent were calculated as follows:

$$\textbf{Relative yield} = \frac{\textbf{Yield * 100}}{\textbf{Maximum yield}}$$

Determination of P Requirement Factor

The P requirement factor (Pf) enables one to determine the quantity of P required per hectare to raise the soil test by 1 mg/kg (1 part per million), and to determine the amount of fertilizer required per hectare to bring the level of available P above the critical level (Nelson and Anderson, 1977). Finally, the value of P requirement factor (Pf) was calculated using available P values in samples taken from unfertilized and fertilized plots after 21 days starting from sowing date. The phosphorous requirement factor was expressed as:

$$\textbf{Pf} = \frac{\textbf{kg P applied}}{\Delta \textbf{ soil P}}$$

Finally, using Phosphorus requirement factor, Phosphorus critical level and initial P values (soil P value from composite soil sample before fertilization) rate of P fertilizer to be applied was calculated as follows:

$$\textbf{Rate of P fertilizer to be applied} = (\textbf{Pc} - \textbf{P i}) \times \textbf{Pf}$$

Where, Pc = critical P concentration, Pi = initial P values and Pf = P requirement factor.

Result and Discussions

Selected Soils Physicochemical Properties Before Planting

The results of particle size distribution of the soil were summarized and presented in Table 2. Accordingly; the values of soil particles size distributions ranged from 14 - 26%, 16 - 36% and 38 – 66% for percent sand , silt and clay content; respectively. As the rating suggested by Hazelton and Murphy (2007) low to moderate for both soil percent sand and silt content while moderate to very high for percent clay content. According the USDA soil textural class triangle all soils of experimental site were clay textural class (Table 2).

The pH (pH_H_2O) values of soil of watershed varied from 6. 07 to 6.50 as indicated (Table 2). As per the pH ratings suggested by Jones (2003) for pH in soil-water ratio were rated slightly acidic media. The values of soil organic matter (OM) were ranged from 1.55 to 2.65 % (Table 2). As per the ratings of Tekalign (1991) OM contents for soils of the experimental sites rated into low to moderate class. The values of total nitrogen (TN) content varied from 0.11 to 0.43% rated as low to moderate as ratings suggested by (Landon, 1991). The values of available phosphorus (Av. P) ranged from 2.02 to 5.04 mg/kg which rated very low to low based on the critical values as determined by the Olsen method established by (Cottenie, 1980). The very low to low categories of these major soils plant nutrients might be due to leaching, continues cereal based monocropping (mostly wheat), low or limited inputs of organic and inorganic sources fertilizers, nutrient fixation and loss as a results of soil erosions.

Table 2. Selected soils physicochemical properties status of experimental sites of Sinana District

Site Name	Soil particle size distributions			Textural Class	PH-H_2O	OM	TN	Av. P (mg/Kg)
	Sand	Silt	Clay					
		(%)				(%)		
Sambitu	14	20	66	clay	6.31	1.55	0.15	5.8
Robe Area	18	16	66	clay	6.50	2.05	0.29	2.94
Amida	18	24	58	clay	6.07	2.26	0.36	4.55
Besaso	14	24	62	clay	6.15	1.75	0.27	4.02
Jafera	26	36	38	clay	6.24	2.26	0.43	2.02
Selka Oda	18	32	50	clay	6.12	2.65	0.33	2.34
Gemora	14	32	54	clay	6.25	2.22	0.11	2.56
Hisu	14	20	66	clay	6.18	2.49	0.11	2.45

Where: OM = soil organic matter, TN = Total nitrogen, Av. P = available phosphorus

Cation Exchange Capacity, Exchangeable Bases and Percent Base Saturation

Cation exchange capacity (CEC) values were ranged from 36.4 to 50.2 $cmol_+$/kg in which as rating suggested by Hazelton (2007) rated into high to very high (Table 3). Exchangeable Bases (Ca, Mg, K and Na) values varied 8.81 to 37.17 $cmol_+$/kg , 0.57 to 1.40 $cmol_+$/kg, 2.13 to 3.49 $cmol_+$/kg and 0.60 to 70 $cmol_+$/kg also as the rating stated by FAO (2006) categorized into moderate to very high , low to moderate , low to moderate and moderate for Ca, Mg, K and Na; respectively. The low class of these basic cations might be due to leaching as results of area have relatively high rainfall.

The results indicate that exchangeable bases followed in the order of; Ca > Mg > K > Na for soils of the experiential sits (Table 3). The results indicated the values of exchangeable bases were optimal for crop production it does not mean no need managements. The calculated values of percent base saturation (PBS) for soils of the experimental sites varied from 33.28 to 88.82% and as per the rating set by Hazelton and Murphy (2007) low to moderate class with having moderately leached (Table 3).

Table 3. Cation exchange capacity, exchangeable bases and percent base saturation status soils of experimental sites of Sinana District

Site Name	CEC	Ca	Mg	K	Na	PBS %
	(cmol₊/kg)					
Sambitu	50.2	24.23	1.40	3.49	0.60	59.22
Robe Area	47.4	14.87	1.23	3.14	0.62	41.90
Amida	36.4	8.81	1.03	2.13	0.64	34.62
Besaso	49.2	11.01	1.11	3.60	0.65	33.28
Jafera	48	37.17	0.57	2.99	0.67	86.25
Selka Oda	47.2	33.62	0.59	2.89	0.69	80.06
Gemora	46.6	28.15	1.27	3.09	0.70	71.27
Hisu	41.8	31.94	1.01	3.34	0.70	88.82

Soil Micronutrients

The results of soils analyzed values for Micronutrients (Fe, Mn, Cu and Zn) varied from 6.53 to 13.37 mg/kg, 1.13 to 8.53 mg/kg, 1.54 to 3.40 mg/kg and 0.14 to 0.98 mg/kg and follows in the order of Fe > Mn > Cu > Zn as presented in Table 4. Based on the ratings of Jones and Benton (2003) rating soils micronutrients (Fe, Mn, Cu and Zn) status of experimental sites categorized as high for Fe, moderate both for Mn and Cu while very low to moderate for Zn (Table 4).

Table 4. Soil micronutrients status of experimental sites of Sinana District

Site Name	Fe	Mn	Cu	Zn
	mg/kg			
Sambitu	7.77	3.90	1.84	0.14
Robe Area	9.12	6.58	2.34	0.33
Amida	12.75	4.69	2.25	0.21
Besaso	13.37	7.08	2.34	0.36
Jafera	6.53	1.24	1.54	0.24
Selka Oda	6.63	1.13	1.92	0.20
Gemora	9.22	5.90	3.40	0.92
Hisu	12.02	8.53	3.26	0.98

Determination of Optimum Nitrogen Fertilizer

Responses of Bread Wheat to Different Nitrogen Fertilizer Rates at Sinana District

According to the ANOVA results, there were significant differences among the yield and yield components of bread wheat responses to nitrogen rates (Table 5). The statistical results of each yield and yield components of bread wheat response to nitrogen rates were summered as follows:

Plant Height

The result of analysis of variance for plant height was significant ($p \leq 0.05$) difference due to the main effect of N rates (Table 5). Accordingly, the highest (98.35 cm) and the lowest (70.49 cm) was obtained from 46 Kg/ha and control plot (without fertilizer); respectively. Plant height was increased significantly in response to increasing the rates of N fertilizer except for N rate of 69 $Kgha^{-1}$. Thus, might be due to optimum N applications causes for higher photosynthetic activities, the availability of more nutrients, which helped, in the maximum vigorous growth. This result is also supported by the finding of Haftom*et al* (2009); (Haile *et al (*2012); Fana *et al* (2012); Gerba *et al* (2013) and Biruk and Demelash (2016) who stated the increments of plant height with increasing nitrogen rate.

Number of Productive Tillers

The analysis of variance indicated that number of tillers was significant ($p \leq 0.05$) influenced by different N rates (Table 5). The highest mean number of tiller (3.68) was obtained from N fertilizer rate (46 N kg/ha) while the minimum number of tillers (1.94) was recorded from control (with zero nitrogen fertilizer). Thus might be due to optimum N applied played a significant role in plant growth and development that has positive effect on cytokinin synthesis which stimulates formation of new tillers. Several authors; Alam*et al*. (2007); Wakene *et al* (2014); Biruk and Demelash (2016); Franklin *et al*. (2017); Alemu *et al* (2019) also reported applying optimum N rate was produced highest number of fertile tillers.

Seed per Spike

The analysis of variance revealed that number of seed per spike was significantly ($p<0.05$) affected by the applications of different N rates fertilizer at the study area. The result showed that number of seed per spike increased as the rate N enhanced from zero to the highest rates of application (Table 5). The highest (52.68 gm) number of seed per spike were recorded at optimum N application (46 kg/ha) while the lowest number of seed per spike (24.44 gm) was recorded by control plot accordingly (Table 5). This result supported with the finding of Shazma *et al* (2016) and Alemu *et al* (2019) who reported that number of seed per spikes for bread wheat was significantly influenced and also increased due to different N rates applied.

Table 5. Responses of bread wheat plant height; number of tiller and seed per spike to N fertilizer application at Sinana District

N Rates (Kg/ha)	PH (cm)	NT	SPS
0	70.49^{c}	1.94^{d}	24.44^{d}
23	88.99^{b}	2.61^{c}	43.08^{c}
46	98.35^{a}	3.68^{a}	52.68^{a}
69	89.29^{b}	3.37^{b}	45.12^{b}
Mean	86.78	2.63	41.33
LSD (<0.05)	13.52	34.17	15.05
CV (%)	3.14	0.27	1.66

Where, PH: plant height, NT: number of tillers, SPS: seed per spike, CV: Coefficient of Variation, LSD: least significant difference, Means followed by the same letter in the column and rows are not significantly different at 5% level of significance

Total above Ground Biomass

As the result indicated that biomass yield was significantly ($p \leq 0.05$) influenced by N rate. Accordingly, the highest (11589.27 kg/plot) and the lowest (6182.81 kg/plot) biomass was obtained from 46 N kg/ha and control plot (without fertilizer); Respectively (Table 6). This might be significant increases in plant height, number of tillers, spike length, number of seed per spike and grain yield from optimum N rate application ultimately contributed to the increased crop biomass yield. Several authors Mohammad *et al.* (2011); Haile *et al* (2012); Gerba *et al* (2013); Wakene*et al*. (2014); Amare and Adane (2015); Franklin *et al*. (2017) and Alemu *et al* (2019) and Alemu (2019) reported the significance increased in total biomass yield as compared to treatment received zero nitrogen rate. This means nitrogen enhance the vegetative growth of plants. Additionally; Haile *et al* (2012) reported that as N rate increased the biomass yield also increased. Additionally; Shazma *et al* (2016) reported optimum N and P increased biomass yield.

Grain Yield

The statistical analysis shows that grain yield values were significant ($p \leq 0.05$) different as influenced by N fertilizer rates (Table 6). The highest grain yield (5657.28 kg/ha) was obtained due to application of 46 kg/ha, whereas the lowest value (2666.41 kg/ha) was recorded from the control treatment. Thus might be due to N significantly enhances the vegetative growth in turn might be the reason for highest grain yield for 46 N kg/ha rate applications. The current result agreement with the achievements of Amare and Adane (2015); Bekalu and Manchore, (2016) and Franklin *et al*. (2017) obtained significant highly grain yield as a results of optimum N application. This highest grain yield at 46 N kg/ha might be due to the ability of N to determine photosynthetic capacity of the crop, and the increased number of seed number per spikes. This result is also supported by the findings of many previous workers Getachew *et al* (2004); Minale *et al* (2005) and Alemu *et al* (2019) who reported significant increases in grain yields of bread wheat with increasing levels of N fertilizer up to optimum rate. Overall, grain yield increased as the amount of nitrogen increased from the low level to 46 kg/ha. This result agrees with the other finding (Woyema *et al.*, 2012; Fana *et al*., 2012; Haile *et al*., 2012; Gerba *et al.*, 2013 ; Bereket *et al*.,2014). This study revealed that nitrogen is more yield limiting factor for bread wheat productions at Sinana District.

The improvements in bread wheat yield and its components under the acceptable increasing N rate (46 N kg/ha) determined for Sinana District. Additionally, Solomon and Anjulo (2017); Dereje *et al.* (2019); Temesgen *et al* (2021) reported better grain quality; high grain yield and nutrient use efficiency obtained at 46 N kg/ha for wheat production. The excess application of N might be resulted in lodging of wheat and caused a dramatic yield decrease. This finding also supported by Kefyalew *et al* (2017) and Kefyalew and Tilahun (2018) who obtained optimum nitrogen rate (46 N kg /ha) for teff and bread wheat productions; respectively.

Thousand Kernel Weights:

The analysis of variance showed that thousand kernel weights had significantly ($p \leq 0.05$) affects by different N rates. Accordingly; the highest (47.29 g) and the lowest (30.66 g) thousand kernel weights was found from 46 kg/ha and control plot; respectively (Table 6). The result indicates application of N is responsive to increase the grain size of bread wheat and give better thousand kernel weights. This finding supported by different workers Arduini *et al* (2006); Shazma *et al* (2016); Zhang *et al* (2017) and Alemu **(**2019).

Table 6. Responses of bread wheat biomass; grain yield and thousand kernel weight to N fertilizer application at Sinana District

N Rates (Kg/ha)	BM (kg/plot)	GY (kg/ha)	TKW (g)
0	6182.81^{d}	2666.41^{d}	30.66^{d}
23	8109.31^{c}	4034.72^{c}	39.71^{c}
46	11589.27^{a}	5657.28^{a}	47.29^{a}
69	10095.64^{b}	5276.29^{b}	42.68^{b}
Mean	8994.00	4409.00	40.08
LSD (<0.05)	28.04	17.38	15.75
CV (%)	674.58	204.98	1.69

Where, BM: above ground biomass, GY: grain yield, TKW: Thousand kernel weights, CV: Coefficient of Variation, LSD: least significant difference, Means followed by the same letter in the column and rows are not significantly different at 5% level of significance.

Responses of Plant Height, Number of Tillers and Seed Per Spike component to combined applications of different NP Fertilizer rates

Plant height was significantly ($p \leq 0.05$) affect by the interaction of N P fertilizers rates in which the highest (100.4 cm) and the lowest (62.32 cm) were obtained from applications of 46 N and 40 P kg/ha and control plot (0 N and 0 P); respectively (Table 7). This the significantly highest plant height due to combined application of NP rates than control might be due to the ability of nitrogen and phosphorus enhance vegetative growth and additional P sources fertilizer also increases the efficiency of nitrogen thereby indicating positive effects on bread wheat as compared to unfertilized. Accordingly, a number of authors Amsal *et al* (2000); EARO(2006); Abebe (2015) state the dramatic response of support the beneficial effects of combined application of optimum N and P fertilizers on yield components and yield of bread wheat. Additionally; thus the highest plant height at 46 N kg/ha and 40 P kg/ha reveled that optimum N supply causes higher photosynthetic activities, vigorous growth and also adequate P enhances many physiological processes and the fundamental processes of photosynthesis, thus, helping in plant growth. Similarly; Bereket *et al* (2014); Alemu *et al* (2019); reported plant height significantly increased with increasing level of NP fertilizers.

Number of productive tillers was significantly ($p \leq 0.05$) affect by the interaction of N P fertilizers rates in which the highest (5.10) and the lowest (0.33) were obtained from applications of 46 N and 40 P kg/ha and control plot (0 N and 0 P); respectively(Table 7). Thus might be due to the fact that optimum combined NP supply played a significant role in plant growth and development, increase in number of grains per spike, number of fertile tillers and grain yield. This result agrees with the findings of Prystupa *et al* (2004) and Alemu *et al* (2019), who reported that number of productive tillers was significantly affected by NP fertilizer application. In case of interactions between nitrogen and phosphorus, tillers significantly increased with increasing P rates up at all N levels (Shazma *et al*., 2016). Higher P rates enhanced tillers survival, emergence and yield, especially for secondary tillers (Fioreze *et al*., 2012). These results are supported by Mattas *et al* (2011) who stated that phosphorus application positively influenced productive tillers.

Seed per spike had highly significant spike ($p \leq 0.05$) affected by interaction of N and P fertilizers rates. Accordingly; the highest number of seeds per spike (62.22) was recorded for 46 N and 40 P kg/ha while the lowest value (20.56) was recorded for the control treatment (0 N and 0 P); respectively (Table 7). This might be due to combined application attributed to N increases dry matter production and P have also positive effect on number of seed produced per plant. These results are also in accordance with Ali *et al* (2002) and Alemu *et al* (2019) reported that highest number of seeds per spike was obtained from optimum combined NP fertilizer application. Additionally; Shazma *et al* (2016) also reported the optimum NP fertilizer increased in number of seed per spikes but beyond the optimum decreased number of seed per spikes.

Table 7. Responses of plant height, number of tillers and seed per spike to combined application of different nitrogen and phosphorus levels for bread wheat production at Sinana District

Treatments	**P Rates (kg/ha)**					
N Rates (kg/ha)	**0**	**10**	**20**	**30**	**40**	**50**
	Plant height (cm)					
0	62.32^{m}	72.21^{l}	76.07^{jkl}	74.22^{kl}	69.00^{lm}	69.11^{lm}
23	95.14^{abcde}	96.29^{abcd}	82.90^{ghij}	96.76^{abc}	82.18^{hij}	80.67^{ijk}
46	95.77^{abcde}	97.61^{ab}	99.00^{ab}	99.122^{a}	100.40^{a}	98.18^{ab}
69	87.27^{fghi}	88.53^{efgh}	89.38^{defgh}	89.07^{defgh}	91.77^{bcdef}	89.76^{cdefg}
CV (%)	**12.87**					
LSD(<0.05)	**7.32**					
N Rates (kg/ha)	**Number of productive Tiller**					

0	0.33^{j}	0.89^{ij}	0.97^{i}	1.00^{i}	1.11^{i}	0.90^{ij}
23	2.62^{fgh}	2.40^{h}	2.556^{gh}	2.500^{gh}	2.91^{defgh}	2.68^{efgh}
46	4.51^{b}	3.17^{cdef}	2.86d^{efgh}	3.400^{cd}	5.10^{a}	3.07^{cdefg}
69	3.50^{c}	3.20^{cde}	3.21^{cde}	3.33^{cd}	3.36^{cd}	3.61^{c}
CV (%)			**33.13**			
LSD(<0.05)			**0.57**			
N Rates (kg/ha)			**Seed Per Spike**			
0	20.56^{k}	22.28^{jk}	25.344^{ij}	24.50^{ij}	26.39^{i}	27.57^{i}
23	41.03^{gh}	40.80^{h}	43.68^{fgh}	43.68^{fgh}	44.57^{fg}	44.72^{f}
46	45.29^{f}	49.14^{de}	50.34^{cd}	55.49^{b}	62.22^{a}	53.60^{bc}
69	43.59^{fgh}	44.18^{fgh}	45.36^{f}	45.14^{f}	46.06^{ef}	46.40^{ef}
CV (%)			**13.37**			
LSD(<0.05)			**3.62**			

Where, CV: Coefficient of Variation, LSD: least significant difference, Means followed by the same letter in the column and rows are not significantly different at 5% level of significance.

Response of Biomass, Grain Yield and Thousand Kernel Weights to Different Nitrogen and Phosphorus Fertilizer Rates

Biomass yield data was statistical significantly ($p \leq 0.05$) different due to interaction effects of NP fertilizer rates. The mean values varied from 4234.81 to 14991.70 kg/plot (Table 8). Different authors Amsal *et al* (2000); EARO(2006); Haile *et al* (2012); Abebe (2015), Gerba *et al* (2013) and Alemu **(**2019) reported the dramatic response of support the beneficial effects of combined application of optimum N and P fertilizers on yield components and yield of bread wheat.

Grain yield values were statistical significantly ($p \leq 0.05$) influenced by the interactions of N and P fertilizers rates. Accordingly; the highest (7018.57 kg/ha) obtained at 46 N kg/ha and 40 kg/ha P while the lowest (1989.92 kg/ha) obtained from the control plot (Table 8). This might be due to NP fertilizer induced vigorous vegetative growth, which in turn, resulted in increased biological yield. This result supported with the finding of Parvez et *al* (2008); Khan et *al* (2010) and Shazma *et al* (2016) who stated applications of optimum NP fertilizer enhanced grain yield. Additionally; Shazma *et al* (2016) also obtained the decline grain yield and yield components due to application NP fertilizer beyond optimum rate. The mean grain yield of bread wheat response to optimum NP fertilizer application was 71.65 % as compared to the unfertilized control mean. Hence, N and P fertilizers should be applied in proper proportion to get higher crop productivity. Thus, result supported by different authors Kefyalew *et al* (2017); Solomon and Anjulo

(2017); Dereje *et al.* (2019); Kefyalew and Tilahun (2018) and Temesgen *et al* (2021) who reported 46 N kg/ha for better grain quality; high grain yield, nutrient use efficiency and economically acceptable.

Thousand kernel weights values had significantly ($p \leq 0.05$) influenced by interaction of N and P fertilizer application. Accordingly; the highest (56.02 g) and the lowest (26.06 g) thousand kernel weights was obtained at 46 N 40 P kg/ha and control; respectively (Table 8). This means nitrogen enhance the vegetative growth of plants. Different authors Shazma *et al* (2016) and Alemu, (2019) stated that highest level of P in combination with an optimum N rate contributed maximum to transfer physiological attributes and assimilates towards the yield attributes.

Table 8. Responses of biomass, grain yield and thousand kernel weight to combined application of different nitrogen and phosphorus levels for bread wheat production at Sinana District

Treatments	**P Rates (kg/ha)**					
N Rates (kg/ha)	**0**	**10**	**20**	**30**	**40**	**50**
	Biomass (kg/plot)					
0	4234.81^{o}	5500.76^{no}	6495.99^{mn}	6693.65^{lmn}	6777.63^{klmn}	7394.02^{jklm}
23	7509.34^{jklm}	7770.75^{ijklm}	7939.56^{ijklm}	8210.19^{ijk}	8672.24^{ghij}	8553.79^{hij}
46	9173.61^{fghi}	10011.74^{efg}	10525.42^{def}	12884.64^{b}	14991.70^{a}	11948.49^{bcd}
69	8052.44^{ijkl}	9042.64^{ghi}	9934.30^{efgh}	10835.99^{cde}	12172.14^{bc}	10536.31^{def}
CV (%)	**24.56**					
LSD(<0.05)	**1447.28**					
N Rates (kg/ha)	**Grain Yield (kg/ha)**					
0	1989.92^{m}	2503.76^{l}	2783.61^{kl}	2847.58^{kl}	2893.4^{k}	2980.18^{k}
23	3556.44^{j}	3605.82^{j}	3867.402^{ij}	4025.32^{hi}	4348.80^{gh}	4804.53^{f}
46	4568.73^{fg}	5246.11^{de}	5410.94^{cd}	5999.88^{b}	7018.57^{a}	5699.46^{bc}
69	4421.31^{g}	4880.62^{ef}	5280.75^{d}	5519.56^{cd}	5892.10^{b}	5663.41^{bc}
CV (%)	**12.86**					
LSD(<0.05)	**371.60**					
N Rates (kg/ha)	**Thousand kernel weight (g)**					

0	26.06^{j}	28.44^{ij}	31.73^{hi}	32.00^{hi}	32.38^{h}	33.35^{h}
23	37.23^{g}	37.05^{g}	39.03^{fg}	39.59^{fg}	44.04^{cd}	41.33^{def}
46	40.22^{efg}	42.43^{cdef}	45.22^{c}	50.15^{b}	56.02^{a}	49.70^{b}
69	41.04^{def}	41.62^{cdef}	41.41^{def}	43.86^{cd}	44.66^{cd}	43.46^{cde}
CV (%)				**13.81**		
LSD(<0.05)				**3.63**		

Where, CV: Coefficient of Variation, LSD: least significant difference, Means followed by the same letter in the column and rows are not significantly different at 5% level of significance.

Partial Budget Analysis for Optimum Nitrogen for Bread Wheat Productions

The results of partial budget analysis showed that highest net benefit of74573.28 (Birr ha^{-1})was obtained from the treatment that received 46 N Kgha^{-1} while the lowest net benefits of 35996.54(Birr ha^{-1})was obtained from the treatment that received0 N Kgha^{-1} or control plot (Table 3).Thus, application of nitrogen fertilizer for bread wheat had positive net benefit over the control treatment (zero nitrogen) which implies that improvement in crop nutrient management strategy increase in farmers' income. Therefore, application of 46 N Kgha^{-1} is economically profitable and recommended for farmers in Sinana district and other areas with similar soil types and agro-ecological conditions.

Table 9. Partial budget analysis for optimum nitrogen rate determination for bread wheat productions at Sinana District

N rates (Kgha^{-1})	UGY (Kgha^{-1})	AGY (Kgha^{-1})	GB (Birr ha^{-1})	TVC (Birr ha^{-1})	NB (Birr ha^{-1})	MRR (%)
0	2666.41	2399.769	35996.535	0.00	35996.54	0.00
23	4034.72	3631.248	54468.72	900.00	53568.72	1952.47
46	5657.28	5091.552	76373.28	1800.00	74573.28	2333.84
69	5276.29	4748.661	71229.915	2490.00	68739.92	

Where, UGY = unadjusted grain yield, AGY = adjusted grain yield, GB= Gross benefit; TVC = Total variable cost; NB = Net benefit; MRR = Marginal rate of return.

Critical P concentration (Pc) for Bread wheat

The correlation between relative bread wheat grain yield response and soil P measured with Olsen method is indicated in Figure 3. The critical P concentration (Pc) was determined from the scatter diagram drawn using relative grain yields of bread wheat and the subsequent soil test P values for all P rates (0-50 kg P ha^{-1}). The Pc defined by the Cate Nelson method in this study was about 22 mg/kg, with mean relative yield response of about 57% (Figure 3).

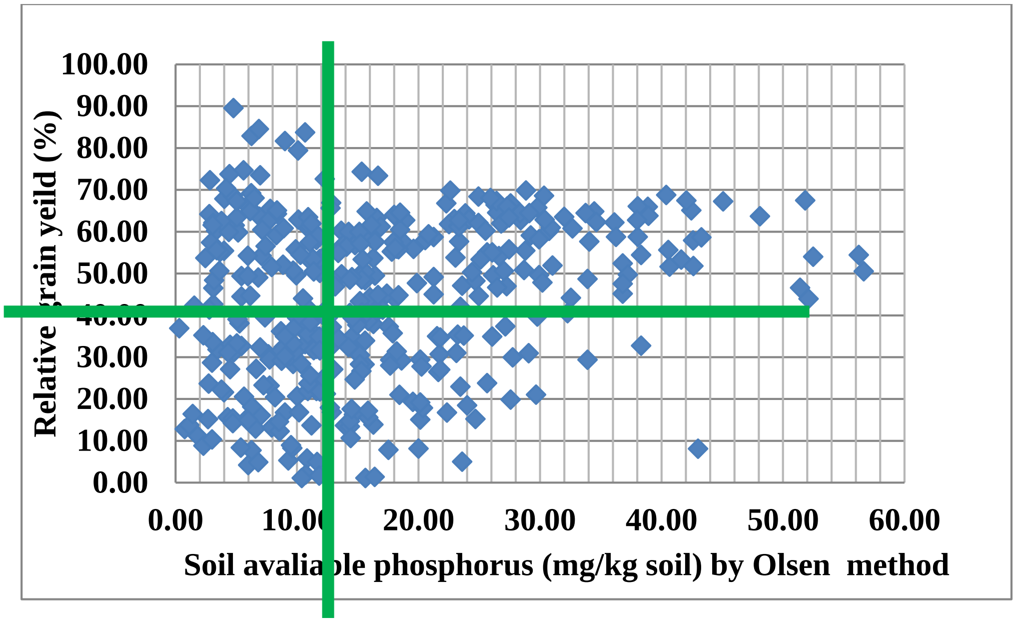

Figure 3: Relationships between soil extractable P measured using Olsen method and relative grain yield of bread wheat according to this Nelson and Anderson graphical method critical limit determined was 22 P mg /kg**.**

P Requirement Factor (Pf) for Bread Wheat

Calculated phosphorus requirement factor (Pf), which is the amount of P in kg needed to raise the soil test P by 1ppm bread wheat production at Sinana District was **5.24 (Table 10)**. These Phosphorus requirement factor enables to determine the quantity of P required per hectare to raise the soil test by 1 ppm, and to determine the amount of fertilizer required per hectare to bring the level of available P above the critical level (Table 10). This implies that P fertilizer application could be recommended for a buildup of the soil P to this critical value, or maintaining the soil P at this level for sustainable crop productions.

Table 10. Determination of P requirement factor (Pf) for bread wheat production at Sinana

Phosphorus Rate	Available P Olsen Method in mg/kg			P increases over control (PI)	Pf
kg/ha	Range		Average		
0	0.30	24.69	12.49		
10	1.50	30.85	16.18	3.68	2.72
20	2.69	31.01	16.85	4.36	4.59
30	2.89	33.93	18.41	4.36	6.89
40	2.50	36.43	19.46	6.97	5.74
50	2.84	38.07	20.46	7.96	6.28
Average					**5.24**

Conclusion and Recommendations

In order to solve the problem of crop production and soil productivity decline because of recommendations fertilizer application site specific soil test based crop response phosphorus calibration study was conducted for three consecutive years (2019 -2021) in Sinana District. Accordingly, the optimum nitrogen rate (46 N kg/ha) have been determined in Sinana District for bread wheat production. Therefore, application of 46 N kg/ha fertilizer advisable for bread wheat productions in Sinana district as well as other areas having the same soil conditions and agro-ecology recommended.

Phosphorus critical (pc) concentration (5.24 ppm) and Phosphorus requirement factor (pf) with the value (22) were determined for bread wheat production during this soil test based crop response phosphorus calibration study. Therefore; farther verification of the result on farmer's field could be a prerequisite before disseminating the technology to the end users.

Generally it can be concluded that soil test crop response based fertilizer application particularly a combined application of optimum nitrogen and phosphorus calibration study significantly improve yield and yield component of bread wheat production in Sinana District since both are the most yield limiting nutrients in the study area.

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Watershed Based Participatory Sustainable Land Management Using Integrated physical SWC measure in Ilasa watershed of Goba District, Bale highland southeastern Ethiopia

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Abstract

Soil erosion is among the most challenging and continuous environmental problems in highland of Bale particularly in Ilasa Watershed of Goba District. Soil erosion which emanates from both anthropogenic and natural causes currently results decline in agricultural productivity, crop productions on the other hand increases downstream flooding and reservoir sedimentation, and loss of valuable plant nutrients. Soil and water conservation (SWC) practices have been carried out to solve of land degradation and erosion severity problems in Ilasa Watershed through participatory approaches with the objective of this study was to implement integrated physical SWC practices through participatory approach in the Ilasa watersheds; to rehabilitate degraded watershed using different physical SWC measures and to minimize the risk of soil erosion and increasing soil depth by trapping sediment loss from Ilasa watershed. Hence, different participatory integrated watershed management practices were introduced in Ilasa watershed for five consecutive years to avert the problem of soil erosion. Community participatory in integrated watershed management particularly soil and water conservation measures interventions for degraded rehabilitation and gulley treatment through were capacitated through training, practical field works and researchable materials supports. Awareness creation, increasing knowledge and skill of farmers, providing technical and resource supports and implementing slope based appropriate SWC structure could help sustainable land management that ensure environmental quality and food security in the study area as well as in the other areas having related biophysical and socioeconomic settings. Among the major types physical SWC structures and gulley rehabilitation structures constructed in the study watershed were soil bund; stone bund; stone faced soil bund and cut-off drains, gully reshaping and filling, brushwood check dam, loose stone check dame, sand bag check dam were the common ones. Theses constructed SWC structures during intervention were supported by vetiver and desho grass using as biological SWC measures. it can be concluded that participatory integrated watershed management intervention brought significant reduction in soil erosion and thereby improvement of rehabilitation. It should be recommended that periodic maintenance, further supporting with biological conservation measures and promote such practices or intervention to similar watershed is needed. Further study on alternative watershed management practices or technologies from different perspectives is advisable to sustainably satisfy the benefits of the community and viability of natural resources.

Key words: Soil erosion, soil and water conservation; degraded land rehabilitation

Introduction

Soil erosion by water threatened the food security and environmental protection of the globe (Lieskovsky and Kenderessy, 2014). The watershed attributes extreme soil erosion, high runoff and the highest rainfall intensity (Belayneh *et al*., 2019; Fazzini *et al*., 2015). Different researches were completed to quantify the rate of soil erosion in the watershed. Soil degradation due to water erosion is one of the serious constraints for agricultural development particularly in the highlands of east Africa (Karamage *et al*., 2017; FAO, 2019). In Ethiopia, about 2 billion tons of soil, 50% of which is from cultivated land, is lost by erosion every year (FAO, 2019). According to Haregeweyn *et al (*2015) and Borrelli *et al* (2017) who reported that on average, the combined erosion forms (sheet, rill, and gully) remove 30 tons of soil $ha^{-1}yr^{-1}$(which exceeds the recommended tolerable rate (10 ton of soil $ha^{-1}yr^{-1}$). Surface runoff (sheet and rill erosions) is dominant forms of soil erosion by water, but less visible (Heri-Kazi and Bielders, 2021).

Soil erosion have different types, forms and severity levels that causes land degradation and loss of crop production in a given watershed. Soil erosions in the form of rill; sheet and gulley are among the hazardous form of erosion causes loss of thousands hectares of cultivated lands abandoned in the country (Belayneh *et al*., 2020). Mitigating soil erosion through proper soil and water conservation (SWC) measures should be a priority to ensure sustainable land uses, particularly on sloping lands subjected to cultivate. In Ethiopia, different SWC measures are implemented in different parts of the centuries (Mukai *et al*., 2021). A study conducted by Belayneh et al. (2019) and Zimale et al. (2017), reported that an average soil loss rate of 42 and 49.2 t ha-1 yr-1, respectively. Wubie and Assen (2019) showed the soil degradation index in the watershed was in the range of -236 to -364%, indicating that the area is subjected to high soil erosion. To reverse this trend, the Ethiopian government with the help of non-governmental organizations started a large-scale watershed development program to increase agricultural productivity, and reduce soil erosion. The program focused on the construction of the physical structure in the highlands for the last two decades.

Integrated watershed management is a method of continuous restoration, growth and efficient use of available natural resources in a watershed, and a multidisciplinary approach to soil depletion pause (Mekonen and Fekadu, 2015). Studies showed that the implemented integrated watershed interventions increased infiltration and decreased runoff production (Taye *et al*., 2013); improved soil fertility (Nyssen *et al*., 2007) and improved vegetation regeneration (Mekuria *et al*., 2007); improved soil fertility (Nyssen *et al*., 2007); improved vegetation regeneration and soil build-ups (Etsay *et al*., 2019); improved groundwater (Nyssen *et al*., 2010). Investments in soil and water conservation (SWC) practices enhance crop production, food security and house hold income (Adgo *et al*., 2013). Recognizing these connections, these study was intiated with the objective: to implement integrated physical SWC practices through participatory approach in the Ilasa watersheds; to rehabilitate degraded watershed using different physical SWC measures; to minimize the risk of soil erosion and increasing soil depth by trapping sediment loss from Ilasa watershed.

Material and Methods

Description of the Study Area

The study was conducted at Goba Districts at Ilasa watershed which is situated 25 km away from Goba town of Bale zone of Southeastern Ethiopia. Ilasa Watershed located between in northern or the lower part of watershed bounded by Walti Magida kebele on the southern or upper part of watershed bounded by Barbare district, on the western part of watershed which is bounded by Walti Qubsa kebele and in eastern part of watershed bounded by wacho Misirge. Geographically, the study district is located at 6°57′30″ to 7°0′30″ North and 40°3′ 30″ to 40°6′0″ East and covering the total area of 506 ha having an elevation ranges from 2462 to 2991 amsl (Figure 1). This watershed where characterized by sever soil erosion; high gully expansion that causes for loss of agricultural land that results for serious problem for community livelihood, crop production and soil productivities in this area.

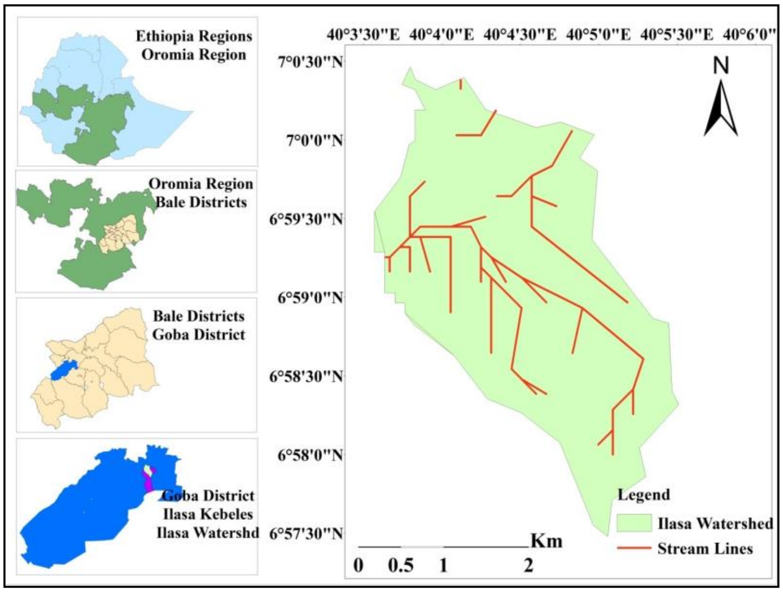

Figure 1. Map of the study site

Topography and Slope Characteristic of Ilasa Watershed

The effects of topography on land degradation depends on the effects of slope steepens and slope length. The ground flat slope is important when considering overall transportation of soil particles. The size and shape of the drainage area and generally its slope major affect runoff rate and velocity (Mulugeta *et al*., 2017). The slope classification based on recommendation for SWC structure implantation and layout given by Lakew *et al* (2005) categorized into five (5) classes namely; flat or almost flat (0 – 3 %) , gently sloping (3 – 8%), sloping (8 – 15%), moderately steep (15 – 30 %) and steep (30 – 50%) as indicated figure 2.

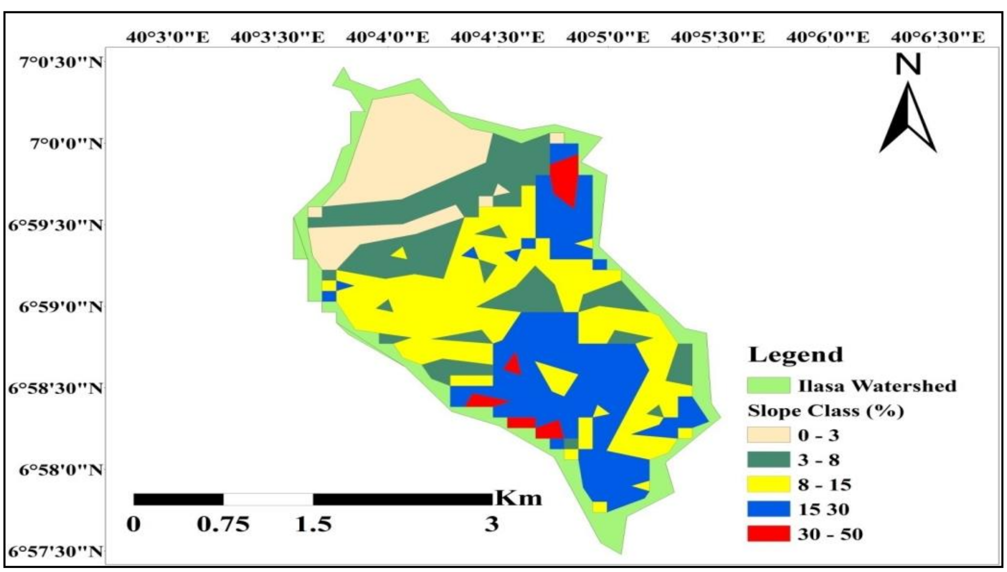

Figure 2. Slope Classes of Ilasa Watershed

Climate

As a part of Bale zone, Ilasa watershed of Goba District has two types of rainfall seasons. The long rainy season extends from March to April with high rain fall during June, July and August. The second rainy season of rain fall regime is influenced by equatorial westerly and easterly winds with rainfall during spring and autumn. Accordingly; the average monthly climate characterize of the watershed 22.64^{o}C; 8.58^{o}C and 195.69 mm; maximum temperature; minimum temperature and rainfall; respectively.

Soil and Vegetation

The major soil types are Chromic, Pellic Vertisols and Luvisols. Vegetation coverage great contribution in interception rainfall, keeping sediment loss and manage interception rainfall, keeping sediment loss and manage soil fertility. Juniperus procera, Eucalyptus, Olea europace, Hagenia Abyssnica, cordial africana, cuppressus and other shrub as well as bush encouragement are grown in the area. However most on the indigenous tree exposed to deforestation for fire wood, construction and agricultural expansion (Mulugeta *et al*., 2017).

Community Participation; Approach and Activities Innervations

The local communities' involvements in watershed management activities through mobilizing through awareness creation; training; labor payment in the form of incentive; FRG and watershed use associations organizing, materials used for SWC measures such as wood and gabion providing which support critical to programme success.

Layout and construction of SWC structures as interventions

In these works Lakew *et al* (2005) and Ministry of Agriculture (2016) guidelines for were adopted in addition to considering slope and soil types. Generally; some constructed soil and water conservation structures in Ilasa watershed were described as follows. In addition to the standard for SWC measures convenient for ox-plowing was considered during intervention practices in Ilasa watershed.

Level soil bund was constructed for slopes above 3 -15% gradient. Based on this the design, layout and minimum technical standards for constructions level soil bund were considered during constructions. Accordingly; Height: min. 60 cm after compaction; Base width for stable soil: 1-1.2 m and (1 horizontal: 2 vertical), Base width for unstable soil: 1.2-1.5m in unstable soils (1 horizontal:1 vertical), Top width: 30 cm (stable soil) - 50 cm (unstable soil); Length of bund: 30-60 m in most cases, higher (max 80m) on slopes 3-5% and need to be spaced staggered for animals to cross and Vertical intervals*:* = 1-1.5 m for slope ranges 3-8%, vertical interval = 1-2 m for slope ranges 8-15% and vertical intervals = 1.5-2.5 m for slope ranges 15-20%, generally follows a flexible and quality oriented approach.

Stone faced soil bund; Design, Layout and Minimum technical standards for constructions stone faced soil bund were grade of lower stone face: 1 horizontal: 3 vertical; lower stone face riser foundation: 0.3 depth x 0.2 - 0.3 width; upper stone face riser foundation: 0.2 x 0.2 m; stone size: 20 cm x 20 cm stones (small and round shape stones not suitable); top width: 0.4- 0.5 m; height: min. 0.7 and max. 1 m ; ties required: at every 3-6 m along channel; sink hole: is required at every 6-8 m; vertical interval: 1-1,5 m for slope 3-8%, 1- 2 m for slope 8-15%, 1.5 - 2.5 m for slope 15-30% while for slope above 30% only in very stable soils or shift to stone bunds.

Cut-off Drain: were constructed follows the SWC measures minimum standard such as gradient: 0, 5 –1% max without scour checks. From 1 to 2% with scour checks; shape: Parabolic or trapezoidal; embankment: minimum 0,5 m top width, all slopes cut to grade of 1 to 1; scour checks (for gradients 1 – 2%).

Stone Check-dam: were constructed follows the SWC measures minimum standard such as spacing estimated on the safe side using S (spacing) m = Height (m) x 1,2/ Gradient (in decimals) ;Side key: 0,7-1 m inside gully sides, Bottom key & foundation: 0,5m depth x width of check dam ;Height: min 1m and max 1,5 m excluding foundation; Base width: min 1,5 and max 3,5 m.

Results and Discussions

Awareness Creation and Capacity Building

There are several factors which affect the farmers' participation in sustainable integrated watershed management technologies so that to ensure successful implementation of these technologies, it is essential to ensure peoples' participation. Keeping this in view, prior to introduce of new integrated watershed management technologies and on layout, technical and design of SWC structures training have a curtail roles for successful innervations. Awareness creation, strength capacity building; improving community participations great role in sustainable integrated watershed management for rural communities on integrating crops, livestock and natural resource management technologies particularly for Ilasa watershed of Goba district in area sever soil erosion and land degradation problems (Mulugeta *et al*.,2017).

The study gives more attention to training and discussion with different stakeholders on the practical and technical training as well as experience sharing of model practices to ensure participatory sustainable natural resource management at Ilasa watershed. Based on this, a totally of, 473 participants involved in the watershed management capacity building program among these 306 and 167 were male and female household; respectively (Table 1). This approach created the positive efforts among farmers in which perceived benefits of SWC measures as socioeconomic pillars, motivate farmers to participate in watershed management, skill enhancement of households, encourage women role and linkages on these intervention works.

Table 1. Training on awareness creation and capacity building at Ilasa watershed

Years	**Experts**			**DAs**			**Farmers**		**Total**
	M	**F**	**Total**	**M**	**F**	**Total**	**M**	**F**	
2008	3	1	4	2	-	2	30	17	47
2009	4	1	5	4	-	4	140	60	200
2010	2	1	3	2	-	2	30	10	40
2011	1	-	1	3	-	3	50	50	100
2012	3	1	4	2	-	2	30	26	56
Sub total	**13**	**4**	**17**	**13**	**0**	**13**	**280**	**163**	**443**

Participatory Implemented Physical SWC Measures and Gulley Rehabilitation Structures

Soil erosion is one of the biggest bottlenecks to agricultural productivity, crop production and community livelihood of Ilasa watershed (Figure 2). The baseline survey show that the watershed was steep slopes, high rainfall and improper cultivations therefore; to reduces these problems integration of physical and biological soil and water conservation measures is very important.

Participatory implementation of degrade land rehabilitation through construction of integrated physical and biological soil and water conservation measure such as Cutoff drains, stone bunds, soil bunds, grass waterway planting of multipurpose trees recommended for Ilasa watershed (Mulugeta *et al*.,2017). Keeping this in view, different soil and water conservation measures (SWC) have been carried conducted in Ilasa watershed of Goba District from 2008 to 2013 for five (5) consecutive years. The most common physical soil and water conservation measures practiced were soil bund; stone bund; stone faced soil bund and cut-off drains as indicated (Figure 3). Similarly; Dimtsu (2018) also reported such physical integrated watershed management structures in Maego watershed of northern Ethiopia.

Gully formation and expansion is the major problems that causes agricultural land loose, damages different resources in the area (Figure 3). Participatory gully rehabilitation, treatments and reclamation for sustainable watershed management through gully reshaping and filling, brushwood check dam, loose stone check dame, gabion check dam, sand bag check dam and gully bed and sidewalls plantation with water loving or moist tolerant tree, shrub and grass (Mulugeta *et al*.,2017). Based on these recommendation gully rehabilitation structures such as stone check dam; wood check dam; sediment storage dam; gully reshaping and planting; live check dam; sand and soil filled check dam; cut-off drains were used were implemented in Ilasa watershed.

Figure 2. Status of land degration and gulley severist at Ilasa watershed before intevation

Figure 3. Picture during community based participation in implementing soil and water conservation structures in Ilasa watershed.

Biological SWC measures Implemented and Distributed at Ilasa Watershed

Applying multipurpose grass as an integrating with physical structure contributes incredible benefits in reversing degraded land via soil and water conservation practice and for sustainability of implemented physical SWC structures. Among them vetiver and Desho grass is the best biological method, which effectively curtails in reducing soil erosion problems. In order to reverse the problems of soil erosion , the adoption of soil and water conservation (SWC) practices which are economically feasible, environmentally sound and replicable is paramount importance for sustainable production of Agricultural crops among this vetiver grass particularly for Bale highland (Mulugeta *et al*., 2017). Based on these recommendation the two common multipurpose grass species vetiver and desho grass distributed in order to farmers establish nursery at community and watershed level, as well as also plantation on private and communal lands these two compatible multipurpose grass species were distributed for Ilasa watershed of Goba district (Table 2).

Table 2. Vetiver and Desho grass distributed for Ilasa watershed managements

Years	Number of Stocks	Numbers of Splits
	Desho grass distributed	
2010	288	10,791
2011	219	8,937
2012	263	12,475
Total	770	32203
	Vetiver grass distributed	
2010	300	12,000
2011	500	15,000
2012	800	10,000
TOTAL	1600	37,000

Figure 5. Planting of biological SWC measures as support of physical SWC structures

Contribution of Intervention Implemented at Ilasa watershed

Following the assessment, resources characterization and mapping of Ilasa watershed of Goba distinct of Bale Highland different SWC structures both physical and biological SWC measures implemented as intervention by Sinana Agricultural Research Center; Soil fertility Improvement and Soil and Water Conservation; Watershed Management Research Team. Consequently, positive impacts were achieved as compared to before intervention. The immediate outcomes of integrated watershed management interventions in Ilasa watershed include rehabilitation of degraded land; reduction in soil erosion and associated downstream siltation; and regeneration of plant resources (Figure 6). The above success of soil and water conservation measures implemented for rehabilitating degraded land following participatory integrated watershed management approach at Ilasa watershed is one of the major indicator for the benefits to local households , farmers, the local community, and the society at large.

Figure 6. Ilasa watershed status after innervations

Conclusion and recommendations

Community participation was developed through given training and experience sharing to develop awareness creation for the local community and capacity building about layout of structures for the local technical leaders should be given. It can be concluded training and awareness creation prior and great role before intervention to ensure effective participatory sustainable integrated watershed management practices at Ilasa watershed. Hence, different integrated watershed management practices were introduced in Ilasa watershed for five consecutive years to reduce the problems of land degradation as results of high soil erosion. Among the major types physical SWC structures and gulley rehabilitation structures constructed in the study watershed were soil bund; stone bund; stone faced soil bund and cut-off drains, gully reshaping and filling, brushwood check dam, loose stone check dame, sand bag check dam were the common ones. Theses constructed SWC structures during intervention were supported by vetiver and desho grass using as biological SWC measures. During theses participatory SWC layout, construction and intervention most of the structures, meet the site specific vertical intervals/slope, width and height standards. The type and quantity of these measures vary by variation in slope, runoff volume and intensity of land degradations. The watershed management intervention in Ilasa watershed of Goba District was effective in several aspects. The findings indicated that the watershed management intervention brought reduction in soil erosion and thereby improvement of rehabilitation.

It should be recommended that periodic maintenance, further supporting with biological conservation measures and promote such practices or intervention to similar watershed needed. Hence, integration among the community, government and non-governmental organizations are needed to for further sustainable management of natural resource resources in Ilasa watershed. Further study on alternative watershed management practices or technologies from different perspectives is advisable to sustainably satisfy the benefits of the community and viability of natural resources.

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Worm Collection and Characterization of Vermicompost produced using different worm species and waste feeds materials at Sinana on – Station of Bale highland southeastern Ethiopia

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Abstract

Soil fertility decline and high prices of inorganic fertilizers are among the major bottlenecks for sustainable crop production and agricultural productivity particularly for small holder farmers. Considering these issues this study was conducted at Sinana Agricultural Research Centre, on - station to evaluate worm collected from different sites and characterizations of vermicompost nutrient content made from different feed sources. Trials house or vermiculture was constructed on 15 m x 13 m land size having six worm bins in the house in which single worm bin 9 m^2 area. Inside worm bin were covered using plastic geo-membranes to make safe for earthworms while on the top and partially, the body of house covered by corrugated iron sheet in order protect from rain, flying predators and mesh wire for aeration purpose was used. The earthworm collection conducted contains two parts. The first part was locally collected from Sinana and Dinsho Districts from moist cool, around dead leaves (straw), moist bark dead trees leaves and farm yard manure stored for a long period of time at home garden. The second part was the red worm (Eisenia fetida) taken from Ambo Agricultural Research Center. Crop residue of field pea, faba bean, wheat and barley after chopped both using grinding machine and manually mixed with farm yard manure were used both for vermicompost and conventional compost. The major chemical properties such as pH, EC, OC, TN, available P, CEC, exchangeable bases (Ca, Mg, K and Na) and micronutrients (Fe, Mn, Cu and Zn) were conducted using standard laboratory procedures. Results for nutrient content characterizations indicated that 6.93 to7.83; 0.003 to 0.007 ds/m ; 12.97 to 28.82%; 1.42 to 4.68%; 6.16 to 9.76%; 25.31 to 89.89 mg/kg and 33.23 to 65.43 $cmol_+/kg$ for pH; Ec; OC; TN; C:N; Av.P and CEC; respectively were obtained. Both exchangeable bases and micronutrients also follows similar trend for major essential plant nutrients in which relatively highest value obtained from vermicompost made using Eisenia Fetida while the lowest values obtained from conventional compost. It can be concluded that high vermicompost quality in terms of nutrient containing such as nitrogen, phosphorus, potassium, exchangeable bases and micro nutrients was produced from the mixture of field pea, faba bean, wheat and barley straw or residue using red earthworms (Eisenia foetida) than locally collected worm species and conventional compost. It should be recommended that multiplication, demonstration of Vermiculture and vermicompost produced using Eisenia fetid and integrated use with inorganic fertilizer is need in Sinana and similar agro - ecology.

Keywords: *Eisenia Fetida*, Vermicompost, Conventional compost, Nutrient quality

Introduction

In different parts of the world currently agriculture practices characterized by excessive inputs of chemical fertilizers, pesticides, and herbicides, while the insufficient application of organic fertilizers (Gill and Garg, 2014). These excess uses of chemical fertilizers and pesticides have resulted in numerous negative effects on the environment, including water, degradation of soil quality and losses of agricultural biodiversity. Vermicomposting is an eco biotechnological process that transforms energy rich and complex organic substances into stabilized humus like product vermicompost having an environmentally sound and economically viable technology particularly for the farming community (ThiruneelaKandan and Subbulakshmi, 2015). Vermicompost one of the enriched with critical nutrients such as Nitrogen, phosphorus, and potassium as well as high concentrations of highly decomposed organic matter that serve as resource for improving soil fertility and crop productivity.

Vermicompost has many advantages over traditional compost in terms of its physical structure, nutritional content and biochemical value due to the higher mineralization and humification rate through the vermicompost process (Lim *et al*., 2014). Earthworms play important roles in soil formation and fertility, functioning as an element of a food web and also responsible for altering dynamics of the ecosystem through the maintenance and modification. The study of earthworms was started by Charles Darwin who made the first report on the role of earthworms in the breakdown of organic matter in the ecosystem (Lowe *et al*., 2014). Preparations of vermicompost technology utilizing earthworms, most frequently from the genus *Eisenia fetida* is plays an essential role in decomposing of organic matter and agro-wastes which supports as improving soil fertility, efficient natural recycling and enhanced plants' growth particularly economically, affordable for small holder farmers (Tajbakhsh *et al*.,2011; Bhat *et al*.,2017 and Kovacik *et al*.,2018).

The earthworms have different effects on the decomposition of organic matter, surface area and its quality. The mature and quality of vermicompost is important to predict its potential impact on soil fertility which depends on knowledge of the microbial structure and functions. Vermicompost is one excellent product technology used as plant growth hormones, higher level of enzymes, greater microbial population and tend to hold more nutrients over a longer period without adversely impacting the environment (Mustafa *et al.*, 2019 and Moustafa *et al*., 2020).

In different areas of the world commonly traditional management practice of post harvest residues rather than incorporation into the soil or uses as sources organic inputs subjected to elimination by open air burning leads to release of green house gases (ThiruneelaKandan and Subbulakshmi, 2015). According to Sartaj *et al* (2016) mixing cow dung crop residues helping to improve their acceptability by *Eisenia fetida* and improved physicochemical characteristics of produced vermicompost. In this study in addition to worm collection and evaluate the adaptability determining vermicompost quality produced from mixed farmyard manure with crop residues such as wheat, barley, faba bean and field pea straw or residue curtail role.

The decomposition rate of vermicompost decomposition rate than conventional compost due to transformation of organic materials takes place through earthworm gut where the end materials contain high microbial activities, rich in nutrient contents, plant growth regulator (Fabio, 2012) In Bale Zone particularly on the highland crop residues such as wheat, barley, faba bean, field pea are the major easily accessible residues mostly the farmers were burn on the field. However, soil fertility declines as results of nutrient leaching, loss through soil erosion, due to limited inputs of both organic and inorganic fertilizer sources major problems for sustainable crop productions and agricultural productivity. Therefore, mixed use of these locally available resources with farm yard manure have curtail role to improve crop productions and agricultural productivity in sustainable ways. Among this vermicompost is environmentally sound full and economically, affordable particularly for small holder farmers. Based on this, the study was initiated with the specific objectives to collect the earthworm from different agro ecology; to evaluate the adaptation of earthworm collected from different agro ecology and to characterize the nutrient contents vermicompost produced by earthworms using different mixed feed sources.

Material and Methods

The study was conducted in Sinana District which is one of the Bale highlands Oromia Regional State, Southeastern Ethiopia. This District is bordered by Goro District in the east, Dinsho District in west, Agarfa and Gassera in the north and northeast and Goba District. Sinana Agricultural Research Center is located about 493 km from the capital city of Addis Ababa. Geographically, Sinana Agricultural Research Center is located at 7º 4' 10" to 7º 9' 10" N and 40º 12' 40" to 40º 16' 40" E (Figure 1).

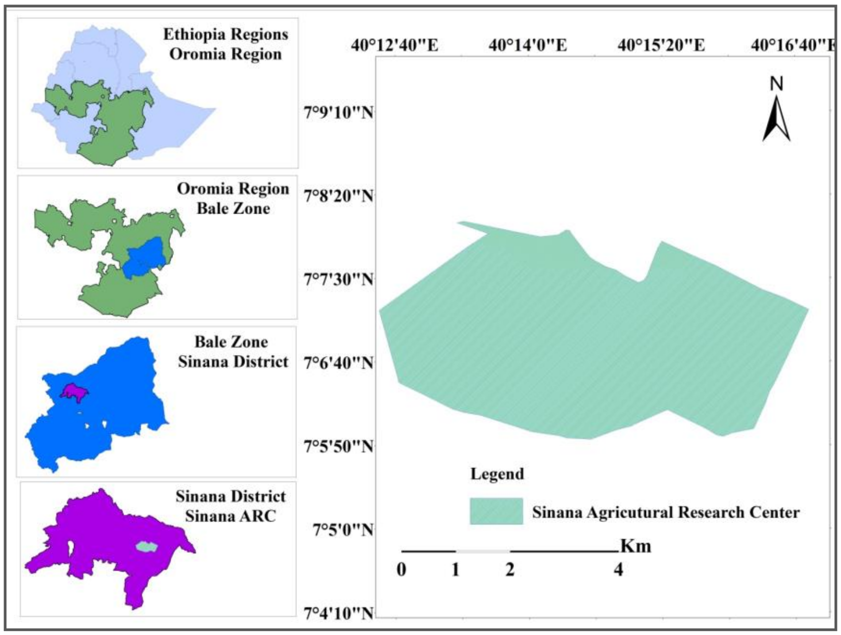

Figure 1. Map of the study site

Worm Shade Construction and Establishment of Vermiculture

Trials house or vermiculture was constructed on 15 m x 13 m land size. In the house three worm worm bin in two replications were constructed from concrete cement in rectangle form at 60 cm depth having area 3 m x 3 m (9 m$^{2)}$ for each worm bin. Window or hole was developed at common sides for each box to make suitable horizontal vermicompost harvest method (figure 2). Inside worm bin were covered using plastic geo-membranes to make safe for earthworms. Partially, the house was covered by Corrugated iron sheet in order to protect rain, flying predators those attack worms and mesh wire was used for aeration purpose (figure 2).

Figure 2. Trail house for vermicompost and Vermiculture establishment at Sinana on- Stations

Feeds or Substrates Preparations and Earthworm Collection

The major locally easy available crop residues wheat, barley, faba bean and field pea straw or residue and farmyard manure were used in mixed ratio as a feed sources for vermicompost produced. The substrates or crop residue were chopped using grinding machine and manually then finally mixed with decomposed farmyard manure in a ration of 2 (field pea):2 (faba bean):1 (wheat straw):1 (barley straw) and 2 (farm yard manure) in a total of 8 kg mixed for each worms and one control (without worm or conventional compost) were used. Using water cane water was added to maintain optimum moisture for worms as it needed and facilitated decompositions as suitable for worms. Feed sources and water were measured and uniformly added to worm bin box (5 kg) for each was used. The vermicompost produced was started by uniformly released 50 worms independently according to their collections into the feed sources (Table 1) while the conventional compost contains only the mixtures of all feeds sources without any worms and the other managements were uniform for all.

The earthworm collection conducted contains two parts, one was the locally collected from Sinana and Dinsho Districts. After field survey on the availability and identification suitable area for earthworm the local worm collection were done from moist cool, around dead leaves (straw), moist bark dead trees leaves and farm yard manure stored for a long period of time at home garden. The second part was the red worm (*Eisenia fetida*) taken from Ambo Agricultural Research Center. After 40th day the numbers of earthworms were taken data obtained indicated a significant variation among worm types collected (Table 1).

Table1. Treatments, feed combination and data collected on earth worm adaptation

No. Bin	Worm Types	IW	WPB	AWL (cm)	FPS	FBS	FYM	WS	BS	TFPB
					Kg					
1	*Eisenia fetida*	50	616.00	3.00	2.00	2.00	2.00	1.00	1.00	8
2	*Eisenia fetida*	50	740.00	3.00	2.00	2.00	2.00	1.00	1.00	8
3	Dinsho Worm	50	269.00	2.30	2.00	2.00	2.00	1.00	1.00	8
4	Dinsho Worm	50	186.00	2.40	2.00	2.00	2.00	1.00	1.00	8
5	Sinana Worm	50	25.00	2.00	2.00	2.00	2.00	1.00	1.00	8
6	Sinana Worm	50	71.00	2.30	2.00	2.00	2.00	1.00	1.00	8

Where: IW = initial worm; WPB = worm per bin; AWL= Average Worm Length; FBS = field pea straw; FBS = Faba bean straw; FYM = Farm Yard Manure; WS=Wheat Straw; BS = barely straw; TFPB = total feeds per bin

Vermicompost Harvesting and Laboratory Analysis

At the end of experiment, a total number of parent earthworms and newly hatched earthworms were recorded. The Vermicompost in the containers were then harvested and sieved (2mm) to remove earthworms and un decomposed materials. The harvested homogeneous vermin-compost was then stored separately and finally the vermin- compost quality was analyses at Sinana agricultural research center soil laboratory and at Haramaya university soil chemistry laboratory. The pH and EC of both vermicompost and conventional compost was measured in the supernatant suspension of a 1:2.5 soil to water ratio using a pH meter and electrical conductivity; respectively (Rhoades, 1982). Walkley and Black (1934) used for the determination of organic carbon. Total nitrogen was determined using the Kjeldahl method as described by Bremner and Mulvaney (1982). Available P was determined following the Olsen method (Olsen, 1954) using ascorbic acid as reducing agent.

Total exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) were conducted for Ca^{2+} and Mg^{2+} were determined by atomic absorption spectrometry (*AAS*) while K^{+} and Na^{+} were determined by flame photometer (Okalebo *et al.*, 2002*)*. Cation exchange capacity (CEC) was determined using (Chapman, 1965). Percent base saturation (PBS) was calculated as follows;

$$\text{PBS (\%)} = \left(\frac{Ca^{+2} + Mg^{+2} + K^{+} + Na^{+}}{CEC} * 100\right)$$

The available micronutrients (Fe, Mn, Cu and Zn) were extracted by diethylenetriaminepenta acetic acid (DTPA). Finally, their contents were quantified using AAS at their wave lengths as described by (Lindsay and Norvell, 1978).

Result and Discussion

Selected chemical properties Vermicompost and conventional compost

The pH and Electrical Conductivity

As the laboratory analysis result revealed that pH value highest (7.83) while lowest (6.93) was recorded for Vermicompost and conventional compost (Table 2). According to Santamaria *et al* (2001), the pH values of all type of vermicompost are found in suitable range for survival of earthworms since pH value greater than 8.5 is harmful to microorganism. This finding agreement with finding of Jouquet *et al* (2013) who stated that the values of pH was ranged from 6.8-8.41 for vermicompost. Additionally, Derib *et al* (2017) reported that, the pH of vermicompost suitable as compared to conventional compost. Electrical conductivity (Ec) values were not significant variation in which totally it ranges from 0.003 to 0.007 ds/m (Table 2). According to Santamaria *et al* (2001), EC values of both conventional and vermicompost were free from salinity. The current values of EC obtained both from vermicompost and conventional compost made from mixed materials are suitable for earthworm feeds sources, survival for earthworms and applicable for crop production. Similarly, Tadele *et al* (2020) also obtained suitable range of vermicompost EC values for both earthworm and crop production.

Organic carbon and total nitrogen

The mean value organic carbon varied from 12.97 to 28.82% in which the highest mean value were obtained vermicompost prepared from *Eisenia Fetida* while the lowest from conventional Compost (Table 2). Different authors Eyasu *et al* (2015); Hiranmai *et al* (2016) and Derib *et al* (2017) also found the higher percentage of organic carbon for vermicompost prepared using *Eisenia Fetida* as compared to conventional compost. The values of total nitrogen in this study ranged from 1.42 to 4.68% in which the highest mean value were obtained vermicompost prepared from *Eisenia Fetida* while the lowest from conventional Compost (Table 2). This might be due to the high nitrification rate in which ammonium ions are converted into nitrates in case of vermicompost produced using *Eisenia Fetida*. This result line with the finding of Ibrahim *et al* (2013) and Tadele *et al.*, (2020) who stated that Total nitrogen content in vermicompost can range quite widely from 0.1% to 4% or more and 3.04 to 4.26%; respectively.

Carbon to Nitrogen Ratio and Available Phosphors

Carbon to Nitrogen Ratio (C: N)

The calculated carbon to nitrogen ratio (C: N) varied from 6.16 to 9.76% **(**Table 2). As the result indicates that the lowest (6.16%) was registered under vermicompost prepared using *Eisenia Fetida* whiles the highest (9.76) from worm collected from (Table 2). The C: N ratio values for worm collected from locally and that of conventional compost almost no significant variation in which all values greater than C:N ratio of vermicompost prepared using *Eisenia Fetida*. This result confirmed with different authors Kalantari *et al* (2009); Hiranmai *et al* (2016) and Derib *et al* (2017) who stated that vermicompost had lowest C: N ratio as compared to conventional compost.

Available Phosphorus

The laboratory analyzed for available phosphorus (Av. P) shows that highest (89.89 mg/kg) while the lowest value of (25.31 mg/kg) values was recorded under vermicompost prepared using *Eisenia Fetida* and conventional compost; respectively (Table 2). This might be due to hormone releases of *Eisenia Fetida that* improve decomposition rate and full decomposition materials used that increased the content of phosphorus in the vermicompost. Similar, Zarei *et al* (2011) and Jayanta *et al* (2015) reported the highest available phosphorus contents in vermicompost. The results of current study revealed that a significant variation among locally collected worms, conventional compost and vermicompost prepared using *Eisenia Fetida*. Muzafer and Pinky (2017) also reported available phosphorus content in vermicompost which depend on the types of earthworm's and feed materials used.

Table 2. Nutrient contents of vermicompost and conventional compost for selected chemical parmeters at Sinana

Treatments	PH-H2O	EC (ds/m)	OC	TN	C:N	Ava. P (mg/Kg)
			%			
Sinana Worms	7.3	0.005	18.83	1.93	9.76	43.29
Eisenia Fetida	7.83	0.007	28.82	4.68	6.16	89.89
Dinsho Worms	7.35	0.005	20.19	2.14	9.43	56.27
Conventional Compost	6.93	0.003	12.97	1.42	9.13	25.31

Cation exchangeable capacity and Exchangeable bases

Cation Exchangeable Capacity

Cation exchangeable capacity (CEC) values of vermicompost prepared using different earthworm species and that of conventional compost using different mixed feed sources were varied from 33.23 to 65.43 $cmol_+/kg$ (Table 3). As the results revealed that the highest (65.43 $cmol_+/kg$) and the lowest (33.23 $cmol_+/kg$) were obtained from vermicompost prepared using *Eisenia Fetida and* conventional compost*;* respectively. This might be due to vermicompost made using *Eisenia Fetida* high nutrient rich particularly due to high organic carbon content, better mineralization and full decompositions of substrates. This result was garment with the finding of Tadele *et al.* (2020) who reported that CEC in vermicompost ranges from 57- 68.70 mg/kg for vermicompost made from different substrates.

Exchangeable Bases (Ca, Mg, K and Na)

The analyzed result showed that the values for exchangeable bases (Ca, Mg, K and Na) were varied from 22 to 34.77 $cmol_+/kg$, 0.31 to 1.40 $cmol_+/kg$, 0.99 to 2.25 $cmol_+/kg$ and 0.35 to 0.55 $cmol_+/kg$ for Ca, Mg, K and Na; respectively (Table 3). In all exchangeable bases (Ca, Mg, K and Na) values the highest were obtained from vermicompost made using *Eisenia Fetida* while the lowest was obtained from conventional compost. In general, the vermicompost obtained using *Eisenia Fetida* using mixed farm yard manure and other straw were rich in exchangeable cations than conventional compost. The result agreement with the findings of Amir and Fouzia (2011) reported that the exchangeable bases (Ca, Ma and K) were significantly increased in vermicompost as compared to pit compost. The calculated percent base saturations (PBS) valued 59.16 to 71.17 % the highest value was obtained from conventional compost while the lowest was from vermicompost made using *Eisenia Fetida.* The lowest percent base saturations (PBS) in vermicompost made using *Eisenia Fetida* might be due to high CEC contents.

Table 3. Cation exchangeable capacity and exchangeable bases status of vermicompost and conversional compost at Sinana

Treatments	CEC	Exchangeable base				PBS
		Ca	Mg	K	Na	
	cmol+/kg					%
Sinana Worms	46.67	28.29	0.68	1.99	0.42	67.80
Eisenia Fetida	65.43	34.77	1.40	2.25	0.55	59.16
Dinsho Worms	45.44	29.71	0.73	1.23	0.42	70.62
Conventional Compost	33.23	22.00	0.31	0.99	0.35	71.17

Micro nutrients contents

The analyzed result for Micro nutrients contents ranges 0.80 to 0.71, 1.20 to 1.48, 1.40 to 1.89, and 0.04 to 3.18 for Fe, Mn, Cu and Zn; respectively (Table 4). The highest Zn values was obtained from vermicompost made using *Eisenia Fetida.* Similarly, Rajiv *et al* (2010) found the highest Zn contents in vermicompost. As the results revealed that vermicompost have better micro nutrients contents than conventional compost for the study conducted using different worms and different mixed feed sources.

Table 4. Available micro nutrients status of vermicompost and conversional compost at Sinana

Treatments	Micro nutrients			
	Fe	Mn	Cu	Zn
	mg/kg			
Sinana Worms	0.72	1.48	1.65	2.25
Eisenia Fetida	0.72	1.48	1.89	3.18
Dinsho Worms	0.80	1.16	1.64	0.08
Conventional Compost	0.71	1.20	1.40	0.04

Summary and Conclusion

The quantity and characteristics of most chemical properties such CEC, NT, Av. P, K, Zn and the like depends on the types of earth warms spices (locally collected or the world wide adapted *Eisenia fetid)* and types of compost (vermicompost or conventional compost). High vermicompost quality in terms of nutrient containing such as nitrogen, phosphorus, potassium, exchangeable bases and micro nutrients was produced from the mixture of field pea, faba bean, wheat and barley straw or residue using red earthworms (*Eisenia fetida*) than locally collected worm species and conventional compost. It should be recommended further multiplication of *Eisenia fetid* and demonstration of Vermiculture in Sinana and similar agro - ecology.

Farther study should be recommended on vermicompost equivalence with inorganic fertilizers to use this technology in integrated ways for crop productions.

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Soil Test Based Crop Response Phosphorus Calibration Study for Food Barely Production in Sinana District of Bale Zone, Southeastern Ethiopia

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Abstract

Soil fertility decline as results of different factors and blanket fertilizer application throughout the country without considering soil types and agro-ecological are among the bottleneck to obtain sustainable desired yield. Therefore, this calls for site-specific soil nutrients managements and soil test based crop response fertilizer recommendations. Accordingly, soil test based crop response P calibration study for food barely production was conducted from 2011-2013 at Sinana district. The objective of the experiment was to determine economically optimum N, and to determine Phosphorus critical (Pc) and Phosphorus requirement factor for food barely production at Sinana district. A field trial were conducted in factorial combination of four levels of N (0, 23, 46 and 69 Kg/ha) and Six levels of P (0, 10, 20, 30,40 and 50 Kg /ha) chemical fertilizer laid out in randomized complete block design with three replications on plot size 3 m x 3 m (9 m^2). Food barely (Robera variety) with a seed rate of 125 kg/ha which had been recommended for area was used. Composite soil sample before plating and intensive soil samples after 21 days of sowing were taken from each plot then subjected to air-dried, prepared and analyzed for selected physicochemical properties following standard laboratory procedures. Phosphorus critical level (Pc) determination was done using C'ate-Nelson diagram method. Agronomic data such as plant height; tiller, seed per spike, biomass, grain yield and thousand kernel weight were collected then subjected to two way factorial analysis of variance (ANOVA) using R software while the partial budget analysis was done using CIMMYT (1998).The results revealed that both N and combined NP fertilizer rates significantly different among agronomic data taken for food barely. Accordingly, Optimum nitrogen rate (46 kg N/ha), critical P (Pc) concentrations (20 ppm) and P (Pf) requirement factors (4.60) for food barely production have been determined, at Sinana District. Therefore, uses of 46 N kg/ha fertilizer for food barely production at Sinana District and areas having similar soil conditions and agro-ecology is advisable. Farther verification of the result on farm land could be a pre request before disseminating the technology to the user.

Keywords: Optimum N, Calibration, Critical P Concentration, P requirement factor,

Introduction

Crop production is controlled by numerous complex interacting factors which include soil fertility, pests and diseases, climate, and farmers' resourcefulness (Altieri, 2018). Soil fertility decline is one of the principal factors contributing to low crop production and agricultural productivity in which this lead food insecurity in Ethiopia (Wogene and Agena, 2017). Soil fertility declines due to removal through crop harvest, leaching, soil erosion by water in the form of surface runoff and cereal based monocropping are among several restricting factors responsible for low crop yields and agricultural productivity. Barley is one of the most important cereal crops in the world, ranking fourth in production area next to wheat, maize and rice (USDA, 2017). However; the barley yields were influenced by different factors which is varies in spatial and temporary. Soil fertility status is dynamic and variable from locality to locality do that it is difficult to end up with a blanket recommendation these low yields of food barely due to low fertilizer application. Barely producing areas mainly located in the highlands which is susceptible to severe soil erosion, poor soil fertility, low pH, particularly deficiency of nitrogen and phosphorus which is the main factor that severely reduces the yield of barely (Mesfin and Zemach, 2015). Barley is very sensitive to insufficient nitrogen and very responsive to nitrogen fertilization (Alam *et al*., 2007; Ketema and Mulatu, 2018).The barley yields was low due to due to most of the farmers in the area do not use fertilizer and few others use very much below the recommended rate (Lake and Bezabih, 2018).

Nitrogen (N) and phosphorus (P) are considered as the most deficient nutrients in soils of Ethiopia (Alemu *et al*., 2019). Likewise, application of a large amount of N fertilizer has been a method of increasing yield which is costly and can cause environmental pollution (Fresew *et al*., 2018) Diammonium phosphate (DAP) and urea have been most of the chemical fertilizers used for crop production with initial understanding that nitrogen and phosphorus are the major limiting nutrients of Ethiopian soils in the form of blanket application. Phosphorus calibration is the way establishing a relationship between a given soil test value and the yield response from adding nutrients to the soil as fertilizer (Abdurrahman *et al*., 2021**)**. The calibrations study is specific for each crop type, soil type, soil pH, climate; plant species, and crop variety (Agegneh and Lakew, 2013).

Soil test based site specific nutrient management curtail role to overcome the traditional blacken fertilizer application that not considers soil types, crop response and agro. Currently, in Oromia Agricultural Research Institute across Oromia by different centers under soil fertility improvement research team the calibrations study were conducted particularly for major crops such as maize; teff; wheat; food barely to brought our farming community towards site specific fertilizer recommendation. In the study area the blanket recommendations applications rather than exposing farmers to increased production costs cannot contribute toward improve the depletion soils plant nutrients and crop productions in sustainable manners. This calls for site-specific soil test based Crop Response Phosphorus Calibration Study in Sinana District of Bale Zone, Southeastern Ethiopia.

The reliable results of soil tests be calibrated against crop response from applications of the plant nutrients in question (Wortmann *et al*., 2013). The results of soil test correlates soil nutrients to plant use, and fertilizer recommendations additionally; used as mean of determine the most economical fertilizer rate for a given crop which can make fertilizer recommendations refined according to the requirements of each field in a given farm (Seif, 2013 and Wakene *et al*., 2014). Supported with this idea Kefyalew *et al* (2017) stated that site specific sound full soil test calibration is essential for successful fertilizer program and crop production. Based on this concept, soil test calibration study was conducted on food barely production at Sinana district from 2011 – 2013 with the objectives; to determine optimum N fertilizer, P-critical and P-requirement factor values for food barely production and develop soil test based P-recommendation guidelines for food barely productions in the Sinana districts.

Materials and Method

Descriptions oF the Study Area

The study was conducted in Sinana District which is one of the Bale highlands Oromia Regional State, Southeastern Ethiopia. This District is bordered by Goro District in the east, Dinsho District in west, Agarfa and Gassera in the north and northeast and Goba District. Sinana district is located about 460 km from the capital city of Addis Ababa. Geographically, Sinana District is located at 6^0 40' 0"to 7^0 20' 0" N and 45^0 55'

0" to 46⁰ 25' 0" E. Topographically, the area consists of gently undulating plain with average slope gradient of 7%. It extends from 1700 to 3100 mean above sea level (masl).

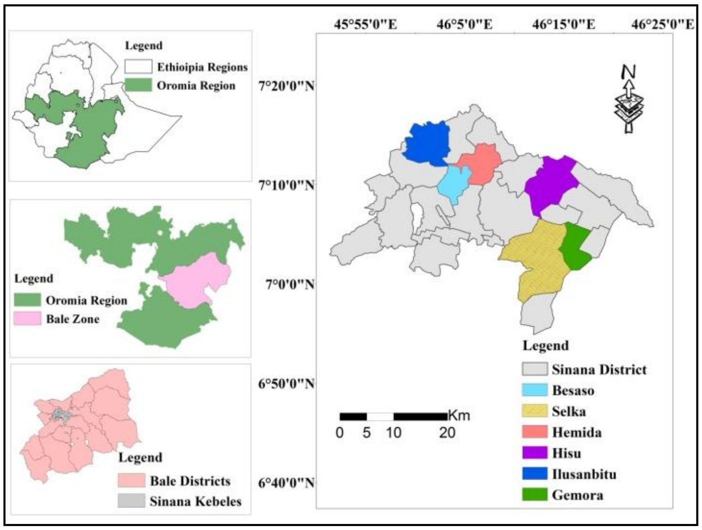

Figure 1.Map the study site

Climate and Agro-ecology

Rainfall climatologically patterns of the area follow a bimodal distribution having SH2 (humid sub humid to cool mild highland) agro ecology. The area is characterized by seasonal mean monthly rainfall varies from 8 to 160 mm, annual rainfall totals of between 452.7 mm and 1129.5 mm and mean temperature maximum ranged from 21.9 to 23.5 °C while minimum varied from 6.8 to 10.1 °C. Agriculture is the main economic practices in the district, from which the major sources of their livelihood income mainly from crop cultivation. Major crops grow in the district include wheat, barley, faba bean, field pea and others.

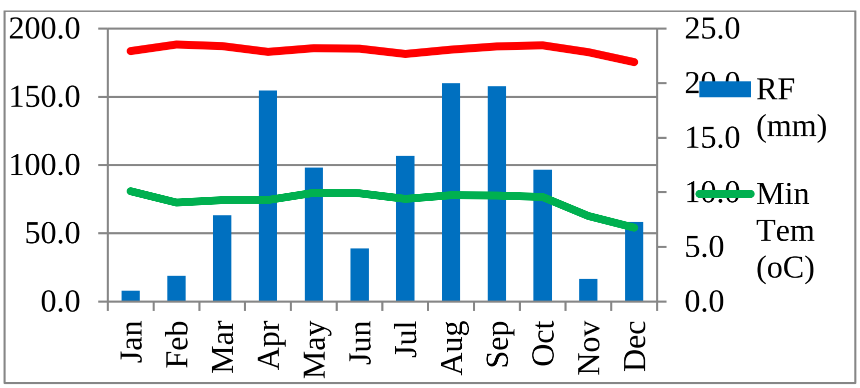

Figure 2. Mean monthly rain fall (mm), Max and Min Temperature (^{O}C) of three years (2018 to 2020) of Sinana District.

Site Selection, Experimental Treatments, Design and Procedures

To obtained representative for experimental sites composite soil samples were collected from 22 farmers' fields in Sinana district, where food barely is a dominant crop. Based on available soil P values determined by the Olsen method, fields were categorized into very low, low, and moderate available soil P contents. Based on this classification, sites with low or below critical available P were selected for the experiment in the district. On-farm field experiments were conducted in Sinana District for the three consecutive year during the main cropping seasons under rain-fed (July to December) from 2011 to 2013 E.C In the first year factorial combination of four levels of N rates (0, 23, 46 and 69 $Kgha^{-1}$) and six rates of P (0, 10, 20, 30, 40 and 50 $Kgha^{-1}$) to determine optimum N rate as indicated was conducted at six locations as indicated Table 1. In the second and third years single six rates of P (0, 10, 20, 30, 40 and 50 Kg/ha) with recommended N rate (46 Kg/ha) were used to determine Pc and Pf.

Treatments laid out in RCBD with three replications, plot size 3 m x 3 m (9 m^2) using food barely (Robera variety) as test crop , N source urea , P source TSP and DAP both in first and second year were used. Land preparation were done both using tractors and oxen while others agronomic managements seed rate (125 kg/ha), hand weeding, herbicide, disease/pest control and row planting in 20 cm according to the recommendations were applied.

Table 1.Discriptions of treatments in the first year

Treatments	**Treatments**	**Treatments**	**Treatments**
N: P (Kg/ha)	**N: P (Kg/ha)**	**N: P (Kg/ha)**	**N: P (Kg/ha)**
T1 = 0 : 0	T7 = 23 : 0	T13 = 46 : 0	T19 = 69 : 0
T2 = 0 : 10	T8 = 23 : 10	T14 = 46 : 10	T20 = 69 : 10
T3 = 0 : 20	T9 = 23 : 20	T15 = 46 : 20	T21 = 69 : 20
T4 = 0 : 30	T10 = 23 : 30	T16 = 46 : 30	T22 = 69 : 30
T5 = 0 : 40	T11 = 23 : 40	T17 = 46 : 40	T23 = 69 : 40
T6 = 0 : 50	T12 = 23 : 50	T18 = 46 : 50	T24 = 69 : 50

Soil Sampling, Preparation and laboratory Analysis

Soil samples of the experimental sites before and after twenty one (21) days after planting at 0-20 cm soil depth were taken from five (5) different auger sampling points then composite soil samples were prepared for each sites and plots. The composite soil samples were labeled with necessary information then air dried, finally crushed using a mortar and pestle to pass through a 2 mm mesh sieve for most soil physicochemical properties except organic carbon and total nitrogen for which the samples further crushed to pass through a 0.5 mm mesh sieve. The analyses were conducted following standard laboratory procedures at Sinana and Melkasa Agricultural Research Center and Haramaya University Soil Laboratory.

Particle size distribution was determined using the Bouyoucos hydrometer method (Bouyoucos, 1962). Finally, the textural class of the soil was assigned using USDA textural triangle classification system (USDA, 1987).The pH of the soil was measured in the supernatant suspension of a 1:2.5 soil to water ratio using a pH meter (Rhoades, 1982). Walkley and Black (1934) used for the determination of organic carbon. Total nitrogen was determined using the Kjeldahl method as described by Bremner and Mulvaney (1982). Available P was determined following the Olsen method (Olsen, 1954) using ascorbic acid as reducing agent.

Total exchangeable bases (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were extracted after leaching the soils with 1N neutral ammonium acetate (NH_4OAc) solution. Exchangeable Ca^{2+} and Mg^{2+} were determined by atomic absorption spectrometry (*AAS*) while K^+ and Na^+ were determined by flame photometer (Okalebo *et al.*, 2002). Cation exchange capacity (CEC) was determined for the soil samples which were first leached with 1 M ammonium acetate (NH_4OAc), washed with ethanol and the adsorbed ammonium was replaced by Na (Chapman, 1965). Then, the CEC was measured titrimetrically by distillation of ammonia that was displaced by Na. Percent base saturation (PBS) was calculated as follows;

$$\textbf{PBS (\%)} = \frac{Ca^{+2} + Mg^{+2} + K^{+} + Na^{+}}{CEC} * 100$$

The available micronutrients (Fe, Mn, Cu and Zn) were extracted by diethylenetriaminepenta acetic acid (DTPA). Finally, their contents were quantified using AAS at their wave lengths as described by (Lindsay and Norvell, 1978).

Agronomic Data Collection

Agronomic data related to yield and yield components such as plant height, numbers of productive tillers, seed per spike, above ground biomass yield; grain yield and thousand kernel weight were taken then finally subjected to standard statistical analysis.

Statistical Analysis

The collected food barely yields and yield component data was subjected to analyses of variance (ANOVA) using R-software computer software 4.0.3. Significant differences among treatments means were separated by least significant differences (LSD) at 5% level of probability and using linear correlation coefficient matrix. Interpretations were made following the procedure described by Gomez (1984).

Partial Budget Analysis

On the other hand, partial budget analysis was performed to investigate the economic feasibility of the treatments. Partial budget, dominance, marginal and rate of marginal return analyses were used. The average yield was adjusted downwards to reflect the difference between the experimental plot yield and the yield farmers will expect from the same treatment. The average grain yield also adjusted by reducing 10% to minimize the over estimation of yield when yield of small plot converted to hectare basis. The average open market price (Birr/kg) of food barely, urea (N) fertilizers were considered for analysis. The minimum acceptable rate of return (MARR) should be 100% (CIMMYT, 1988), which is suggested to be realistic. This enables to make farmer recommendations from marginal analysis.

Determination of Critical P Concentration

The critical P concentration (Pc) value was determined by the Cate-Nelson diagram method (Nelson and Aderson, 1977). Where soil test P put on the X-axis and relative yield on the Y-axis based on values obtained trials conducted at 22 sites of Sinana District. A pair of perpendicular lines drawn on it to produce four quadrants displayed the relative yield. The diagram of the results is divided into four quadrants that maximize the number of points in the positive quadrants and minimize the number of points in the negative quadrants.

The observations in the upper left quadrant overestimate the fertilizer P requirement while the observations in the lower right quadrant underestimate the fertilizer requirement. The optimum is indicated by the point where the vertical line crosses the x-axis and critical P value was determined using relative grain yield against the soil test values at different rates of applied phosphorous fertilizer for a given of nutrient rate. The relationship between grain yield response to nutrient rates and soil test P values, relative grain yields in percent were calculated as follows:

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

Determination of P Requirement Factor

The P requirement factor (Pf) enables one to determine the quantity of P required per hectare to raise the soil test by 1 mg/kg (1 part per million), and to determine the amount of fertilizer required per hectare to bring the level of available P above the critical level (Nelson and Anderson, 1977). Finally, the value of P requirement factor (Pf) was calculated using available P values in samples taken from unfertilized and fertilized plots after 21 days starting from sowing date. The phosphorous requirement factor was expressed as:

$$Pf = \frac{\text{kg P applied}}{\Delta \text{ soil P}}$$

Finally, using Phosphorus requirement factor, Phosphorus critical level and initial P values (soil P value from composite soil sample before fertilization) rate of P fertilizer to be applied was calculated as follows:

$$\text{Rate of P fertilizer to be applied} = (Pc - P\,i) \times Pf$$

Where, Pc = critical P concentration, Pi = initial P values and Pf = P requirement factor.

Result and Discussions

Selected Soils Physicochemical Properties Before Planting

The results of particle size distribution of the soil were summarized and presented in Table 2. Accordingly; the values of soil particles size distributions ranged from 14 - 26%, 16 - 36% and 38 – 66% for percent sand , silt and clay content; respectively. As the rating suggested by Hazelton and Murphy (2007) low to moderate for both soil percent sand and silt content while moderate to very high for percent clay content. According the USDA soil textural class triangle all soils of experimental site were clay textural class (Table 2). The pH (pH_H_2O) values of soil of watershed varied from 6. 07 to 6.50 as indicated (Table 2). As per the pH ratings suggested by Jones (2003) for pH in soil-water ratio were rated slightly acidic media. The values of soil organic matter (OM) were ranged from 1.55 to 2.65 % (Table 2). As per the ratings of Tekalign (1991) OM contents for soils of the experimental sites rated into low to moderate class. The values of total nitrogen (TN) content varied from 0.11 to 0.43% rated as low to moderate as ratings suggested by (Landon, 1991). The values of available phosphorus (Av. P) ranged from 2.02 to 5.04 mg/kg which rated very low to low based on the critical values as determined by the Olsen method established by (Cottenie, 1980). The very low to low categories of these major soils plant nutrients might be due to leaching, continues cereal based monocropping (mostly wheat), low or limited inputs of organic and inorganic sources fertilizers, nutrient fixation and loss as a results of soil erosions.

Table 2. Selected soils physicochemical properties status of experimental sites of Sinana District

Site Name	Soil particle size distributions			Textural Class	$PH-H_2O$	OM	TN	Av. P (mg/Kg)
	Sand	Silt	Clay					
		(%)				(%)		
Sambitu	14	20	66	clay	6.31	1.55	0.15	5.8
Robe Area	18	16	66	clay	6.50	2.05	0.29	2.94
Amida	18	24	58	clay	6.07	2.26	0.36	4.55
Besaso	14	24	62	clay	6.15	1.75	0.27	4.02
Jafera	26	36	38	clay	6.24	2.26	0.43	2.02
Selka Oda	18	32	50	clay	6.12	2.65	0.33	2.34
Gemora	14	32	54	clay	6.25	2.22	0.11	2.56
Hisu	14	20	66	clay	6.18	2.49	0.11	2.45

Where: OM = soil organic matter, TN = Total nitrogen, Av. P = available phosphorus

Cation Exchange Capacity, Exchangeable Bases and Percent Base Saturation

Cation exchange capacity (CEC) values were ranged from 36.4 to 50.2 $cmol_+/kg$ in which as rating suggested by Hazelton (2007) rated into high to very high (Table 3). Exchangeable Bases (Ca, Mg, K and Na) values varied 8.81 to 37.17 $cmol_+/kg$, 0.57 to 1.40 $cmol_+/kg$, 2.13 to 3.49 $cmol_+/kg$ and 0.60 to 70 $cmol_+/kg$ also as the rating stated by FAO (2006) categorized into moderate to very high , low to moderate , low to moderate and moderate for Ca, Mg, K and Na; respectively. The low class of these basic cations might be due to leaching as results of area have relatively high rainfall. The results indicate that exchangeable bases followed in the order of; Ca > Mg > K > Na for soils of the experiential sits (Table 3). The results indicated the values of exchangeable bases were optimal for crop production it does not mean no need managements. The calculated values of percent base saturation (PBS) for soils of the experimental sites varied from 33.28 to 88.82% and as per the rating set by Hazelton and Murphy (2007) low to moderate class with having moderately leached (Table 3).

Table 3. Cation exchange capacity, exchangeable bases and percent base saturation status soils of experimental sites of Sinana District

Site Name	CEC	Ca	Mg	K	Na	PBS %
	(cmol+/kg)					
Sambitu	50.2	24.23	1.40	3.49	0.60	59.22
Robe Area	47.4	14.87	1.23	3.14	0.62	41.90
Amida	36.4	8.81	1.03	2.13	0.64	34.62
Besaso	49.2	11.01	1.11	3.60	0.65	33.28
Jafera	48	37.17	0.57	2.99	0.67	86.25
Selka Oda	47.2	33.62	0.59	2.89	0.69	80.06
Gemora	46.6	28.15	1.27	3.09	0.70	71.27
Hisu	41.8	31.94	1.01	3.34	0.70	88.82

Soil Micronutrients

The results of soils analyzed values for Micronutrients (Fe, Mn, Cu and Zn) varied from 6.53 to 13.37 mg/kg, 1.13 to 8.53 mg/kg, 1.54 to 3.40 mg/kg and 0.14 to 0.98 mg/kg and follows in the order of Fe > Mn > Cu > Zn as presented in Table 4. Based on the ratings of Jones and Benton (2003) rating soils micronutrients (Fe, Mn, Cu and Zn) status of experimental sites categorized as high for Fe, moderate both for Mn and Cu while very low to moderate for Zn (Table 4).

Table 4. Soil micronutrients status of experimental sites of Sinana District

Site Name	Fe	Mn	Cu	Zn
	mg/kg			
Sambitu	7.77	3.90	1.84	0.14
Robe Area	9.12	6.58	2.34	0.33
Amida	12.75	4.69	2.25	0.21
Besaso	13.37	7.08	2.34	0.36
Jafera	6.53	1.24	1.54	0.24
Selka Oda	6.63	1.13	1.92	0.20
Gemora	9.22	5.90	3.40	0.92
Hisu	12.02	8.53	3.26	0.98

Determination of Optimum Nitrogen Fertilizer

Responses of Food Barely to Different Nitrogen Rates in Sinana District

Plant Height

The statistical analysis for plant height shows that significantly ($p \leq 0.05$) difference among means comparison of food barley due to N rates (Table 5). The highest mean plant height (84.12 cm) was obtained from N rate of 46 Kgha^{-1} while the lowest plant height (59.88 cm) was recorded under control plot or zero nitrogen application. Plant height was increased significantly in response to increasing the rate of N fertilizer from nil up to 46 N kg/ha while decline at 69 N kg/ha. Thus, the possible reason might be the optimum rate of nitrogen application may have played an essential role for plant growth and development. Additionally, low or excess dose of nitrogen also causes reduction in vegetative growth of plant. This result supported by the finding of Haftom*et al*. (2009) and Biruk and Demelash (2016) who stated the increments of plant height with increasing nitrogen rate. Likewise, Fazal *et al.* (2012) and Hadi *et al*. (2012) reported that highest plant of barley recorded on high N treatments applied.

Number of Fertile Tillers

The analysis of variance indicated that number of tillers was highly significant ($p \leq 0.05$) influenced by N rates (Table 2). The highest mean number of tiller (3.90) was obtained from N fertilizer rate (46 N kg ha^{-1}) while the minimum number of tillers (1.79) was recorded from control (with zero nitrogen fertilizer). This might be due to nitrogen is an essential nutrient for growth and development of the plant as well improve the plant tillers. Several authors Alam*et al*. (2007); Suleiman *et al.* (2014); Wakene*et al.* (2014); Biruk and Demelash (2016); Franklin *et al* (2017) also reported applying optimum N rate was produced highest number of fertile tillers.

Spike Length

The statistical analysis among the means comparison of spike length were significantly ($p \leq 0.05$) influenced by N fertilizer rates (Table 5). The highest (5.93 cm) and the lowest (3.83 cm) spike length were obtained from 46 kgha^{-1} N rate and control plot; respectively (Table 5). This implies that spike length considered as a yield contributing factor as larger spikes have more grains as compared to shorter spikes which ultimately effect better grain yield. This result supported with the finding of Laghari *et al*. (2010), Aghdam and Samadiyan (2014); Biruk and Demelash (2016) and Ketema and Mulatu (2018) who reported spike length became higher at the optimum doses of nitrogen source fertilizer.

Table 5. Responses of food barely plant height; number of tiller and seed per spike to N fertilizer application at Sinana District

N Rate ($Kgha^{-1}$)	PH (cm)	NT	SL(cm)	SPS
0	59.88^{d}	1.79^{d}	3.83^{c}	22.43^{d}
23	72.33^{c}	2.92^{c}	5.08^{b}	27.19^{c}
46	84.12^{a}	3.90^{a}	5.93^{a}	38.65^{a}
69	78.50^{b}	3.35^{b}	5.29^{b}	34.06^{b}
Mean	**73.71**	**2.99**	**5.03**	**30.58**
LSD (<0.05)	**3.90**	**0.23**	**0.26**	**2.21**
CV (%)	**19.80**	**28.65**	**19.07**	**26.99**

Where, PH: plant height, NT: number of tiller, SL: spike length, SPS: seed per spike, CV: Coefficient of Variation, LSD: least significant difference, Means followed by the same letter in the column and rows are not significantly different at 5% level of significance.

Biomass Yield

As the result indicated that biomass yield was very highly significantly ($p \leq 0.05$) influenced by N rate (Table 6). The maximum of biomass yield (6936.21 kg/ha) was obtained from 46 kg/ha while the minimum of biomass yield was recorded at control treatment which produced 3834.80 kg/ha (Table 6). This might be significant increases in plant height, number of tillers, spike length, number of seed per spike and grain yield from optimum N rate application ultimately contributed to the increased crop biomass yield. This result is consistent with study of several authors Mohammad *et al.* (2011); Wakene *et al*. (2014); Amare and Adane (2015) and Franklin *et al*. (2017) reported the significance increased in total biomass yield as compared to treatment received zero nitrogen rate. This means biomass yield has positive correlation with food barley growth parameters such as total number of plants, tillers per unit area and final plant height. Besides this result also agreed with the finding of Ketema and Mulatu (2018) who obtained the highest biomass yield from plot receiving different rates of while the lowest biomass yield from control plot (zero nitrogen rate).

Grain Yield

The means comparison of food barely grain yield were significantly ($p \leq 0.05$) difference as influenced by N fertilizer rates (Table 6). Accordingly, the highest of grain yield (4267.91 kg/ha) was obtained from 46 kg/ha while lowest of grain yield of food barely was recorded at control treatment which produced 1921.22 kg/ha. Thus indicated that application of optimum nitrogen enhanced the grain yields of all food barley while excess uses might causes for economic loss and possible for lodging of the crop. Improvement in food barley yield with optimum N fertilizer application can be attributed due to the stimulating effects of nutrients on plant growth that provides ideal condition for crop as the supply to plants need. The current result agreement with the achievements of Amare and Adane (2015); Bekalu and Manchore, (2016) and Franklin *et al*. (2017) and Ketema and Mulatu (2018) who obtained significant highly grain yield as a results of optimum N application due to positive effects of N on crop growth conditions. Grain yield is a complex character depending upon a large number of yield components such as number of tiller, spike length, seed per spike and biomass yield that might be the reason for highest grain yield at 46 N kg/ha rate applications. This finding supported by Kefyalew *et al* (2017) and Kefyalew and Tilahun (2018) who obtained optimum nitrogen rate (46 N kg /ha) for teff and bread wheat productions; respectively.

Thousand Kernels Weight

Thousand kernels weight of food barely was significantly ($P \leq 0.05$) influenced by main effect of N fertilizer rate. The highest thousand kernels weight (36.13 g) was obtained from 46 N kg/ha however the lowest thousand kernels weight (24.87 g) was obtained from control plot (Table 6). Thousand kernels weight is an important yield determining component which is mostly genetic character that is influenced least by environmental factors. This result supported with the finding of Asghari *et al*. (2006); Biruk and Demelash (2016); Ketema and Mulatu (2018) who obtained the increasing rate of nitrogen application were increased thousand kernel weights. Thus, suggest that optimum application of N fertilizer may led to an increased in photosynthesis process and accumulations of carbohydrate in kernel to produce heavy kernels and consequently increased thousand kernels weight of food barely.

Table 6. Responses of food barely biomass; grain yield and thousand kernel weight to N fertilizer application at Sinana District

N Rate (Kgha^{-1})	BM (kgha^{-1})	GY (kgha^{-1})	TKW (g)
0	3834.80^{d}	1921.22^{d}	24.87^{d}
23	4954.55^{c}	2636.38^{c}	29.64^{c}
46	6936.21^{a}	4267.91^{a}	36.13^{a}
69	5923.06^{b}	3697.62^{b}	33.03^{b}
Mean	**5412.00**	**3130.80**	**31.23**
LSD (<0.05)	**433.43**	**170.08**	**0.79**
CV (%)	**29.94**	**20.31**	**9.59**

Where, BM: above ground biomass, GY: grain yield, TKW: Thousand kernel weights, CV: Coefficient of Variation, LSD: least significant difference, Means followed by the same letter in the column and rows are not significantly different at 5% level of significance.

Responses of Plant Height, Number of Tillers and Seed Per Spike Component to Combined Applications of Different NP Fertilizer Rates

Plant height was significantly ($P \leq 0.05$) affected by different rates of NP application (Table 7). The maximum plant height (87.47 cm) was recorded from application of 46:50 NP kg/ha and zero application of NP result the minimum (51.21 cm) plant height, which was significantly lower than the effect of other rates. This increment of plant height with increased NP rates might be due to related to the response of optimum nitrogen and phosphorus promotes vegetative growth as other growth factors are in conjunction with it. This result is in line with the report of, Rashid et al (2007); Wakene et al. (2014) and (Mesfin and Zemach, 2015) who stated that plant height of barely was increase with increasing rates of NP up to optimum level. The probable reason might be that optimum NP supply played an essential role in plant growth and development.

Number of fertile tillers was significant ($P \leq 0.05$) influenced to the interaction effects of both nitrogen and phosphorus fertilizer (Table 7). Accordingly; the highest (4.56) and the lowest (0.88) number of fertile tillers were obtained from 46: 40 NP kg/ha and 0: 0 NP kg /ha (control plot); respectively. This might be due to nitrogen stimulate the plant growth and phosphorus improve nitrogen availability. This result supported with the work of Wakene *et al* (2014) and Mesfin and Zemach (2015) who reported the significant increase number of fertile tillers due to interaction effects of N and P fertilizer levels.

The values seeds per spike were significantly (P ≤ 0.05) influenced by the interactions of different NP fertilizer application rates (Table 7). Accordingly; the highest (43.20) and the lowest (18.56) number of fertile tillers were obtained from 46: 40 NP kg/ha and 0: 0 NP kg /ha (control plot); respectively. This might be due to nitrogen and phosphorus responsible for plant growth through the translocation of food materials in plants therefore it play vital role in grain setting as well as in producing higher number of grains. Supporting with this finding Mesfin and Zemach (2015) reported the significant increase number of seeds per spike response to different rates of NP fertilizers.

Table 7. Responses of plant height, number of tillers and seed per spike to combined application of different nitrogen and phosphorus levels for food barely production at Sinana District

Treatments	**P Rates (kg/ha)**					
N Rates (kg/ha)	**0**	**10**	**20**	**30**	**40**	**50**
	Plant height (cm)					
0	51.21^{j}	60.02^{ij}	64.50^{ghi}	59.87^{ij}	62.87^{hi}	60.82^{ij}
23	72.50^{defgh}	71.04^{efgh}	73.39^{defg}	69.11fghi	72.96^{defg}	74.98^{cdef}
46	81.14^{abcd}	83.73^{abc}	83.07^{abc}	84.64^{ab}	84.66^{ab}	87.47^{a}
69	78.10^{abcdef}	80.36^{abcde}	78.14^{abcdef}	77.79^{bcdef}	78.73^{abcdef}	77.90^{abcdef}
CV (%)	**20.00**					
LSD(<0.05)	**9.66**					
N Rates (kg/ha)	**Number of productive tiller**					
0	0.88^{h}	2.63^{fg}	2.90^{cdefg}	2.68^{efg}	2.74^{defg}	2.17^{g}
23	3.71^{abcd}	3.16^{bcdefg}	3.68^{abcd}	3.80^{abc}	3.56^{abc}	3.80^{abc}
46	3.62^{abcde}f	3.79^{abc}	3.60^{abcdef}	3.84^{abc}	4.56^{a}	3.99^{ab}
69	3.67^{abcde}	3.46^{bcdef}	4.07^{ab}	3.82^{abc}	4.08^{ab}	3.77^{abc}
CV (%)	**44.29**					
LSD(<0.05)	**0.99**					
N Rates (kg/ha)	**Seed per spike**					
0	18.56^{l}	22.23^{kl}	22.94^{jkl}	24.81^{hijk}	23.03^{ijkl}	22.98^{jkl}
23	29.53^{efgh}	24.17^{hijk}	27.64^{ghij}	$26.36g^{hijk}$	27.03^{ghijk}	28.41^{fghi}
46	38.09^{abc}	33.83^{cde}	38.72^{abc}	39.54^{ab}	43.20^{a}	38.52^{abc}
69	33.42^{cdef}	34.70^{bcde}	30.87^{defg}	35.48^{bcd}	35.31^{bcd}	34.61^{bcde}
CV (%)	**26.85**					
LSD(<0.05)	**5.38**					

Response of Biomass, Grain Yield and Thousand Kernel Weights to Different Nitrogen and Phosphorus Fertilizer Rates

Biomass yield was significantly ($P \leq 0.05$) affected by different rates of NP application (Table 8). The maximum plant height (8774.98 kg/ha) was recorded from application of 46:40 NP kg/ha and zero application of NP result the minimum (3238.93 kg/ha) biomass yield, which was significantly lower than the effect of other rates. This might be because of the biomass the complex character depending upon a large number of food barely components such as number of tiller, spike length, seed per spike and grain yield that might be the reason for highest biomass yield at 46 N kg/ha rate applications. Similarly; Wakene *et al* (2014); Mesfin and Zemach, (2015) reported the significantly increment of total above ground biomass response to N and P fertilizer interactions. Thus current study indicated that optimum application of nitrogen leads to high photosynthetic activity, vigorous vegetative growth and dark green color and finally improves the utilization of carbohydrates while adequate or optimum of phosphorus increases tiller emergence especially secondary tillers and proper regulation of carbohydrates translocation which it helps in increasing the biomass yield through.

Grain yield values were statistical significantly ($p \leq 0.05$) influenced by the interactions of N and P fertilizers rates application for food barely production. Accordingly; the highest (4877.73 kg/ha) was recorded from application of 46:40 NP kg/ha and zero application of NP (control plot) result the lowest (1700.11 kg/ha) grain yield (Table 8). This might be because of the grain yield the complex character depending upon a large number of food barely components such as number of tiller, spike length and seed per spike that might be the reason for highest gain yield at 46:40 NP kg/ha rate applications. The mean grain yield of food barely response to optimum NP fertilizer application was 65. 15 % as compared to the unfertilized or control plot. Similarly; Dejene *et al* (2014) reported significant difference in grain yield due to interaction phosphorus and nitrogen fertilization rates in which yield increased from control (without fertilizer) up to optimum combination of these fertilizers.

Thousand seed weight was significantly influenced different rates of NP application (Table 8).The highest thousand kernels weight (38.14 g) was recorded at application of 46:40 NP kg/ha while the lowest thousand kernels weight (22.14 g) was observed at control plot which is below the standard thousand kernels weight (35 – 40 g).

Table 8. Responses of biomass, grain yield and thousand kernel weight to combined application of different nitrogen and phosphorus levels for food barely production at Sinana District

Treatments	**P Rates (kg/ha)**					
N Rates (kg/ha)	**0**	**10**	**20**	**30**	**40**	**50**
	Biomass (kg/plot)					
0	3238.93^{l}	3776.99^{kl}	3976.67^{jkl}	3891.79^{jkl}	3949.55^{jkl}	4052.65^{ijkl}
23	4806.20^{ghijk}	4306.91^{hijkl}	5130.55^{fghi}	4737.39^{ghijk}	5302.79^{efgh}	5693.490^{defg}
46	4917.78^{fghij}	6301.33^{de}	7828.99^{ab}	7454.08^{bc}	8774.98^{a}	8070.119^{ab}
69	6447.43^{cd}	5726.27^{defg}	5943.75^{def}	5851.85^{defg}	5591.26^{defg}	5783.33^{defg}
CV (%)	**31.47**					

LSD(<0.05)			**1.97**			
N Rates (kg/ha)			**Grain Yield (kg/ha)**			
0	1700.11^{k0}	1775.94^{k}	1764.51^{k}	2072.19^{jk}	2115.42^{jk}	2099.14^{jk}
23	2251.50^{ij}	2625.63^{hi}	2592.73^{hi}	2748.33^{h}	3290.27^{fg}	5 2865.39^{gh}
46	3709.61^{def}	3881.32^{cd}	4309.23^{bc}	4495.09^{ab}	4877.73^{a}	4334.47^{b}
69	3408.49^{ef}	3516.49^{def}	3728.93^{de}	3744.89^{de}	3745.88^{de}	3679.93^{def}
CV (%)			**21.06**			
LSD(<0.05)			**433.16**			
N Rates (kg/ha)			**Thousand kernel weight (g)**			
0	22.14^{h}	25.03^{g}	29.95^{f}	25.66^{g}	25.39^{g}	25.49^{g}
23	29.91^{f}	29.32^{f}	25.50^{g}	28.94^{f}	29.58^{f}	30.15^{f}
46	34.31^{cd}	35.90^{bc}	35.66^{bc}	37.34^{ab}	38.14^{a}	35.40^{c}
69	32.79^{de}	32.35^{e}	34.19^{cde}	32.92^{de}	33.16^{de}	32.767^{de}
CV (%)			**9.31**			
LSD(<0.05)			**1.89**			

Partial Budget Analysis for Optimum Nitrogen for Food Barely Productions

The results of economic analysis showed that the highest economic net return 44293.43-birr ha^{-1} with acceptable MRR (1857.84%) was obtained from 46 $kgha^{-1}$ nitrogen rate application (Table 9). Thus, application of nitrogen fertilizer for food barley had positive net benefit over the control treatment (zero nitrogen) which implies that improvement in crop nutrient management strategy increase in farmers' income. Therefore, application of 46 N $Kgha^{-1}$ is economically profitable and recommended for farmers in Sinana district and other areas with similar soil types and agro-ecological conditions.

Table 9. Partial budget analysis for optimum nitrogen rate determination for food barely productions at Sinana district

N rates (Kgha^{-1})	UGY (Kgha^{-1})	AGY (Kgha^{-1})	GB (Birr ha^{-1})	TVC (Birr ha^{-1})	NB (Birr ha^{-1})	MRR (%)
0	1921.22	1729.098	20749.176	0.00	20749.18	**0.00**
23	2636.38	2372.742	28472.904	900.00	27572.90	**758.19**
46	4267.91	3841.119	46093.428	1800.00	44293.43	**1857.84**
69	3697.62	3327.858	39934.296	2490.00	37444.30	

Where, UGY = unadjusted grain yield, AGY = adjusted grain yield, GB= Gross benefit; TVC = Total variable cost; NB = Net benefit; MRR = Marginal rate of return.

Critical P Concentration (Pc) for Food Barely

The critical P concentration (Pc) was determined from the scatter diagram drawn using relative grain yields of food barely and the subsequent soil test P values for all P rates (0-50 P kg/ha). The Pc defined by the Cate Nelson method in this study was 20 mg/kg P with mean relative yield response of about 65 % as indicated Figure 3. When the soil test value is below the critical value additional information is needed on the quantity of P required to elevate the soil P to the required level. At values of greater than or equal to 20 mg/ kg , the crop achieved about 65 % of its maximal yield in the absence of P fertilizer application (Fig. 3). This implies that P fertilizer application could be recommended for a buildup of the soil P to this critical value, or maintaining the soil P at this level. Increasing P beyond this level, the cost of additional P fertilizer to produce extra yield would liky be greater than the value of the additional yield.

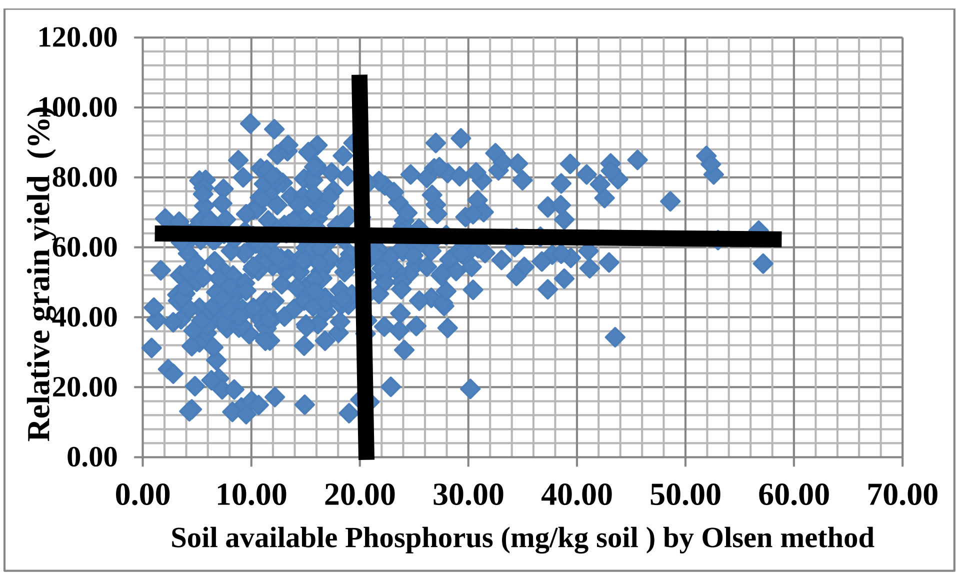

Figure 3: Relationships between soil extractable P measured using Olsen method and relative grain yield of food barely according to this Nelson and Anderson graphical method critical limit determined was 22 P mg /kg**.**

P Requirement Factor (Pf) for Food Barely

Calculated phosphorus requirement factor (Pf), which is the amount of P in kg needed to raise the soil test P by 1ppm food barely production at Sinana District was 4.60 (Table 10). This factor enables one to determine the quantity of P required per hectare to raise the soil test by 1 mg kg 1 (1 part per million) and to determine the amount of fertilizer required per hectare to bring the level of available P above the critical level. It was calculated using available P values in samples collected from unfertilized and fertilized plots.

Table 10. Determination of P requirement factor (Pf) for food barely production at Sinana

P rate (kg ha^{-1})	Range	Average	PI	Pf
0	0.827 - 43.526	12.00		
10	2.066 - 37.328	15.49	3.49	2.87
20	3.444 - 37.741	15.93	3.93	5.09
30	3.306 - 57.163	17.97	5.97	5.03
40	2.810 - 52.617	20.04	8.04	4.98
50	3.361 - 56.749	21.95	9.95	5.03
Average				**4.60**

Conclusion and Recommendations

In order to solve the problem of crop production and soil productivity decline because of recommendations fertilizer application site specific soil test based crop response phosphorus calibration study was conducted for three consecutive years (2019 -2021) in Sinana District. Accordingly, the optimum nitrogen rate (46 N kg/ha) have been determined in Sinana District for food barely production. Therefore, application of 46 N kg/ha fertilizer advisable for food barley productions in Sinana district as well as other areas having the same soil conditions and agro-ecology recommended. Phosphorus critical (pc) concentration (4.60 ppm) and phosphorus requirement factor (pf) with the value (20) were determined for food barely production during this soil test based crop response phosphorus calibration study. Therefore; farther verification of the result on farmer's field could be a prerequisite before disseminating the technology to the end users. Generally, it can be concluded that soil test crop response based fertilizer application particularly a combined application of optimum nitrogen and phosphorus calibration study were significantly improve yield and yield component of food barely production in Sinana District since both are the most yield limiting nutrients in the study area.

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Soil Test Crop Response Based Phosphorus Calibration Study for Bread Wheat in Shashemene District of West Arsi Zone, Oromia, Ethiopia

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Abstract

*Soil test crop response based phosphorous calibration study was conducted in Shashemene district on bread wheat during the main cropping seasons of 2018, 2019 and 2020 with the objectives to determine economically optimum N level, to determine Pc and Pf for bread wheat op, and to establish site-specific soil test based phosphorus fertilizer recommendation. RCBD design was used with 3 replication using 5 rates of N (0, 46, 69 and 92 kg ha^{-1}) and 5 rates of P (0, 10, 20, 30 and 40 Kg ha^{-1}) in a factorial combination. In the second and third years, 5 levels of P (0, 10, 20, 30, and 40 Kg ha^{-1}) and 69kg N ha^{-1} of optimum nitrogen rate obtained were applied uniformly for all plots A total of experimental plot size 3m*3m (9 m^2) and sSeed rate of 150 kg ha^{-1} were used. After 21 days of planting, Composite Surface soil samples from 0-20cm depth were collected from each experimental plot for analysis of available P using Olsen method. The result of the study showed that low to extremely high available P ranged from 7.7-56ppm. The mean maximum grain yield (5358kg/ha) was obtained from the application of 69 kg N/ha and 92 kg P_2O_5 /ha. Whereas the lowest (1873kg /ha) was obtained from control treatment. On the other hand, the combination of 69kg N/ha and 92kg P_2O_5/ha could result the highest net benefit of 114,425 birr per hectare. From phosphorous calibration study, P-critical value (21 ppm) and P-requirement factor (4.43) were determined for phosphorus fertilizer recommendation for bread wheat production in the area. Therefore, verification of the obtained result and further study of e economic benefit across farmers' fields could be given attention in the future.*

Keywords: Calibration, Phosphorous, Soil Test, West Arsi, Bread wheat

Introduction

The population of Ethiopia is currently growing at a faster rate and demands an increased proportion of agricultural products. On the other hand, growth in food production is not in equal footings with population pressure. Strengthening food production capability of the country by wisely exploiting its existing human and natural resources is critical option to avert the existing situation. Ethiopia is one of the sub-Saharan African countries where severe soil nutrient depletion restrains agricultural crop production and economic growth. The annual per-hectare net loss of nutrients is estimated to be at least 40 kg N, 6.6 kg P and 33.2 kg K (Scoones and Toulmin, 2004). Continuous cropping, high proportions of cereals in the cropping system, and the application of suboptimal levels of mineral fertilizers aggravate the decline in soil fertility (Tanner *et al*., 2002). The identification of the proper fertilizer mix is beneficial at the macroeconomic level by improving the efficiency of fertilizer procurement and resource allocation. It is generally understood that crop response to fertilizer inevitably declines, if nutrient applications are continually unbalanced. But, if harvested nutrients are replaced, intensive agricultural systems can be sustained indefinitely, provided that measures are taken to halt soil erosion and to minimize detrimental changes in soil pH.

Fertilizer use in Ethiopia has focused mainly on the use and application of nitrogen and phosphorous fertilizers in the form of NPS and urea for almost all cultivated crops for both market and food security purposes for the last several years. Such unbalanced application of plant nutrients may aggravate the depletion of other important nutrient elements in soils such as K, Mg, Ca, S and micro-nutrients. Though, nitrogen, phosphorus and potassium are the three major nutrient elements required in large quantities for normal growth and development of crops, some nutrient elements such as potassium are not being used as a commercial fertilizer for agricultural crop production under Ethiopian conditions (Abiye *et al*., 2004; Asgelil *et al*., 2007).

Nitrogen and phosphorus are the most yield limiting nutrients in Ethiopia. The use of chemical fertilizer to overcome these nutrient deficiencies is a practice that is receiving a wide acceptance in the country. Some attempts were made in the past to relate soil test data to crop performance and yields but were not successful mainly due to inappropriate design used, inadequate sampling intensity and high level of variability in soil test data (Holetta Genet progress report, 1973/74 and 1975/76). Soil test based fertilizer recommendation plays a vital role in ensuring balanced nutrition to crops. Sound soil test calibration is essential for successful fertilizer program and crop production. It is essential that the results of soil tests could be calibrated or correlated against crop responses from applications of plant nutrients in question as it is the ultimate measure of a fertilization program. An accurate soil test interpretation requires knowledge of the relationship between the amount of a nutrient extracted by a given soil test and the amount of plant nutrients that should be added to achieve optimum yield for each crop. Calibrations are specific for each crop type and they may also differ by soil type, climate, and the crop variety (Alem *et al*., 2008; Fufa and Hassen, 2005). Therefore, fertilizer application schedules should be based on the magnitude of crop response to applied nutrients at different soil fertility levels (Wassie *et al.*, 2011). Like other regions of the country, a fertilizer recommendation for wheat in shashemene district is also not based on soil test results.

The objective of this study was:

To determine economically optimum level; of nitrogen fertilizer for wheat production in the study area

To determine Phosphorous critical level and phosphorous requirement factor for wheat in Shashemene district.

Material and Methods

Site Description

The project was conducted in Shashemene district of West Arsi Zone, Ethiopia. Shashemene district is located at 38° 56´ N, 7° 23´ E, and average altitude of 2002 m.a.s.l. The rainfall pattern of the district is characterized by bimodal distribution with small rainy season *belg* (March-June) and main rainy seasons *Meher* (July-November). The annual total rainfall is 1520 mm mean annual average temperature of 19.7. t The dominant soil unit of Shashemene district is andosol. Texturally, the soils of the area are classified as sandy loam. Wheat, Barley, potato, maize and teff are the major crops produced in this district.

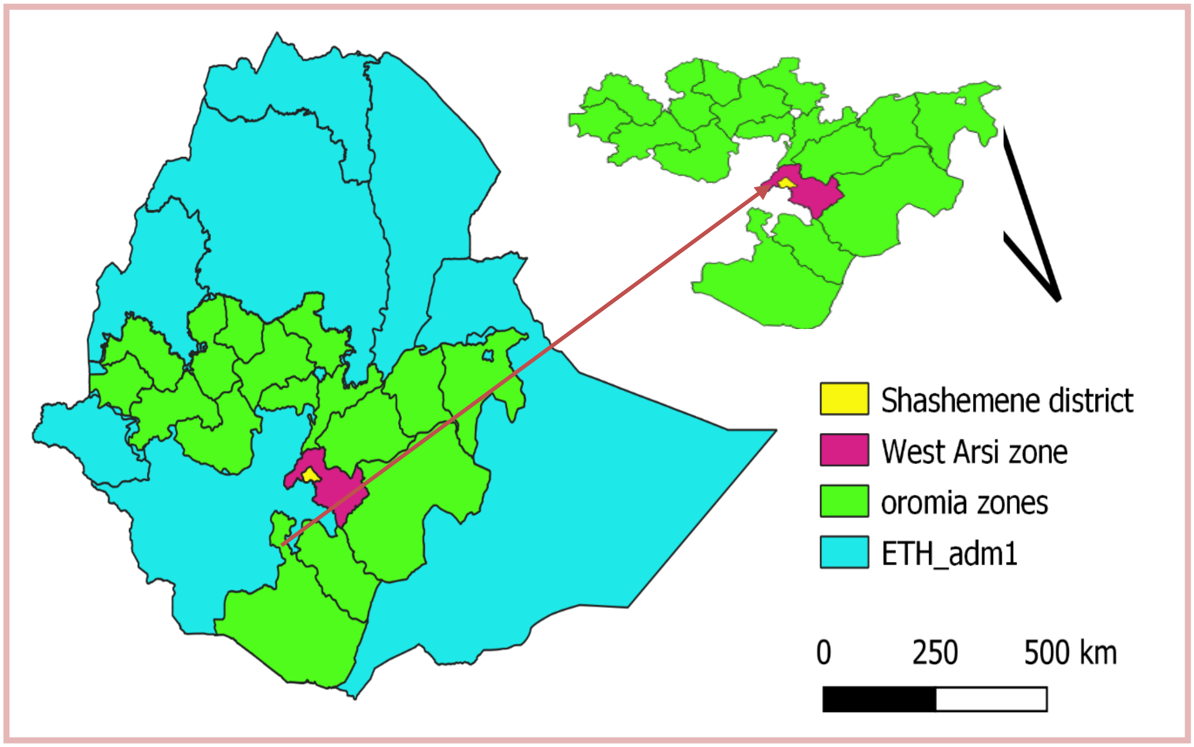

Fig 1 Location of Shashemene district in West Arsi Zone, Oromia

Site Selection

Potentially wheat growing areas in the district was selected with the collaboration of office of agriculture and natural resources of Shashemene district. Composite soil samples were collected from the selected area to analyze total soil pH, Nitrogen and phosphorous. Based on the result of analysis, the sites were classified in to low; medium and high level of available phosphorous.

Treatments and Experimental design

The study was conducted at three purposively selected villages depending on their potential for wheat production. In the first year, the study was conducted on six farmers' field to determine economically optimum level of Nitrogen in the district. Accordingly, four level of N (0, 46, 69 and 92 kg ha^{1-}) and four level of P (0, 20, 30,and 40 kg ha^{-1}) were used in factorial combination having three replications. In the second year, a basal dressing of recommended, economically optimum nitrogen was given to all plots.

The P-calibration experiment was conducted at ten and eleven farmers' field in the second and third years respectively on experimental plot size of 3m*3m for each treatment. Treatments were five levels of P (0, 10, 20, 30 and 40 and kg ha^{-1}) and optimum amount of N-fertilizer applied uniformly for all plots.

The experiment was laid out in randomized complete block design (CBD) with three replications. Representative composite soil samples were collected from each farmer's field before planting to the depth of 0-20cm for physio-chemical analysis. The recently introduced improved wheat variety, Ogolcho was used for the trial. After 21 days of planting, intensive composite soil samples were collected from each plot to analyze the available phosphorous.

Treatment Combinations for determination of optimum Nitrogen

Treatments (N,P) levels				
(0,0)	(0,10)	(0,20)	(0,30)	(0,40)
(46,0)	(46,10)	(46,20)	(46,30)	(46,40)
(69,0)	(69,10)	(69,20)	(69,30)	(69,40)
(92,0)	(92,10)	(92,20)	(92,30)	(92,40)

Treatments for determination of P-critical and P-requirement factor

Treatments	Optimum N (kg/ha)	Level P kg/ha	Source of fertilizer
T1	69	0	UREA
T2	69	10	UREA and TSP
T3	69	20	UREA and TSP
T4	69	30	UREA and TSP
T5	69	40	UREA and TSP

Data Collection

Physiochemical properties, such as pH, available phosphorous, EC, Total nitrogen and soil texture were analyzed. In addition, yield data was collected and recorded.

Soil Sample Collection and Analysis

Composite soil samples for laboratory chemical and physical characterization was collected at 0-20cm depth from each field initially before fertilizer application. Composite samples were also collected three weeks after planting for the determination of available phosphorus and analyzed using Olsen method.

Determination of Critical P Concentration

Critical value for soil Phosphorus was determined from the relationship between relative yields (yield /maximum yield x 100) and P-soil test values. Critical value is the value below which there is P response and above which there is no P –response. Critical P value was determined following the Cate-Nelson graphical method where soil P values (available P after 3 weeks of application extracted using Olsen method) were put on the X-axis and the relative yield values on the Y-axis. The Cate-Nelson graphical method is based on dividing the Y-X scatter diagram into four quadrats and maximizing the number of points in the positive quadrants while minimizing the number of points in the negative quadrats (Nelson and Anderson, 1977). Percentage yield values were obtained for a wide range of locations where results of fertilizer rate studies are available.

Relative yield%= $\frac{Yield}{MaximumYield} * 100$

Determination of P Requirement fFactor

Phosphorus requirement factor is the amount of P in kg needed to raise the soil P by 1ppm. Phosphorus requirement enables to determine the quantity of P required per hectare to raise the soil test by 1ppm, and to determine the amount of fertilizer required per hectare to bring the level of available P above the critical level.

Phosphorus requirement factor= $\frac{kg\ P\ applied}{\Delta\ soil\ P}$

Finally, Rate of P fertilizer to be applied = (Critical P conc.- initial P values) × P requirement factor

Data Management and Analysis

All agronomic and soil data which collected across locations were properly managed using the EXCEL computer software. The collected data was subjected to the analysis of variance using the SAS/STAT computer package version 9.0 (SAS Institute, 2001). Statistical (Minitab-19) was used to develop graphs and correlation analysis

Economic Analysis

Economic analysis was performed to investigate the economic feasibility of the treatments. Partial budget and MRR (%) analyses were used to determine the economic analysis (CIMMT, 1988). The average open market price (Birr kg^{-1}) for different crops and the official prices of N, P and K fertilizers were used for analysis.

Marginal rate of return **(MRR) was calculated** using the formula

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

Total variable cost is a cost incurred due to application of P fertilizer (both but in separate of Soil test based P calibration result and farmers' fertilizer rate) with the assumption that the rest of the costs incurred are the same for all treatments.

Gross income is obtained by multiplying mean grain yield (kg/ha) of each treatment by the price of one kg of the grain. ***Net income*** is calculated by subtracting the total variable cost from the gross income.

Result and Discussion

Soil physiochemical characteristics of the study sites

Composite soil samples were collected from each experimental site to characterize the physiochemical properties. Soil laboratory analysis to determine the physical and chemical properties of the sites before planting and soil pH. Soil organic carbon, electrical conductivity (EC), total nitrogen (TN), initial soil phosphorous (pi) and soil texture were analysed (Table 1).

Soil pH

soil pH is an indicator of soil acidity or alkalinity level. Accordingly, the average pH levels of the study sites were 6.71 which is in the acceptable range for optimum crop production (table1). The level pH usually affects the availability of major crop nutrients. The desirable soil pH range for optimum plant growth varies among crops. Generally, soil pH 6.0-7.5 is recommended for most plants as most nutrients become available in this pH range (US Environmental Protection Agency, 2004).

Table1: Soil physiochemical properties of experimental sites before application

Sites	Soil properties						
	Soil pH	Initial Ava.P in ppm	SOC (%)	Total N (%)	EC mmhoms/cm	C:N	Soil texture
1.	6.50	7.72	3.66	0.14	0.19	26.14	Sandy Loam
2.	5.98	10.00	2.83	0.17	0.57	16.65	Sandy Loam
3.	6.50	7.40	2.66	0.15	0.18	17.73	Sandy Loam
4.	7.20	31.00	2.37	0.14	0.13	16.93	Sandy Loam
5.	6.75	13.18	2.82	0.17	0.23	16.59	Sandy Loam
6.	7.35	18.82	2.96	0.18	0.19	16.44	Sandy Loam
7.	7.12	20.76	2.83	0.15	0.20	18.87	Sandy Loam
8.	6.50	11.20	2.66	0.22	0.21	12.09	Sandy Loam
9.	6.50	15.04	2.83	0.14	0.19	20.21	Sandy Loam
10.	5.98	14.12	2.98	0.17	0.57	17.53	Sandy Loam
11.	6.50	19.96	2.68	0.15	0.18	17.87	Sandy Loam
12.	7.20	12.28	2.37	0.14	0.13	16.93	Sandy Loam
13.	6.75	13.32	2.82	0.17	0.23	16.59	Sandy Loam
14.	7.35	18.88	2.96	0.18	0.19	16.44	Sandy Loam
15.	7.12	20.24	2.83	0.15	0.20	18.87	Sandy Loam
16.	6.50	17.84	3.16	0.22	0.21	14.36	Sandy Loam
17.	6.78	14.22	3.71	0.25	0.23	14.84	Sandy Loam
18.	6.40	10.56	3.66	0.22	0.21	16.64	Sandy Loam
19.	6.90	15.04	2.99	0.18	0.19	16.61	Sandy Loam
20.	6.50	7.72	2.79	0.14	0.19	19.93	Sandy Loam
Mean	**6.71**	**14.96**	**2.92**	**0.17**	**0.23**	**17.41**	

Soil Organic Carbon

Soil organic carbon is a measureable component of soil organic matter. It is an indicator of the potential ofsoil nutrient retention and turnover, soil structure, moisture retention and carbon sequestration. As it is indicated in table 1, the average SOC of the study site was 2.92%. The study by Emanuel *et,al*, 2018 also showed that soil organic carbon on agricultural land varies from 1.34-9.75% depending on its degree of degradation and land management.

Total Nitrogen

Total Nitrogen (Tot N) exists in organic forms and inorganic (or mineral) forms such as plant avail ammonium (NH4 +) and nitrate (NO3 -). It was identified that soil total nitrogen content of the study area was 0.17% which is found to be classified as low (table1). The majority of Tot N is bound in soil organic matter. Soil microorganisms decompose organic matter to liberate energy stored in chemical bonds to fuel their activity and to harvest carbon and nitrogen to build their biomass. Soil biota requires nitrogen for the synthesis of their proteins and other nitrogen containing organic molecules. As dynamic microbial populations grow, if there is insufficient nitrogen in the organic matter they are decomposing they can out-compete crop plants for inorganic nitrogen. This is called immobilization. Conversely, if the organic matter contains sufficient nitrogen to satisfy microbial demands, excess inorganic N is released to crop plants (Harold van, *et.al*, 2020)

Soil available phosphorous: Next to nitrogen, phosphorus is often the limiting nutrient for crop production in tropical soils. In soil phosphorus availability studies, the selection of an appropriate methodology is a key factor. In Ethiopia, the Olsen's NaHCO3 method (Olsen et al., 1954) is often used for determining soil available P. Available P contents of most of tropical soils were categorized as very low for available is $p<5$ mg kg^{-1} , low for available p is between 5–9 mg kg^{-1},Midium for available p between 9-17 mg kg^{-1} and high for available p between 18–25 mg kg^{-1} (Cottenie, 1980, *FAO Soil Bulletin* 38/2, 2012). The average available phosphorous content of the soil in the study area before the application of the treatment were 14.96ppm (Table1). Accordingly, P contents of the soil in the study area were categorized under medium status. Application of phosphorous fertilizer at different rate significantly affect soil available phosphorous ($p<0.05$). Soil available p was increasing with increased level of application. Available P (Olsen extractable) in the studied sites varied between 18.64 and 32.04 mg kg−1 after 21 days of the treatment application (Table2). Therefore, according to Cottenie, 1980, *and FAO Soil Bulletin* 38/2, 2012, available p of the site after application of phosphorous fertilizer was increased and categorized to be very high. This result is also in agreement with the findings of Debele, (2001), Mamo *et al.*, (2004), Negassa and Gebrekidan, (2010) who reported that availability of phosphorous to the crop usually affected by the level of soil phosphorous fertilizer applied, soil organic matter content and level of soil pH. They argued that Soils with inherent pH values between 6 and 7.5 are ideal for P-availability, while pH values below 5.5 and between 7.5 and 8.5 limits P-availability to plants due to fixation by aluminum, iron, or calcium. Soil PH of the study area was 6.71 (Table 1) which is nearly neutral and ideal level for availability of phosphorous to the crop

Table2: Available Phosphorous after 21 days of application

Treatment	Level of P2O5 in kg /ha applied	Average Available P in PPM	Std dev	Minimum	Maximum
1	0	14.07[d]	4.92	5.50	28.42
2	23	18.64[c]	4.32	10.00	30.68
3	46	27.17[b]	5.25	18.33	37.00
4	69	29.77[ab]	6.92	17.00	41.00
5	92	32.04[a]	6.25	19.00	47.00
CV (%)		15.44			
LSD(0.05)		2.86			

Economically Optimum Level of Nitrogen Fertilizer

The maximum grain yield (5358kg/ha) was obtained at the combined application of 69kg/ha N and 92kg/ha P_2O_5 while the lowest grain yield (1873kg/ha) was obtained at the control treatment. Similar study by Shaver (2014) indicated that optimum yield can be gained in the presence of all available essential nutrients at balanced and optimum level where phosphorus and nitrogen are the most deficient essential nutrient in the country. The main effect for nitrogen fertilizer significantly ($p<0.05$) affected the grain yield. It was significantly vary from 2428kg/ha to 4587kg/ha in applying 46kg N and 92kgN respectively (Table 3).

However, there is no significance differences ($p<0.05$) between the combined effects of Nitrogen and phosphorous fertilizers level above 46kg/ha on grain yield response. This implies that application of N and P_2O_5 greater than 46kg/ha may not be economically important. On the other hand, the economic analysis was conducted to determine economically optimum level of nitrogen fertilizer. Accordingly, maximum net benefit of 89,575birr was obtained where 69kg/ha N was applied. For a treatment to be considered as worthwhile to farmers, 100% marginal rate of return (MRR) was the minimum acceptable rate of return Dejene *et al*, 2020. Therefore, 69 N kg ha^{-1} N fertilizers was determined as economically feasible optimum N rates at 1341%, MRR on vitric andosol in Shashemene district for Bread wheat.

Table2: Partial budget analysis using CIMMT, 1988

No.	**(N,P205)**	**Av. GRY/ha**	**TVC/ha**	**GB**	**NB**	**MRR (%)**
1	(0,0)	2575	0	38625	38625	
2	(0,23)	3247	650	48705	48055	1451
3	(0,46)	3545	1300	53175	51875	1019
4	(0,92)	3455	2600	51825	49225	408
5	(46,0)	2925	600	43875	43275	775
6	(46,23)	3655	1250	54825	53575	1196
7	(46,46)	4275	1900	64125	62225	1242
8	(46,92)	4525	3200	67875	64675	814
9	(69,0)	3575	1200????	53625	52425	1150

10	(69,23)	4568	1850	68520	66670	1516
11	(69,46)	6055	2500	90825	88325	1988
12	(69,92)	6225	3800	93375	89575	1341
13	(92,0)	4764	2400????	71460	69060	1268
14	(92,23)	5321	3050	79815	76765	1250
15	(92,46)	5725	3700	85875	82175	1177
16	(92,92)	6255	5000	93825	88825	1004

Table 3: Response of wheat grain yield to NP fertilizers application

Level of N in kg/ha	Level of phosphorous(P_2O_5) in kg/ha			
	0	23	46	92
0	1873^{g}	2154^{fg}	2308^{fg}	2853^{defg}
46	2428^{efg}	3516^{cdef}	4498^{abc}	5358^{a}
69	3886^{bcde}	4093^{abcd}	4600^{abc}	4891^{abc}
92	4587^{abc}	5106^{ab}	5319^{a}	4626^{abc}
LSD (5%)	1466			
CV	12.47			

Determination of Phosphorus Critical Value

For the determination of critical values of P, the Cate-Nelson diagram method (Nelson and Anderson, 1977) was used, where soil P values were put on the X-axis and relative yield values on the Y-axis, and scatter points were divided into two populations. Then, by moving the two perpendicular lines vertically and horizontally, until the number of points showing through the overlay in the two positive quadrants is at a maximum (or conversely, the number of points in the negative quadrants is at a minimum). Finally, the point where the vertical line crosses the X-axis was defined as critical soil test P levels.

The critical P concentration (Pc) was determined from the scatter diagram drawn using relative grain yields of bread wheat and the subsequent soil test P values. According to the Nelson, P critical level will be determined for the top 20 cm of soil using Olsen method. The P critical defined by the Cate Nelson method in this study area was about 21 mg P kg^{-1}, with mean relative yield response of about 75% (Fig. 2). The relative crop yield showed a decreasing trend even though the soil test P value is above the critical. If available P is increasing beyond this level, the cost of additional P fertilizer to produce extra yield would likely be greater than the value of the additional yield (Kefyalew . *et al*., 2017). These results are in accordance with the results of several studies, which showed the positive response of wheat grain yield and other cereals to phosphorous fertilization in Ethiopian highland areas (Admassu, 2017; Agegnehu *et al*., 2015). Additionally, Admassu (2017) also stated the importance of soil test based P fertilizer application for improving yield and yield components of tef and wheat in Ethiopia.

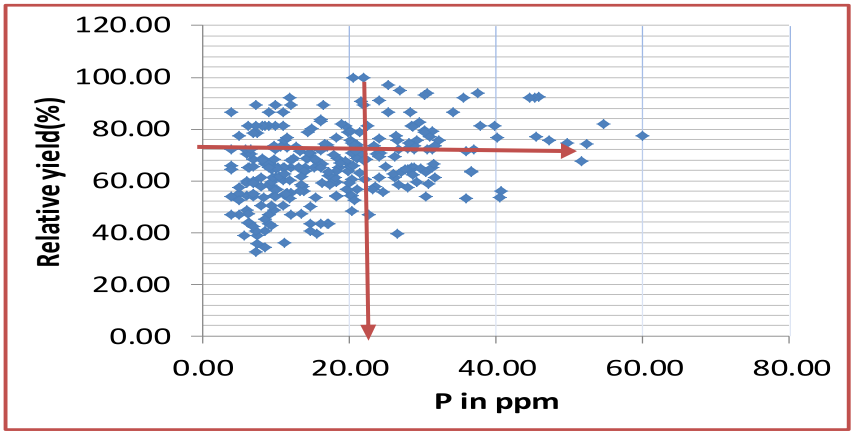

Figure 2: Phosphorus Critical Value as determined by Olsen method

Phosphorous requirement factor

Calculated phosphorus requirement factor (Pf), the amount of P required to raise the soil test P level by 1mg kg^{-1} for bread wheat production on Eutric andosol in Shashemene district was 4.43 (Table 4). s. Thus the rate of P fertilizer required per hectare can be calculated using the soil critical P concentration, initial soil P determined for each site before planting and the P requirement factor (pf).

Table 4: Phosphorous requirement factor for wheat in Shashemene district

No	applied P (kg /ha)	P Olsen ppm (ave.)	ΔP over the control	Pf
1	0	18.20	-	-
2	10	21.10	2.9	3.44
3	20	23.15	4.95	4.04
4	30	24.25	6.02	4.98
5	40	26.95	8.75	4.57
Average				4.43

Conclusion and Recommendations

Chemical fertilizers are one of the most important inputs for maintaining agricultural production and productivity of the country. Adequate and balanced levels of phosphorus (P) and other nutrient are important to get maximum and sustainable production. Therefore, sound soil test calibration is essential for successful fertilizer program and crop production. Phosphorus calibration study has been conducted on bread wheat for two years (2019-2020 growing season) at Shashemene district. ccordingly, economically optimum nitrogen rate (69 kg N/ha), critical P (Pc) concentrations (21 ppm) and P (Pf) requirement factors (4.43) for bread wheat was determined for the study area. Farther verification of the result on farmers' field could be a prerequisite before disseminating the technology to the user.

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Evaluation of Gypsum and Leaching Application on Salinity Reclamation and Crop Yield at Dugada District,East Shoa Zone Of Oromia

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Abstract

The study was conducted in Dugda district of East Shoa Zone of Oromia, Ethiopia from 2018 to 2020 with the aim to evaluate the effect of leaching and gypsum treatments on the removal of exchangeable sodium and soluble salts and the effects of these treatments on crop yield. Onion variety (Bombe red), the most commonly produced crop by farmers, was used as the test crop. Three levels of gypsum (50 %, 75 % and 100% GR) and leaching were combined and arranged in RCBD design with three replications having an area of 3mx4m plot each. It was identified that application of 100 % GR (gypsum requirement (and leaching produced economically optimum yield (326 ku/ha). The effect of Gypsum (100 % GR) combined with leaching enhanced reclamation process and caused more decreases in EC, pH, SAR, ESP (exchangeable sodium percentage) and Na^+ concentration were highly significant ($p<0.05$). The level of EC, pH, SAR and ESP showed a decreasing trend as the level of Gypsum requirement increases from 50 % to 100 % combined with leaching. Moreover, the effect of leaching alone did not significantly affect ($p<0.05$) the levels of Na^+ compare to application of l00 % GR both alone and supported by leaching. In general, the present results showed that combined application of gypsum and leaching were relatively superior to either one alone in reducing the soil sodicity and increasing the yield. Hence application of combined gypsum and leaching is recommended to improve onion yield on sodic soils. Therefore, considering its economic benefit and its effect on soil sodicity reclamation potential, the results of the study showed that 100 % GR combined with leaching is preferred as a strategy in reclamation of salt affected soil.

Keywords: Soil sodicity, Application, Gypsum, leaching, Reclamation, Irrigation, yield

Introduction

Salinity is a major abiotic stress responsible for reduced crop production in many parts of the world. In Ethiopia, salinity, sodicity and water-logging are the most serious problems affecting the irrigated agriculture and limit crop productivity in arid and semi-arid regions (Gizaw, 2008). In East Shewa Zone of Oromia Region, most ground water sources are of poor quality for irrigation purpose that contains soluble salts in amounts that are harmful to plants or have adverse effects to convert soils into saline or sodic which require improvements in existing soil management systems and irrigation practices (Abay *et al.*,2016).

Studies in different areas of semi-arid regions of the world have compared the effectiveness of various amendments in improving physico-chemical properties of saline-sodic soils (Hanay *et al*., 2004). The relative effectiveness of gypsum has received most attention because it is widely used as a reclamation amendment. It is, however, blamed for its slow reaction but being still much popular due to its low cost and availability (Heluf, 1995). One way to alleviate salinity hazards in crop production is to remove the salts from the root zone by leaching. Salt leaching requires adequate irrigation management, which is based on adding sufficient amounts of water beyond the water requirement for meeting evapotranspiration demands, in order to leach the excess salt from the root zone (Russo *et al*., 2009). It follows that the higher the salt concentration in the irrigation water, the greater the amount of water that must be passed through the soil to keep the salt concentration in the root zone at or below a critical level. This approach to overcoming salinity has been intensively studied for many years. One of the earliest reports on this issue can be found in a handbook published by the U.S. Salinity Laboratory Staff (Salinity Laboratory Staff, 1954), which was further discussed by (Rhoades, 1974). Since these publications, many other studies and reviews have been published on this subject (Ayers and Wescot, 1985; Russo et al., 2009).

Research information with regard to the role of combining gypsum and leaching treatments in improving saline-sodic properties and their residual effect on crop production is inadequate particularly in East Shewa Zone of Oromia Region. The present study was conducted to evaluate the effect of leaching and gypsum treatments on the removal of exchangeable sodium and soluble salts and the effects of these treatments on crop yield.

Material and Methods

Description of the Study Area

The study was conducted in Dugda District of East Shewa Zone of Oromia where small scale irrigation is the main economic activity for many farmers. The district is generally characterized by dry low land agro-climate with the altitude ranging from 1576-1750 m.a.s.l. The rainfall pattern is erratic, insignificant mean monthly precipitation and higher potential evapo-transpiration as compared with precipitation. Mean daily temperature is 25^{o}C during the rainy season. Sandy loam is the dominant soil texture identified during the soil salinity assessment and characterization (Kasahun *et al*., 2016). As far as vegetation is concerned, mid rift valley in general and Dugda district in particular is characterized by scattered acacia wood lands.

Farmers Selection and Treatments

Two farmers who are using ground water for irrigation were purposively selected depending on their interest for evaluation of different soil salinity management interventions. The treatments considered for the experiment had two factors, gypsum and leaching. Three levels of Gypsum requirement (50 %, 75 % and 100 %) were applied. From previous study by (kasahun and Abay, 2020) 100 % gypsum requirement for study area is 4 t ha^{-1}.

The implemented treatments were assessed with a randomized complete block design (RCBD) with three replicates. The experimental treatments were:

T1- control (no treatment)

T2 - gypsum (50 % GR) + leaching

T3- Gypsum (75 % GR) + leaching

T4- Gypsum (100 % GR) + leaching

T5- Gypsum (100 % GR) alone

T6- leaching alone

Onion variety (bombe red), which is one of the major vegetable crops produced by the farmers in the area, is used as the test crop. The treatments were replicated three times having $12m^2$ (3 m*4 m) area for each plot. Site management (weeding, pesticide application, monitoring and watering) was done uniformly for all plots and experimental sites.

Estimating applied water for a desired leaching requirement to determine how much water to apply to meet crop ET demands and the leaching requirement, the following equation were used:

$$AW=\frac{ETc}{[1-\left(\frac{LR}{100}\right)]} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

Where AW is applied water depth in inches, ETc is crop evapotranspiration in inches, and LR is the leaching requirement (%).

Determining the leaching requirement for a crop (LR) is defined as the amount of water that is needed to maintain crop productivity. It depends on the salinity of water, soil salinity, salt crop tolerance and other factors. To determine the LR the following steps were followed.

Step1. Determine the soil salinity (ECe) threshold that causes the loss for crop type (Ayers and westcot, 1985).

Step2. Determine the average salinity of the water (ECw) used to irrigate the crop. Most water suitability tests report salinity concentration either in units of electrical conductivity (dS/m)

Step3.The final step is to use the equation below to estimate the leaching requirement

$$L\ R = \frac{(ECw*100)}{5ECe-ECw} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (2)$$

Where ECw is the salinity of the irrigation water and ECe is the soil salinity threshold in the root zone above which crop yield is reduced.

Once the depth of application (AW) and leaching requirement is known, the next step is for how long it will be irrigated. To calculate time required to irrigate a predetermined amount of water the following formula can be used through the using the 3-inch parshall flume.

$$\text{Time require (t)} = \frac{10*a*d}{q*60} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (3)$$

Where q is flow rate as measured l/sec, a is area of the plot to be irrigated in sq.m and d is the depth of the water to be irrigated in cm.

Soil Sampling and Data Collection

Soil samples were collected from each plot before application and after harvesting to the depth of 20cm and were sent to soil laboratory for soil physiochemical analysis. The extent of salinity before and after intervention were identified based on four main parameters such as EC (electrical conductivity), pH, ESP (exchangeable sodium percentage), SAR (sodium adsorption ratio) because these values are used in the guidelines for classification of salt affected soil by different authors and organizations (FAO, 1988; Qadir & Schubert, 2002; Gonzalez *et al*., 2004). In addition, Exchangeable cations such as CEC, Calcium, Magnesium, Sodium, and Potassium were analyzed. Crop yield was also taken and recorded to evaluate the effect of the treatments on total onion yield.

Results and Discussion

Soil Sample Collection and Laboratory Analysis

The initial obtained data showed that, physical and chemical properties of the studied soil of the experimental area are sodic and the dominant textural class is sandy loam.

Table 1: soil physical and chemical characteristics of experimental site before treatments application

Soil characteristics	value
Sand %	54
Silt %	6
Clay %	40
Texture	sandy loam
PH	8.61
Ec (dsm^{-2})	3.54
Exchangeable Na^{+} Cmol (+) kg^{-1} soil	19.45
Exchangeable Ca^{++} Cmol (+) kg^{-1} soil	12.33
Exchangeable Mg^{++} Cmol (+) kg^{-1} soil	5.62
SAR (mmol l^{-1})	15.82
ESP (%)	45

The Effect of Leaching and Gypsum Treatments upon the yield of Onion

Biological yield as affected by leaching and gypsum amendments at harvesting are given in Table (2). The yield in ku/ha was increased steadily from 305 to 326 as gypsum application rates increased from 50 % to 100 % GR with leaching. Treatments with leaching plus gypsum were far superior to control and as well as gypsum and leaching alone. Significantly a higher value of yield was recorded when leaching and gypsum 100 % GR rate applied together than their application alone. The statically significant yield of onion is due to the replacement of exchangeable Na^{+} by Ca^{++} and leaching of the released Na^{+} below the root zone. This result was supported by (Mohammod *et al.*,2010*)* who noted that gypsum was effective in lowering the chemical parameters that might be due to substitution of exchangeable Na^{+} by Ca^{++} that produced more soluble salts and was leached by the irrigation water.

The yield of onion is lower in leaching alone when compare with that of gypsum treated one. This finding is in line with work of (Heluf, 1995) who suggested that the decrease in yield as a result of leaching the soil without treatments might be due to the aggravated effect of exchangeable Na^+ on soil properties with decreasing electrolyte concentration of soils. On the other hand, the relative increment in the yield with increasing percentage of GR rates might be due to the reduction of the toxic concentration of Na^+ at the soil exchange site. This result was also supported by (Alawi *et al.*, 1980) and (Kwaer *et al.*, 2006) who suggested that applied chemical treatments on saline sodic soils and then leached with water can significantly wash down the toxic concentration of Na^+.

Table 2: The Effect of Leaching and Gypsum Treatments upon the Yield of Onion

Treatments	yield in ku/ha
Control	249.13c
50 % GR and leaching	305.09b
75 % GR and leaching	307..7b
100 % GR and leaching	326.34a
100 % GR alone	310.15b
Leaching alone	298.72b
Mean	293.16
CV%	10.66
LSD(p,0.05)	16.85

Means with the same letters are not significantly different

The Effect of Leaching and Gypsum Treatments upon Soil Chemical Properties

Table 3: Chemical characteristics of studied soil as affected by gypsum and leaching treatments after onion harvesting

Treatments	pH	Ec (mmhos /cm)	Exchangeable cations (cmol (+) /kg^{-1}			SAR	ESP
			Ca^{++}	Mg^{++}	Na^+		
T1=control	8.62a	3.64a	12.13b	9a	18.76a	17.1a	43a
T2=50 % GR and leaching	8.55a	2.69a	13.51b	10.18a	17.5a	13.6bc	22.5b
T3=75 % GR and leaching	8.50a	2.64a	13.6b	10.15a	17.10a	13.4bc	20.37b
T4=100 % GR and leaching	7.77b	0.75b	20.98a	10.2a	11.37b	10.9b	13c

T5=100 % GR alone	8.37ab	0.95b	19.65a	11.18a	13.13b	12.8bc	14.7c
T6=Leaching alone	8.56a	2.83a	13.03b	9.03a	17.43a	14.5c	22b
Mean	8.43	2.83	14.66	9.16	16.22	13.91	25.13
CV%	4.7	17	5.7	16.25	16.36	3.12	5.63
LSD(p,0.05)	1.4	1.95	2.06	NS	1.66	3.07	5.37

Means with the same letters are not significantly different

Effect on Soil pH

The soil-pH at end of the experiment is shown in Table 3. The result showed that application of gypsum at rate 100 % GR combining with leaching significantly affected soil pH. The minimum decrease in soil pH was recorded in the control soil (treated with neither of the treatments) while the greater decrease in soil pH over the control was recorded in the soil treated by combined application of 100 % GR along with leaching. The initial soil-pH (having 8.61) was reduced to 7.77. Though, statistically they were not deferrer among other treatments they have showed a decline trend when compare to the control one. Efficiency of the treatments was T4 > T5 > T3 > T2 > T6 > T1. The decrease in soil pH due to gypsum application was probably due to combination of more than one factor, mainly the replacement of sodium by calcium and the formation of neutral salts with $SO_4^{=}$. The decrease in soil pH may have been related to a decrease in sodium concentration as a result of application of gypsum followed by leaching.

Effect on Electrical Conductivity (Ec in ds/m)

The changes in the EC of the untreated and treated sodic soil are shown in (Table 3). The minimum decrease in soil ECe was recorded in the control soil (treated with neither of the treatments) while the greater decrease in soil ECe over the control was recorded in the soil treated by combined application of 100 % GR and leaching. The result showed that application of gypsum at rate 100 % GR combining with leaching and alone significantly affected soil Ec. Ec showed a decreasing trend from 2.69 mmhos/ cm to 0.75 mmhos/cm as the levels of gypsum requirement was increasing from 50% to 100% combining with leaching (Table 3). The effect of leaching alone did not significantly affect ($p<0.05$) the levels of Ec compare to l00% GR alone. Treatment with gypsum followed by leaching is far more effective in reducing Ec than is without gypsum. This result was supported by (Muhammed *et al.*, 2010) who conclude that the decrease might be the result of gypsum addition. The reduction of EC may probably be due to leaching of soluble salts into the deeper layers of the profile. Gypsum provides calcium ions for the replacement of exchangeable sodium and for the formation of a more desirable calcium-sodium ratio in the soil, and reduces the dispersion and puddling which is usually associated with alkali soils.

Effect of Treatments on Soil Basic Cations (Na^+, Ca^{++} and Mg^{++})

Sodium concentration was relatively very high (18.76 cmol (+) kg^{-1}) and highly significantly different ($p<0.05$) for the control treatment as compared with both 100 % GR combined with leaching (11.37 cmol (+) kg^{-1}) and 100 % GR (13.13 cmol (+) kg^{-1}) alone treatments. It was very low (11.37 cmol (+) kg^{-1}) at treatment received 100% GR combined with leaching (Table 3). The effect of leaching alone did not significantly affect ($p<0.05$) the levels of Na^+ compare to application of l00 % GR both alone and supported by leaching. These results led to the conclusion that gypsum is a good source of Ca^{++} that replaced Na^+ on the exchange complex, which in turn leached out with water. This result was supported by (Muhammad *et* *al*., 2010) who noted that gypsum was effective in lowering the chemical parameters that might be due to substitution of exchangeable Na by Ca that produced more soluble salts (NaCl, or Na2SO4) and was leached by the irrigation water. Similar studies by different authors also indicated that the increase in Ca^{++} occurred due to direct application of gypsum (Wright *et al*., 2008). This Ca^{++} replaced Na^{+} on exchange sites that was leached down during continuous irrigation so that there was net increase in Ca content and very high decrease in the amount of Na from the soil solution (El-Sanat *et al*., 2017).

Calcium concentration varied negatively with the sodium concentration in the soil (Table 3). It was very low at the control treatment (12.13 cmol (+) kg^{-1}) where no gypsum and leaching were applied. Significantly, higher values (20.98 cmol (+) kg^{-1}) and (19.65 cmol (+) kg^{-1}) were recorded at the treatments received 100 % GR plus leaching and gypsum alone respectively compare to other treatments (Table 3). The effect of gypsum and leaching was not significant for the levels of magnesium concentration. But, magnesium contents in soil were higher as a result of gypsum and leaching application compared with the control.

Effect of Treatments on ESP and Sodium Adsorption Ratio (SAR)

The amount of salts remaining in soil samples after onion harvesting i.e. the corresponding leaching process with gypsum treatments are presented in Table (3). The results revealed that ESP decreased with leaching water and was related to the rate of amendments. Exchangeable sodium percentage was highly significantly different ($p<0.05$) among the treatments. ESP was very high at the control treatment (43 %) where there was no application of Gypsum and leaching treatments. ESP value showed a decreasing trend from 25.5-13 % as the level of Gypsum requirement increases from 50 % to 100 % (Table 3) combined with leaching. Gypsum accompanied by leaching were more effective in reducing ESP when compared with leaching alone Table (3). The SAR takes the same trend as that of the ESP. The SAR value showed decrease which ranged between 13.6 and 10.9. Significantly, greater decrease in SAR (10.9) was recorded at the treatments received 100 % GR plus leaching Table (3). Soil receiving gypsum at higher rate removes the greatest amount of Na^{+} from the soil columns and causes a substantial decrease in EC and SAR (A. Hamza and W. K. Anderson, 2003). Noticeable effect of leaching on the SAR was higher with gypsum treatments and lower with leaching alone. This might be due to gypsum application, which is good source of Ca^{+2} that replaced Na^{+} and Na^{+} leached down below crop root by leaching water. The result also supported by (Izhar *et al*., 2007) who concluded that the reduction in SAR may be the result of increased Ca^{++} + Mg^{++} that help displace Na^{+} from the soil exchange site.

Economic Analysis

Table4. Effect of gypsum and leaching on the economic benefit of onion production

Treatments	**Mean yield in ku/ha**	**Input cost /ha (Birr)**	**Labor costs /ha (Birr)**	**Total cost/ha (Birr)**	**Market price of Onion/ku (Birr)**	**Total revenue /ha In Birr**	**Net income/ ha in Birr**	**benefit /cost ratio**
Control	249.13	85000	83905	168905	2000	498260	329355	2.95
50 % GR and Leaching	305.09	88600	88554	177154	2000	610180	433026	3.44

75 % GR and Leaching	307.7	88703	88704	177407	2000	615400	437993	3.47
100 % GR and Leaching	326.34	88860	88862	177722	2000	652680	474958	3.67
100 % GR alone	310.15	88865	88865	177730	2000	620300	442570	3.49
Leaching alone	298.72	85710	85715	171425	2000	597440	426015	3.49

The economic analysis was done to select the most economically important soil salinity amendments that were evaluated using onion production as test crop. The study demonstrated that it is profitable and viable with reference to net income and benefit-cost ratio. As indicated in (Table 4), the highest total cost of gypsum and leaching was 177730 ETH Birr ha^{-1} was recorded for the application of 100 % GR rate. The cheapest cost of production 168905 ETH Birr ha^{-1} was recorded on the control one. The maximum gypsum rate earns the maximum cost of production. However the greater profit from the yield was from 100 % GR rate. The total revenue obtained was also directly proportional to the onion yield; in that, the maximum 652680 ETH Birr ha^{-1} was found when 100 % GR was applied along with leaching and the minimum 498260 ETH Birr ha^{-1} was on the control experiment.The net income and benefit cost ratio showed also a positive relation to the onion yield and total revenue; (i.e maximum and minimum net income was 474958 and 329355 ETH Birr ha^{-1} and maximum and minimum benefit cost ratio were 3.67 and 2.95 respectively). The net benefit showed an increasing trend as the level of gypsum application was increasing from 50 % GR to 100 % GR. Similar studies by (Wienhold and Trooien, 2005) and (Abdel-Fattah, 2012) reported that gypsum amendment is the most economical amendment used on sodic soils.

Conclusions and Recommendations

The effects of leaching and gypsum treatments on the reclamation of sodic soil in the mid rift Valley of East shoa zone of Oromia region were followed by soil analysis and by measuring yields of onion. The productivity of this sodic soil can be raised from low productivity to reasonable levels by treatment with large quantities of gypsum along with leaching application. On all gypsum-treated plots onion yield increments were seen. The yield showed an increasing trend as the level of gypsum application was increasing from 50 % GR to 100 % GR.The lower yield of onion obtained from plots untreated and the highest was obtained from plots treated with gypsum and leaching and is attributable to the removal of excess salinity by leaching. Application of gypsum combined with leaching enhanced reclamation process and caused more decreases in EC, pH, SAR, and ESP compared with control. The efficiency of treatments in reducing exchangeable Na and increasing exchangeable Ca increased significantly with increasing applied rate of gypsum from 50 % to 100 % GR along with leaching. In general 100 % GR rate and leaching are recommended to make farmers benefited from the reclamation of sodic soil. The calculated result also confirmed that the largest net farm income and benefit cost ratio was obtained from this treatment combination.

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Determination of NPS Fertilizer Rates Based on Calibrated Phosphorus for Tef in Chora District, Western Oromia

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Abstract

Determination of NPS fertilizer rates based on calibrated phosphorus for tef in Chora district was assessed for two years. Different rates of P critical levels (Pc) (0, 25, 50, 75 and 100 %) calculated from NPS fertilizer and the previously recommended 100% Pc calculated from DAP fertilizer was included as check. Tef variety(dursi) was used as a test crop. The experiment was laid out in RCBD design with three replications. The surface soils of the experimental sites before intervention were characterized by strongly acidic, very low available Phosphorus, low organic carbon content and clay in texture. The analysis of variance among NPS fertilizer rates showed significant differences ($P \leq 0.05$) for almost all the tef characters tested. The shortest (58.1) mean days to 50% heading was obtained from 100% Pc from DAP fertilizer, whereas the longest (65.8) days was recorded for the unfertilized plot. The maximum mean biomass yield (4.6 t ha^{-1}) and grain yield (1.5 t ha^{-1}) were recorded for 100% Pc from NPS fertilizer. Whereas, the lowest mean grain yield (0.4 t ha^{-1}) were recorded for the treatment with no fertilizer. Economic analysis for nutrient management indicated that the highest acceptable MRR of 620% was achieved from use of 75% Pc from NPS. Hence application of 75% Pc from NPS fertilizer is agronomically and economically feasible for tef production and recommended for the end users in Chora district. The result also showed that the soils of the study sites had poor chemical fertility and integrated soil fertility management practices can improve the current situation.

Key Words: Nitrogen, NPS rate, P-critical level, Phosphorus,

Introduction

Soil fertility depletion presents a major challenge to bring about increased and sustainable productivity in order to feed the ever increasing population of the country. The loss of soil fertility from continual nutrient mining by crop removal without adequate replenishment, combined with imbalanced plant nutrition practices, has posed a serious threat to agricultural production (FAO, 2006). The secret of ensuring food security for the ever increasing world population is strongly linked to the productivity of soils (Wakene, 2001). Quinenes *et al.* (1992) also stated that unless something is done to restore soil fertility first, other efforts to increase crop production would end up with little success. Kelsa *et al. (*1992) reported that using chemical fertilizers can increase yield under Ethiopian.

Inorganic fertilizers overcome soil fertility problems and responsible for increasing large part of world's food production (Sanchez and Leakey,1997). When the soil does not supply sufficient nutrients for normal plant development and optimum productivity, application of supplemental nutrients is required. The proper application rates of plant nutrients are determined by knowledge about the nutrient requirement of the crop and the nutrient supplying power of the soil. The nutrient supplying power of a soil depends on dissociation of the nutrients from the exchange site, which is in turn dependent on the degree of saturation of the nutrients on the exchange site, type of clay and complementary ion effect (Foth and Ellis, 1997). The quantity of fertilizer nutrients required for optimum crop production depends on the inherent capacity of soils to supply adequate levels of nutrients to growing plants (Sanchez,1976).

Tef is among the major Ethiopian cereal crops grown on about 3 million hectares annually (CSA, 2015), and serving as staple food grain for over 70 million people. majority of people are preferring grain of tef for consumptions by making Enjera and local beverage. It accounts for about 15% of all calories consumed (Lester and Bekele, 1981). It has good mineral content and considerable amount of Iron content when compared with other cereal crops (Mengesha, 1965). The crop is not only important for grain consumption but also its straw is highly nutritious and more palatable for livestock compared to straw of other cereals crop especially during dry season. Generally, the area devoted to tef cultivation is high because both the grain and straw fetch high domestic market prices. Despite the aforementioned importance and coverage of large area, its productivity is very low (CSA, 2014). Some of the factors contributing to low yield of tef are low soil fertility and suboptimal use of mineral fertilizers in addition to weeds, erratic rainfall distribution (Fufa, 1998).

Soil test crop response based nutrient calibration study is a means of establishing a relationship between a given soil test value and the yield response from adding nutrient to the soil as fertilizer. So that it provides information how much nutrient should be applied at a particular soil test value to optimize crop growth without excessive waste and confirm the validity of current P recommendations (Getachew *et al*., 2013). Optimum return from the investment on input and minimum environmental pollution are the two major issues to be addressed while prescribing soil test based nutrient recommendations (Singh *et al*., 2010).

Realizing the plant nutrients requirement of an area could help to implement demand-driven soil fertility management practices. On the other hand, crop productivity can also be limited because of toxicity and/or deficiency of essential plant nutrients. In view of this, Bedele Soil Research Center, the then, Bedele Agricultural Research Center was conducted soil test crop response based Phosphorus calibration study for tef using DAP fertilizer in Chora District; and recommended Phosphorus critical level and requirement factor **(**Dagne *et al.*, 2015**).** On the other hand, Ethiopia has realized that agricultural soils commonly suffer from multiple nutrient deficiencies, and nutrient balances are generally negative, and an effort has been made since 2015 to introduce different types of fertilizers among which, NPS fertilizer is one of it. However, the rate and response of the newly introduced NPS fertilizer was not adjusted to the previously calibrated phosphorus using DAP fertilizer. Therefore, the objective of this study was to determine NPS fertilizer rate based on calibrated phosphorus for tef in Chora District, Western Oromia.

Materials and Method

Description of the Study Area

A study was conducted in Chora District on ten farmers' fields in 2019 and 2020 main cropping seasons. Chora District is located at 08°13’33.7”to 08°33’55.0”N and 035°59’59.7”to 036°15’15.8”E with altitude ranged from 1000 to 2060 masl (Fig 1). The 18 years weather information at nearby study area (Ethiopian Metrology Agency Bedele District Branch) indicated that a uni-modal rainfall pattern with average annual rain fall of 1945 mm. The rainy season covers April to October and the maximum rainfall is received in the months of June, July and August. The minimum and maximum annual air temperatures are 12.9 and 25.8°C, respectively, The predominant soil type in Southwest and Western Ethiopia in general and the study area in particular, is Nitisols according to the (FAO, 2001) soil classification system. Its vernacular name is "*Biyyee Diimmaa*" meaning red soil. On the average, the soil is deep and relatively highly weathered, well drained, clay in texture and strongly to moderately acidic in reaction. Nitisols are highly weathered soils in the warm and humid areas of the west and southwest Ethiopia (Mesfin, 1998)

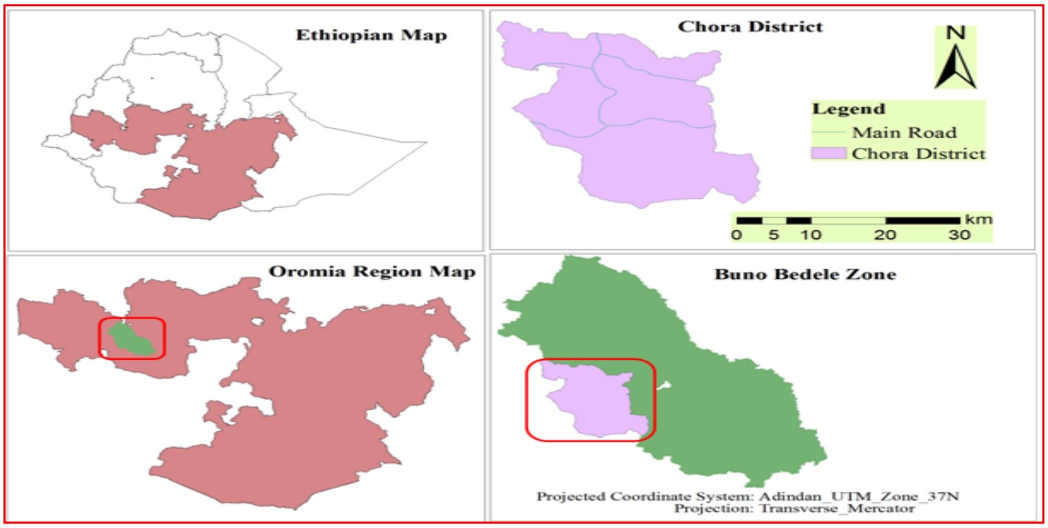

Figure 1. Map of the study area (Chora district)

Soil Sampling and Analysis

Composite surface soil samples (0-20) cm depth were collected from ten experimental sites before planting to analyze soil pH (H_2O), exchangeable acidity, available P, (%OC), CEC and textural class. The collected soil samples were prepared and analyzed following standard laboratory procedures at soil analysis laboratory of, Bedele Agricultural Research Center. Accordingly, the soils were characterized as strongly acidic in reaction ranged from (4.2 to 5.3), low available Phosphorus ranged from (1.0 to 2.8 ppm), low organic carbon ranged from (1.0 to 3.3 %), low to moderate CEC ranged from(13.5 to 18.3)(cmol$^{(+)}$/kg soil) and clay in texture (Table 1).

Table 1: Initial soil data before planting in Chora district

Sites	pH (H_2O)	Exch.A ($cmol^{(+)}$/kg soil)	Av. P (ppm)	OC (%)	CEC ($cmol^{(+)}$/kg soil)	Textural class
1	4.4	1.5	1.2	1.0	16.5	Clay
2	4.7	1.3	1.0	2.1	16.8	Clay
3	4.9	0.6	1.4	1.6	16.0	Clay
4	4.2	1.6	1.2	2.3	13.8	Clay
5	5.3	0.9	2.2	2.6	13.5	Clay
6	4.5	0.7	1.4	2.0	18.3	Clay
7	4.4	1.1	1.9	3.3	16.0	Clay
8	4.6	0.6	1.1	3.3	15.8	Clay
9	4.9	0.5	2.8	2.4	16.7	Clay
10	4.6	1.7	2.8	1.6	14.5	Clay

OC= Organic Carbon, CEC= Cation Exchange Capacity, P= Phosphorus

Treatments, Experimental Design and Procedures

The treatments consisted of five (0, 25, 50, 75 and 100 %) P critical levels (Pc) calculated from NPS fertilizer and one previously recommended P critical level (100% Pc) calculated from DAP was included ,which was used as check, that means the total number of treatment were six. The experiment was laid out in RCBD with three replications. The gross plot size was $12m^2$ (3m x4m). Dursi tef variety was used as a test crop. Phosphorus rate was calculated and applied according to the formula, P (kg ha^{-1}) = (Pc – Po)*Pf, where Pc= Phosphorus critical level, Po = initial soil Phosphorus in the soil and Pf= Phosphorus requirement factor. Recommended N (46 kg N ha^{-1}) determined during Phosphorus calibration study for tef in the district was used. 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., and treated with lime for soil pH less than 5.5, and the amount of lime needed per hectare was calculated based on exchangeable acidity..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 35 days after planting in the form of urea. The field was kept free of weeds by hand weeding during the period of the experiment. All other recommended agronomic management practices disease and insect pest control was done. Finally, days to 50% heading, grain and biomass yields were collected. The collected data was subjected to analysis of variance using SAS software. Mean separation was done by LSD.

Economic Analysis

Costs that vary among treatments were also assessed using the CIMMYT partial budget analysis (CIMMYT, 1988). The cost of NPS, DAP,UREA, the cost of labor required for the application of fertilizer, and cost for trashing were estimated by assessing the current local market prices. The price of NPS (1548.87ETB 100 kg-[1]), DAP (1997.00ETB 100 kg-[1]), UREA (1394.00ETB 100 kg-[1]), daily labors (35 ETB per one person day based on governments' current scale in the study area) and the cost of tef trashing (1 ETB $kg^{-1)}$) were considered to get the total cost that vary among the treatments. Time elapsed during fertilizer application for some plots of each treatment was recorded to calculate daily labor required for one hectare. One person per day was estimated based on eight working hours per day. Tef grain yield was valued at an average field price of 30 ETB $kg^{-1,}$. However, other non-varied costs were not included since all agronomic managements were equally and uniformly applied to each experimental plot. Before calculating gross revenue, tef grain yields obtained from each experimental plot were adjusted down by 10%. Finally, gross revenue was calculated as total yield obtained multiplied by field price that farmers receive for the sale of the crop. The net benefit and the marginal rate of return (MRR) were also calculated as per standard manual (CIMMYT, 1988).

Results and Discussion

Days to Heading

There were significant differences (P≤0.05) among NPS rates and DAP fertilizers for tef days to heading. Days to heading. ranged from (58.1) to (65.8) days (Table 2). The longest (65.8) and shortest (58.1) days to heading were recorded from without fertilizer and 100% Pc from DAP, respectively. This indicated that physiological maturity of tef was significantly hastened by the highest rate of fertilizers.

Grain and Biomass Yields

Treatments also showed significant differences (P ≤ 0.05) in grain and biomass yields performance (Table 2). Grain yield ranged from 400 kg ha^{-1} to 1500kg ha^{-1} with the grand mean of 1100kg ha^{-1}.The highest mean grain and biomass yields (1500 kg ha^{-1}) and (4600 kg ha^{-1}) were recorded from 100% Pc from NPS fertilizer, respectively. On the other hand, minimum value was recorded for un fertilized plot However, statistically similar results of biomass and grain yields were obtained between the two fertilizers (100% Pc from NPS and DAP) fertilizers. Extra use of NP for tef grain yield production was not economical because of its genetic potential and an alarming increase of fertilizer cost from year to year (Habtamu *et al.,* 2000). Moreover, the biomass and height of the crop were very high which made it logging.

Table 2; Mean days to heading, grain yield and Biomass yields of Tef in Chora District

Treatments	Days to Heading (days)	Grain yield ($kgha^{-1}$)	Biomass yield ($kgha^{-1}$)
Without fertilizer	65.8^{a}	400^{e}	1300^{c}
25% Pc from NPS +Rec N	61.6^{b}	800^{d}	2700^{b}
50% Pc from NPS +Rec N	60.1^{cd}	1000^{c}	2800^{b}
75% Pc from NPS +Rec N	59.2^{cd}	1300^{b}	3200^{b}
100% Pc from NPS+Rec N	58.9^{cd}	1500^{a}	4600^{a}
100% Pc from DAP+Rec N	58.1^{d}	1400^{ab}	4200^{a}
Mean	60.6	1100	3200
CV (%)	3.6	31.5	47
LSD	1.6	100	700

Mean followed by the same letters in the column are not significantly different at P≤ 5%, CV = Coefficient of Variation, LSD = Least Significant Difference, Pc= Phosphorus critical level, Rec N =Recommended Nitrogen

Partial Budget and Marginal Analysis for Treatments

The economic analysis indicated that the highest acceptable marginal rate of return (MRR) were achieved from the use of 75% Pc from NPS fertilizer(Table 3). This indicated that NPS fertilizer reduced recommended Phosphorus during P calibration using DAP fertilizer by 25%.

Table 3: Partial budget and marginal analysis for treatment applied for Tef

Treatments	Av.GY (tha^{-1})	Adj.GY (tha^{-1})	TVC Birr	Gross benefit Birr	Net benefit Birr	D.A	MRR
Without fertilizer	400	300	2145.00	9000.00	6855.00		-
25% Pc from NPS+Rec N	800	7 00	5760.00	21000.00	15240.00		230
50% Pc from NPS+Rec N	1000	900	6794.00	27000.00	20206.00		480
75% Pc from NPS+Rec N	1300	1200	8043.00	36000.00	27957.00		620
100%Pc from NPS+Rec N	1500	1400	8892.20	42000.00	33107.80		600
100%Pc from DAP+ Rec N	1400	1300	9076.90	39000.00	29923.10	D	-

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, Pc= Phos0horus critical level, NPS= Nitrogen, Phosphorus and Sulfur, Rec N = Recommended Nitrogen fertilizer

Conclusion and Recommendation

The surface soils of the study areas were low in chemical property and clay in texture. Tef agronomic characters tested were significantly affected by NPS fertilizer rate. The highest marginal rate of return was obtained from the use of 75%Pc from NPS fertilizer, this indicated that NPS fertilizer reduced recommended Phosphorus during P calibration using DAP fertilizer by 25%. Accordingly NPS fertilizer increased tef productivity in the study area. In conclusion, based on the data obtained from this study 75% Pc from NPS fertilizer is economically feasible for tef production and hence recommended for the end users in Chora district. Therefore, demonstration and training should be conducted in the farming community to popularize the technology.

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Verification of Soil Test Crop Response Based Phosphorous Recommendation for Maize in Dega District, Western Oromia

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Abstract

On-farm verification trial of soil test crop response based calibrated phosphorous for maize was conducted in Dega District, Western Oromia in 2020 main cropping season. The aim of the study was to verify the recommended nitrogen (92 kg N ha^{-1}), determined P-critical level (8.5 ppm) and P- requirement factor (6.64) of Phosphorus recommended for maize during soil test crop response based phosphorus calibration study. The treatments consisted of control (without fertilizer) (T1), (blanket recommendation) (T2)) and soil test crop response based phosphorus recommendation (STCRBPR) (T3). The treatments were simply arranged side wise and replicated over ten farmers' fields. The surface soils of experimental sites were strongly acidic, very low available Phosphorus, low organic carbon content and clay in texture. The analysis of variance among treatments showed significant differences ($P \leq 0.05$) on maize plant height, grain yield and thousand kernel weight. The maximum mean grain yield (7.5 t ha^{-1}) were recorded for STCRBPR. Whereas the lowest (1.0 t ha^{-1}) was recorded for the treatment without fertilizer. Economic analysis for nutrient management indicated that the highest net benefit of 43657.30 ETB ha^{-1}with MRR of 290% were achieved by the application of STCRBPR. Hence fertilizer application of STCRBPR is agronomically and economically feasible for maze production and recommended for the end users in Dega District. The result also showed that the soils of the study areas were poor in chemical nutrient contents (soil fertility) hence, integrated soil fertility management practices can improve the current situation.

Key words: P- requirement factor, P-critical level, soil test crop response based phosphorus recommendation (STCRBPR)

Introduction

Phosphorus (P) plays a critical role in the life cycle of plants. It is an essential component of deoxy-ribonucleic acid (DNA), the seat of genetic inheritance in plants as well as animals, and RNA needed for protein synthesis (Brady and Weil, 2002). It functions as universal fuel for all biochemical works in living cells. Adenosine tri-phosphate (ATP), a compound of P that contains high energy bonds, releases its energy for work when converted to adenosine di phosphate (ADP) (Foth, 1990). Obviously, P is essential for numerous metabolic processes and functions of the plant. Among those very important functions, photosynthesis, N-fixation, flowering and fruiting, seed formation, root development, strengthening straw in cereal crops and improving the qualities of forages and vegetables are the major ones (Tisdale *et al.*, 1993;Brady and Weil, 2002).

On the other hand, plants deficient in P are stunted, maturity is often delayed compared to plants containing abundant phosphate (Brady and Weil, 2002). Phosphorus deficiency retards growth and decreases shoot/root dry matter ratio in cereals, tillering is also affected. The formation of fruits and seeds is especially depressed in plants suffering from P deficiency. Thus, not only low yields but also poor quality fruits and seeds are obtained from P deficient crops (Mengel and Kirkby, 1996).

The amount of P in the soil solution at any one time is very small and usually about one parts per million (ppm) (Ahn, 1993). Available literature indicates that P is deficient in soils of different areas and it is most of the time becomes unavailable by forming insoluble phosphate compounds of Al, Fe and Ca (Raya, 1988). Most Nitisols and other acid soils are known to have low P contents, not only due to the inherently low available P content, but also due to the high P fixation capacity of the soils (Murphy, 1968; Eylachew, 1987). Several research results (Tekalign and Haque, 1987;) indicated that most of the highland soils of Ethiopia are inherently P deficient and hence it is one of the limiting elements in crop production. The variability in the levels of available P in soils is related to factors such as, soil reaction, amount and forms of P, OM level, type and amount of clay, calcium content and amount of iron and aluminum oxides in the soil (Tekalign and Haque, 1987: Wakene, 2001 and Mohammed *et al.,* 2005)). This necessitates that P fertilizer should be added regularly in sufficient amount considering the fixation potential of the soil and crop requirement for the intended yield level.

Phosphorus calibration is a means of establishing a relationship between a given soil test value and the yield response from adding nutrient to the soil as fertilizer. So that it provides information how much nutrient should be applied at a particular soil test value to optimize crop growth without excessive waste and confirm the validity of current P recommendations (Getachew *et al*., 2013). Optimum return from the investment on input and minimum environmental pollution are the two major issues to be addressed while prescribing soil test based nutrient recommendations (Singh *et al*., 2010). On the other hand, the blanket recommendations that are presently in use all over the country were issued several years ago, which may not be suitable for the current production systems. Since the spatial and temporal fertility variations in soils were not considered, farmers have been applying the same P rate to their fields regardless of soil fertility differences (Gete *et al*., 2010).

Soil test crop response based phosphorus calibration study was conducted and completed for maize. Hence nitrogen fertilizer (92 kg Nha^{-1}), phosphorus critical level (8.5 ppm) and phosphorus requirement factor (6.64) were determined and recommended based on initial P value in the soil. Therefore, the objectives of this experiment were to verify P critical level and requirement factor as well as N for maize; and to compare soil test crop response based recommended phosphorus with farmers' practices fertilizer application and control in Dega district.

Materials and Method

Description of the Study Area

Dega is located at latitude $08^0$10'41.66" to $08^0$42'45.01"N; Longitude $035^0$59'17.77" to $036^0$14'55.67"E and an altitude ranged from 1810 to 2285 meter above sea level; in Buno Bedele Zone of the Oromia regional state, Ethiopia (Fig.1).The 18 years weather information at nearby study area (Ethiopian Metrology Agency Bedele District Branch) indicated that a uni-modal rainfall pattern with average annual rain fall of 1945 mm. The rainy season covers April to October and the maximum rainfall is received in the months of June, July and August. The minimum and maximum annual air temperatures are 12.9 and 25.8°C, respectively, The predominant soil type in southwest and western Ethiopia in general and the study area in particular, is Nitisols according to the (FAO, 2001) soil classification system. Its vernacular name is "*Biyyee Diimmaa*" meaning red soil. On the average, the soil is deep and relatively highly weathered, well drained, clay in texture and strongly to moderately acidic in reaction. Nitisols are highly weathered soils in the warm and humid areas of the west and southwest Ethiopia (Mesfin, 1998)

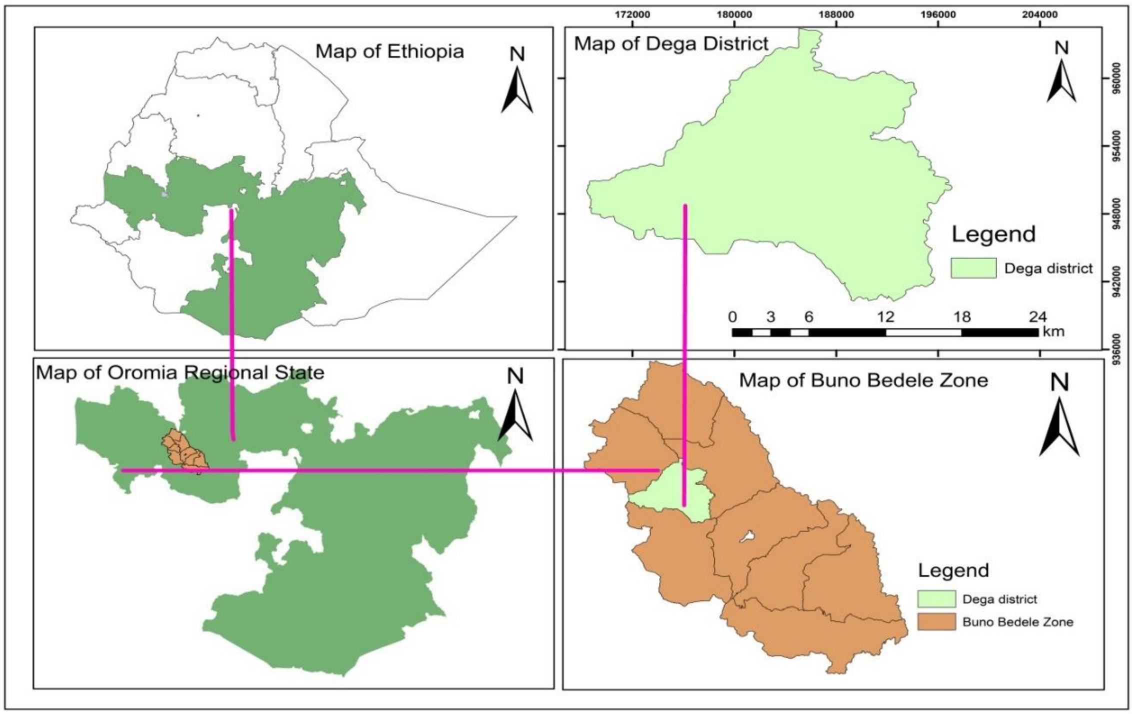

Figure 1. Map of the study area(Dega district)

Soil Sampling and Analysis

Ten farmers' fields were selected purposively based on their willing and initial soil P-value. Composite surface soil samples (0-20) cm depth were collected from each experimental sites before planting to analyze soil pH (H_2O), Exchangeable acidity, available P, (%OC), TN, CEC and textural class. The collected soil samples were prepared and analyzed following standard laboratory procedures at soil analysis laboratory of Bedele Agricultural Research Center. The result indicated that strongly acidic in reaction, low available Phosphorus, low organic carbon, Low TN, low to moderate CEC and clay in texture (Table 1).

Table 1: Initial soil data before planting in Dega Distric

Sites	pH (H2O)	Exch.A (cmol(+)/kg soil)	Av. P (ppm)	OC (%)	TN (%)	CEC (cmol (+)/kg soil)	Textural class
1	5.0	0.3	1.8	2.9	0.3	10.3	Clay
2	4.9	0.2	1.2	2.1	0.2	9.6	Clay
3	4.8	0.3	2.3	1.3	0.2	16.2	Clay
4	4.4	0.9	1.6	1.6	0.3	15.5	Clay
5	4.6	0.4	2.1	2.9	0.2	15.0	Clay
6	4.9	0.3	1.6	2.0	0.3	11.1	Clay
7	4.2	1.5	2.9	2.0	0.2	10.3	Clay
8	4.9	0.2	1.9	2.0	0.3	15.1	Clay
9	5.1	0.2	1.1	2.6	0.2	11.3	Clay
10	4.8	0.2	2.0	2.6	0.2	11.0	Clay

OC= Organic, TN= Total Nitrogen, CEC= Cation Exchange Capacity, P= Phosphorus

Treatments, Experimental Design and Procedures

The treatments consisted of control (without fertilizer)(T1), Blanket Rec (T2) and STCRBPR (T3), that were arranged in simple adjacent plots and replicated over ten sites. The growth plot size was 10 m by 10 m for each plot. maize variety (BH 661) which is high yielder as compared to other improved maize varieties in the study areas was used as a test crop, that was planted in rows with spacing of 80 cm between rows and 25 cm among plants within a row. Phosphorus rate was calculated and applied according to the formula, P (kg ha^{-1}) = (Pc – Po)*Pf, where Pc= Phosphorus critical level, Po = initial soil Phosphorus in the soil and Pf= Phosphorus requirement factor. Recommended N (92 kg N ha^{-1}) determined during Phosphorus calibration study for maize was used for soil test. whereas, 100$kgha^{-1}$ DAP and UREA for each were used for farmers' practices. 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., and treated with lime for soil pH less than 5.5, and the amount of lime needed per hectare was calculated based on exchangeable acidity. Full dose of phosphorous as per the treatment and one-third of N was applied at sowing. The remaining two-third of N was top dressed at 35 days after planting in the form of urea. The field was kept free of weeds by hand weeding during the period of the experiment. All other recommended agronomic management practices disease and insect pest control were done. Grain yield data was collected from net plot area. The collected data was subjected to analysis of variance using SAS software. Mean separation was done by LSD.

Economic Analysis

Costs that vary among treatments were also assessed using the CIMMYT partial budget analysis (CIMMYT, 1988). The cost of DAP and UREA, the cost of labor required for the application of fertilizer, and cost for trashing were estimated by assessing the current local market prices. The price of DAP (1997 ETB 100 kg^{-}

^{1}), UREA (1394 ETB 100 kg^{-1}), daily labors (35 ETB per one person day based on governments' current scale in the study area) and the cost of maize trashing (1 ETB $kg^{-1)}$) were considered to get the total cost that vary among the treatments. Time elapsed during fertilizer application for some plots of each treatment was recorded to calculate daily labor required for one hectare. One person per day was estimated based on eight working hours per day. Maize yield was valued at an average field price of 9 ETB $kg^{-1,}$. However, other non-varied costs were not included since all agronomic managements were equally and uniformly applied to each experimental plot. Before calculating gross revenue, maize grain yields obtained from each treatments were adjusted down by 10%. Finally, gross revenue was calculated as total yield obtained multiplied by field price that farmers receive for the sale of the crop. The net benefit and the marginal rate of return (MRR) were also calculated as per standard manual (CIMMYT, 1988).

Results and Discussion

Plant Height

The treatments were significantly ($P \leq 0.05$) varied for plant height. Plant height ranged from 1.8 to 2.7 m. STCRBPR was the tallest treatment (2.7 m) followed by farmers' practices (2.5 m) while the shortest was for without fertilizer (1.8 m). The least plant height in unfertilized plots might have been due to low soil fertility level in the study area. In conformity with the results obtained from this study, Plant growth and development may be retarded significantly if any of nutrient elements is less than its threshold value in the soil or not adequately balanced with other nutrient elements (Landon,1991)

Grain Yield and Thousand Kernel Weight

Significant variations ($P \leq 0.05$) were observed among treatments in grain yield and thousand kernel weight (Table 2). The STCRBPR treatment has the highest grain yield and thousand kernel weight followed by farmers' practices while the smallest was recorded for no fertilizer. STCRBPR increased grain yield and thousand kernel weight by 88% and 17% as compared to farmer's practices, respectively. This yield increment for STCRBPR is due to sufficient nutrients application. Maize cannot produce maximum yields unless sufficient nutrients are available (Delorite, and Ahlgren,1967). Moreover, Plant nutrient deficiency is one of the foremost problems hamper the development of an economically successful agriculture (Fageria and Baligar, 2005). Kelsa etal, (1992) also indicated that low soil fertility is among the greatest constraints to maize production in Ethiopia.

Table.2: Mean plant height, grain yield and thousand kernel weight of maize in Dega District

Treatments	PH (m)	Grain Yield ($kgha^{-1}$)	TKW (g)
Without Fertilizer	1.8^b	1000^c	214.8^c
Blanket Rec	2.5^a	4000^b	318.8^b
STCRBPR	2.7^a	7500^a	374.4^a
Mean	2.3	4200	302.7
CV(%)	13.0	12.7	15.8
LSD	0.3	500	44.8

Mean followed by the same letters in the column are not significantly different at P≤ 5%, CV = Coefficient of Variation, Farmers' Blanket Rec = Blanket Recommendation, LSD = Least Significant Difference, PH = Plant Height, STCRBPR= Soil Test Crop Response Based Phosphorus Recommendation

Economic Feasibility of Maize Production

The highest net benefit of 43657.30 ETB $ha^{-1}$with an acceptable marginal rate of return (MRR) of 290% , were achieved from use of STCRBPR. The minimum net benefit was obtained from the treatments without fertilizer (Table 3).

Table 3. Partial budget analysis for verification of STCRBPR on maize in Dega District during 2020 cropping season

Treatments	Av.GY ($kg\ ha^{-1}$)	Adj.GY ($kg\ ha^{-1}$)	TVC (ETB)	Gross benefit (ETB)	Net benefit (ETB)	D.A	MRR (%)
Without fertilizer	1000	900	1385.00	8100.00	6715.00		
Blanket Rec	4000	3600	10131.00	32400.00	22269.00		177
STCRBPR	7500	6800	17542.70	61200.00	43657.30		290

Adj.GY= Adjusted grain yield to 10% =Av.GY= Average grain yield, D= Dominated, D.A = Dominance analysis, Blanket Rec = Blanket Recommendation, MRR= Marginal Rate of Return, STCRBPR= Soil Test Crop Response Based Phosphorus Recommendation =TVC= Total Variable Costs.

Conclusion and Recommendation

Crop response to different soil fertility management is very important to come up with sustainable crop production**.** The surface soils of the study areas were low in chemical property and clay in texture. All the studied STCRBPR effects on maize yield and yield components would be promising to grow maize in the study area, The results of the study revealed that the maximum mean grain yield, the highest net benefit and acceptable MRR were recorded for STCRBPR, whereas the lowest were recorded for the treatment without fertilizer. Accordingly STCRBPR increased maize productivity in the study area; which indicated that maize productivity in the study sites were reduced due to high demand for external nutrient inputs. In conclusion, based on the data obtained from this study determined Nitrogen (92 kg N ha^{-1}), Pc (8.5 ppm) and Pf 6.64 are recommend for maize production in Dega District.

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Split Application of Lime for Acid Soil Amelioration and Better Maize Yield at Yubdo Districts West Wollega Zone, Oromia, Ethiopia

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Abstract

Soil acidity is one of the major yield limiting factors for crop production in the western of Oromia Region, Ethiopia. A study experiment was done on acid soils to assess the ameliorating ability of lime when applied in split application and its effects on maize yield and selected soil properties in the study area. The experiment comprised six treatments namely [T_1]:Control (without any input), [T_2]:Only blanket fertilizer recommendation, [T_3]:Full dose of lime applied at one time, [T_4]:50% of the dose applied in the first year and the rest 50% in the second year, [T_5]:33% of the dose applied in the first year, 33% in the second year and the rest 33% in the third year and [T_6]:25% of the dose applied in the first year, 25% in the second year, 25% in the third year and the rest 25% in the fourth year and laid out in a randomized complete block design with three replicates. Lime requirement was determined based on exchangeable acidity of the soil. Soil analysis revealed that split lime application at different year raised soil pH from 5.01 to 5.30 and reduced the exchangeable acidity from 1.90 - 0.85 cmolc/kg of soil. Likewise yield of maize was significantly affected by the treatments. In order to reduce the large amounts of lime at once, split application of lime also gave similar higher yield of maize as that of at once lime application. Therefore, application of lime at once is un-affordable due to large amounts required per hectare of land and split application of lime could be considered as an alternative option for poor resource farmers for sustainable soil health and crop productivity.

Keywords: Soil acidity, Split application of Lime, Maize yield, Soil properties

Introduction

Soil acidity is among the major land degradation problem worldwide. It is estimated that over 11 million ha of land is exposed to soil acidity around the world. Tropical and sup tropical regions as well as areas with moderate climatic conditions are mostly affected in soil acidity. Worldwide, 32% of all arable land is acid and that figure claims to be 50% in tropics. In this region, high rain fall and temperature are dominating throughout the year round and results into high rate of weathering of the soil, high rate of leaching nutrients from soils, very rapid destruction of soil physical structure and texture, quick and sever erosion of the top soil and acute drought stress are signals of severe soil acidity (Eswaran *et al.,* 1997).

Soil acidity is now a serious threat to crop production in most high lands of Ethiopia. Ethiopian Soil Information System (EthioSIS, 2014) shows about 43% of the Ethiopian arable land has affected by soil acidity, of these about 28.1% of soils are dominated by strongly acidic soils (pH 4.1-5.5). The main soil forming factors giving rise to increase soil acidity in Ethiopia involve climatic factors such as rainfall, temperature, topographic factors, morphological factors and severe soil erosion (Mesfin Abebe, 1998). Nitisol/Oxisol zones are the main soil classes dominated by soil acidity. These soils are predominantly acidic and have been found that more than 80% of the land masses originated from Nitisol are acidic.

Soil acidity is an impediment to agricultural production in areas where heavy rainfall is causing nutrient loss by way of leaching and soil erosion. It is a complex process resulting in the formation of an acid soil due to excessive concentration of non-soluble and toxic ions in the soil solution. In the context of agricultural problem soils, acid soils are soils in which acidity dominates the problems related to agricultural land use. Consequently, the level of Al^{3+} and H^{+} becomes too high causing the soil's negatively charged CEC to be overwhelmingly blocked with positively charged H and Al, and the nutrients needed for plant growth become unavailable resulting into inhibition of root growth and plant development (Juo *et al.* 1995).

Crop yield in acid soils are frequently reduced by 40-50% and can be reduced to zero. This adverse effect is attributed to the fact that soil pH affects nutrient solubility and influences the sorption or precipitation of nutrients with Al and Fe (Hue, 1992). The principal direct factors causing poor growth and low yield of crops are Al and Mn toxicity and Mg, Ca and Mo deficiency. Added to this list is P deficiency caused by adsorption of P to colloidal fractions in acid soils and conversion to insoluble Al and/or Fe compounds (von Uexkull and Bosshart, 1989). Increased soil acidity is likely to lead to poor plant growth and water use efficiency as a result of nutrient deficiencies and induced Al and Mn toxicity.

The population of Ethiopia is currently growing at a fast rate and demands an increasing proportion of agricultural products. On the other hand, growth in food production is not in equal footings with population pressure. Strengthening food production capability of the country by exploiting its existing human and natural resources is critical option to prevent the existing situation. Amid the various opportunities sought to increase agricultural development, exploitation of degraded lands devoid of crop production as consequence of soils acidity is one of the area of priority to tackle. The research approach used so far gave little attention to this threatening problem and it need for urgent solution to minimize its adverse impact and foster its contribution to the country's food security and poverty eradication efforts. Therefore the objective of this experiment was to assess the ameliorating ability of lime when applied in split application and determine effects of split application of lime on maize yield and selected soil properties in the study area.

Materials and Methods

Description of the study area

The study was conducted at FTC of Wera Gutu Kebele, Yubdo district, West Wollega Zone Oromia, Ethiopia. The district is located at a distance of 520 km, west of the capital Addis Ababa. Geographically, the district lies at 09°01.947' N latitude and 035°20.067' E longitude with an altitude ranges from 1600-1800 meters above sea level. The major rainy seasons in the district from April-November. The annual temperature ranges from 16-32 ºC and the annual rainfall is ranges from 1600-2000 mm. The predominant soil type in southwest and western Ethiopia in general and the study area in particular is Nitisols according to (FAO, 2001) soil classification system.

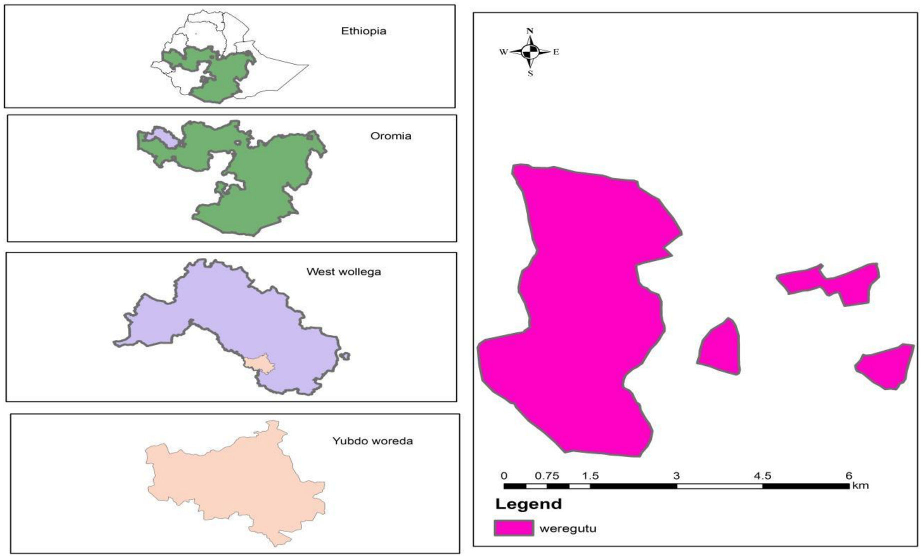

Figure1. **Location map of the study area**

Experimental Materials and Design

Field experiment on maize crop was established for four cropping seasons(2017-2020) on acid soils located at Yubdo districts of Wera Gutu FTC kebela of West Wollega zone, Oromia. The lime recommendation on this study was based on the amount of exchangeable acidity measured by the lime requirement of soil test. The amount of lime applied at each level was calculated based on the basis of exchangeable Al^{3+} and H^{+} of the site. The experiment was laid out by RCBD with three replications. The treatments are arranged as follows. Control(without any input), Only blanket fertilizer recommendation, Full dose of lime applied at one time, 50% of the dose applied in the first year and the rest 50% in the second year, 33% of the dose applied in the first year, 33% in the second year and the rest 33% in the third year and 25% of the dose applied in the first year, 25% in the second year, 25% in the third year and the rest 25% in the fourth year. The blanket recommended fertilizer was applied uniformly to all treatments. Lime was uniformly applied to the plots as per treatment by hand and incorporated into the soil a month before planting. Application of Urea was in split. The plots were reserved permanently for the duration of the experiments to observe effects of split application of lime. Initial composite soil samples collected at the depth of 0-20 cm soil before lime application were analyzed for soil pH, available phosphorus and exchangeable acidity. Similarly, After harvest soil samples were also collected from each plots and analyzed for soil pH, available phosphorus and exchangeable acidity, exchangeable bases(Ca and Mg) and Cation exchangeable capacity(CEC) . Maize (BH -661 variety) which is the main staple crop in the area was used as the test crop. The agronomic recommendation of inorganic fertilizer rate for maize in the area was used as per treatment. Soil and agronomic data was collected and analyzed. Initial lime needed for the site was 5960 kg/ha and splited to the plots based on plot size. Based on initial soil test data, the treatments were arranged as below in (Table 1).

Table 1. Treatment arrangements

Treatments	Years			
	2016/17	**2017/18**	**2018/19**	**2019/20**
T1	2.235kg	2.235kg	2.235kg	2.235kg
T2	2.98kg	2.98kg	2.98kg	0
T3	4.47kg	4.47kg	0	0
T4	8.94kg	0	0	0
T5	Control(-ve)	0	0	0
T6	Only Fertlizer	Only Fertlizer	Only Fertlizer	Only Fertlizer

Statistical Analysis

The collected data was entered into Microsoft excel and subjected to analysis of variance (ANOVA) using SAS software version 9.2 (SAS Institute, 2002).

Results And Discussion

Selected chemical properties of the soil prior to the application of the treatments are presented in (Table 2).

Table 2. Initial selected soil chemical properties and Lime Requirement

pH(H_2O)	**Av. P (Mg/Kg Soil)**	**Exch. Acidity(Al^{3+}+H^{+})**	**Lime Requirement(kg/ha)**
4.63	4.70	3.97	5960

Exch.Acidity = Exhangeable acidity; OC = Organic carbon; Av. P = Available phosphorous;

Effects of Split Application of Lime on Some Soil Chemical Properties

Analysis of variance showed that soil pH and available phosphorous were significantly increased while, exchangeable acidity decreased due to split application of lime as compared to control and inorganic fertilizer application treatments. Application of split lime application slightly increased soil pH from 5.01 to 5.30 (Table 3). The increment of soil pH in response to split application of lime at different rates was about 5.47% over the control (no lime applied soil) and 2.45% over blanket recommended inorganic fertilizer. On the other hand, split application of lime significantly reduced the exchangeable acidity from 1.90 - 0.85 over the control plot . Generally, there was no significant difference among different split application of lime in terms of soil pH, available P, exchangeable acidity, exchangeable bases(Ca and Mg) and CEC. However, split application of lime gave significantly higher values of soil pH, available P, exchangeable acidity, exchangeable bases(Ca and Mg) and CEC over the control and inorganic fertilizer application only.

In general liming of acidic soils could increase soil pH, which enhances the release of phosphate ions fixed by Al and Fe ions into the soil solution. Therefore, lime application by different method is important for the management of acid soil.

Table 3. Mean effects of split application of lime on selected soil chemical properties

Treatments	Soil pH (1:2.5 H_2O)	Exch. Acidity (cmol(+) /kg soil)	Av.P (ppm)	cmol(+)/kg soil)		OC(%)	CEC(cmol(+)/kg soil)
				Ca	Mg		
Control	5.01b	1.90a	1.48c	4.50dc	6.00a	2.36b	17.56a
25% lime every year	5.28a	1.19b	2.28ba	5.38bc	8.20a	3.36a	19.53ba
33% lime every year	5.30a	1.03b	2.72a	5.96ba	9.53a	3.21ba	20.33ba
50% lime every year	5.28a	0.92b	2.38ba	6.65a	9.01a	3.17ba	20.66ba
Full dose of lime (100%) at once	5.27a	0.85b	2.37ba	6.85a	9.26a	3.19ba	22.36a
Only Fertlizer	5.17ba	1.71a	1.74bc	3.65d	7.68a	3.20ba	15.10c
Lsd	0.186	0.409	0.704	1.132	3.618	0.911	4.00
CV(0.05)	1.96	17.91	17.70	11.31	24.01	16.23	11.41

Exch.Acidity = Exhangeable acidity; OC = Organic carbon; Av. P = Available phosphorous;Ca= Calcium; Mg = Magnesium; CEC = Cation exchange capacity.

Effect of Split Application of Lime on Maize Yield

The findings of the study revealed that the yield and yield components of maize responded positively and significantly to the split application of lime and once lime application even though they are statistically non-significant (Table 4). All split lime application treatments gave significantly higher grain yield of maize over control and inorganic fertilizers only. Inorganic fertilizers are vital for high yields, but their use is saddled with many ramifications such as soil acidification. The increase in crop yield through application of lime may be attributed to the neutralization of Al^{3+}, supply of Ca^{2+} and increasing availability of some plant nutrients like Phosphorous. Furthermore, increase in grain yield with the application of lime is attribute to its favorable effect on the chemical properties of the soil.

Table 4. Effect of split application of lime on maize grain yield (kg ha^{-1})

Treatment	Grain yield (kg ha^{-1}) in year				Mean
	2016/17	2017/18	2018/19	2019/20	
Control	2981.1b	3688.7	2355.3b	2970.0b	2998.78
25% lime every year	5820.0a	6227.8	6120.0a	4930.0a	5774.45
33% lime every year	5461.1a	6001.9	5776.7a	5470.0a	5677.42
50% lime every year	6330.0a	6561.1	6368.0a	5493.3a	6188.10
Full dose of lime (100%) at the first year (at once)	5637.8a	7194.4	5903.3a	5366.7a	6025.55
Only Fertlizer	5330.0a	5746.3	5270.0a	5130.0a	5369.07
Lsd	1894.3	2195.5	1303.4	1688.9	
CV(0.05)	19.79	20.44	13.52	18.97	

Summary and Conclusions

Soil acidity is a major yield-limiting factor for crop production nationwide and in Ethiopia particularly, in the western region of the country, which receive high rainfall to leach down basic cations of the soils. Even though soil acidity is major problems in the study area, no studies have been conducted on split application of lime for soil acidity management in the area. Therefore, this study was conducted to to assess the ameliorating ability of lime when applied in split application and determine its effects on maize yield and selected soil properties in the study area.

The study findings support the idea that liming ameliorates soil acidity and improves soil chemical property making it favorable for the crop growth. Split application of lime increased the soil pH from strongly acidic to medium range (pH 4.8 - 5.30) and reduced the exchangeable acidity from 1.90 - 0.85 cmolc/kg of soil. Through its ameliorating effects and thus indirectly favoring the creation of more suitable medium for nutrient uptake by the crop. This condition creates a favorable soil environment that enables efficient use of nutrients which ultimately resulted in better performance in terms of yield and yield components of the crop. Liming can be used to reduce soil acidity. They can be used either splitly or at once. The use of split application of lime along with recommended rate of inorganic fertilizer significantly influenced grain yield of maize in similar way as that of at once lime application. Therefore, it is advisable for farmers to use lime in split or at once to maximize maize grain yield on acid soils of western Oromia where soil acidity is a major production constraint. Lime recommendations have to be as specific as possible, taking soils, crops, time and place into account. Other alternatives such as choice of acid-tolerant crop varieties and use of organic fertilizer may further reduce the amounts of lime required and make farming more attractive.

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Effect of Biochar on Soil organic Carbon and Grain yield of Maize at Dugda District, East Shewa Zone, Oromia, Ethiopia

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Abstract

Proper farming practices include low carbon farming using (Biochar and compost) that require careful and effective management of the soil and the plant it supports. Therefore, a study was conducted on twelve farmers' fields in Dugda District of East Shewa Zone, Oromia, during the main cropping seasons of 2019-2020. The study aimed to identify the biochar nutrient contents and the role of biochar on soil organic carbon as well as maize grain yield. So, biochar was prepared conventionally at Farmer's field and its product was submitted to Horticop Ethiopia and Batu soil research center for the analysis of different parameters. Accordingly, biochar nutrient contents were analyzed and urea equivalent Nitrogen was determined. The treatments were consisted of control, 25% biochar+75% urea+100%Pc, 50% biochar+50% urea+100%Pc, 75% biochar+25% urea+100%Pc, 100% biochar+100% Pc, 100% urea+100%Pc and 100% biochar alone that gives seven treatments. The experiments were laid out in randomized complete block design (RCBD) with three replications and the gross plot size was 3 m x 3 m (9 m^2) were used and also harvested from 9m^2 plot areas. The pre-soil test result indicated that the soil textural class was sandy loam, Ec and pH were salt-free and neutral respectively, which were suitable for crop productions. Moreover, the nitrogen content of biochar was 1.02% and its urea equivalent ratio was around 45 ton/ha. The analysis of variance indicated that the highest (4723.3 kg ha^{-1}) grain yield and the highest (12.58 ton ha^{-1}) biomass yield, the highest (29.3 gm) thousand kernels weight, and the highest (16.64 cm) ear length were recorded by combined application of 25%biochar + (75% urea + 100% Pc) while the lowest values were recorded by control plots. However, the highest (208.18 cm) plant height and the highest (13.71) number of rows per ear were recorded by combined applications of 100%biochar+ (zero % urea + 100% pc) and 100% *biochar alone, respectively. Moreover, the economic analysis revealed that for a treatment to be considered as worthwhile to farmers (100% marginal rate of return) and sustainable soil productivity, application of 25%biochar + (75% urea + 100% Pc) is profitable which gave the highest (52762 Birr) net return with an acceptable (107%) marginal rate of return and recommended for farmers in Dugda district*

Keywords: Biochar, Maize yield, NP fertilizer, Phosphorus critical, and phosphorus requirement

Introduction

Maize is the second most widely cultivated crop in Ethiopia and is grown under diverse agro-ecologies and socio-economic conditions typically under rain-fed production. Global Maize production in 2018 was estimated at 1147 million tons from 193 million ha area harvested with an average yield of 5924 kg ha^{-1}. However, in Ethiopia Maize production in 2018 was estimated at 7360201 tons from 2235872 ha area harvested with an average yield of 3293 kg ha^{-1}(FAOSTAT, 2018). According to this report despite the large area under maize in Ethiopia, the national average yield of maize is 80% far below the world's average yield. The low productivity of maize is attributed to many factors like declining soil fertility, poor agronomic practice, limited use of input, frequent occurrence of drought, and insufficient technologies (Tsedeke, *et. al*., 2015).

Low soil fertility is a common problem in many regions around the world (El- Naggar *et al*., 2019). In soils with low soil organic matter (SOM), content and coarse texture essential plant nutrients are easily leached from the topsoil layer by rainwater or become unavailable during drought periods. Relatively higher temperatures enhance SOM mineralization, resulting in the decrease of aggregate stability and capacity to retain water and nutrients. These phenomena become one of the most important challenges towards sustainable agronomy and crop production (Zheng *et al*., 2012).

Soil organic matter can be improved by the application of FYM, poultry manure, crop residues, compost, etc. But one of the good sources for increasing the fertility of the soil is biochar, which draws the attention of many scientists around the globe. Biochar is a resistant organic matter that is being used by scientists as a source of organic matter (Lehman *et al*., 2003). The carbon content in biochar is more as compared to other organic matters and hence became useful to be used in cereals crops (Rahim *et al*., 2019). Biochar has drawn the attention of many researchers to improve degraded soil because it improves the physical, chemical, and biological properties of soil (Chan *et al*., 2008).

On the other hand, Atmospheric carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the key long-lived greenhouse gases (GHGs) forcing global warming. World agriculture accounted for an estimated emission of 5.1–6.1 Pg CO_2 equivalents yr^{-1}, contributing 10 –12% to the total global anthropogenic emissions of GHGs in 2005 (Smith *et al*. 2007). While agriculture releases a significant amount of CH_4 and N_2O to the atmosphere, the net GHGs emission of CO_2 equivalents from farming activities can potentially be decreased by changing agricultural management to increase soil organic matter content and/or decrease CH_4 and N_2O emissions (Mosier *et al*. 2006).

Biochar production and application from crop straw has been proposed as one effective counter mean to mitigate climate change (Lehmann, 2007) through increasing soil carbon storage (Fowles, 2007) while decreasing direct GHGs emissions and improving soil fertility and crop productivity (Major *et al*. 2010a). The high porosity of biochar may also be very beneficial for improving soil structure and water holding capacity (Vaccari *et al*., 2011) and, therefore, mitigating the increasing drought stress in dryland agriculture due to climate change. Moreover, (Medynska *et al*., 2021) reported that the application of biochar improved soil physical properties and water retention, reducing plant water stress during hot dry summers, and thus resulting in better maize growth and higher yields. Therefore this experiment was conducted with the following objectives:-

- ❖ To assess and identify the nutrient contents of biochar and determine its urea equivalent nitrogen ratio
- ❖ To determine the optimum combination of biochar with fertilizer for maximum maize grain yield production and soil carbon restoration

Materials and Methods

Description of the Study Area

The experiment was conducted on a Farmers' field in Dugda District, East Shewa Zone of Oromia regional state in central Ethiopia for two consecutive years (2019 -2020). The district is Part of the East Shewa Zone located in the Great Rift Valley. Dugda is bordered on the Southeast by Lake Zuway, on the South by Adami Tullu Jido Kombolcha district, on the West by the Southern Nations, Nationalities and Peoples Region, on the Northwest by the Southwest Shewa Zone, on the north by the Awash River. Dugda district has a latitude of 8° 09' 60.00'' N and a longitude of 38° 49' 59.99'' E with an elevation of 1636 meters above sea level.

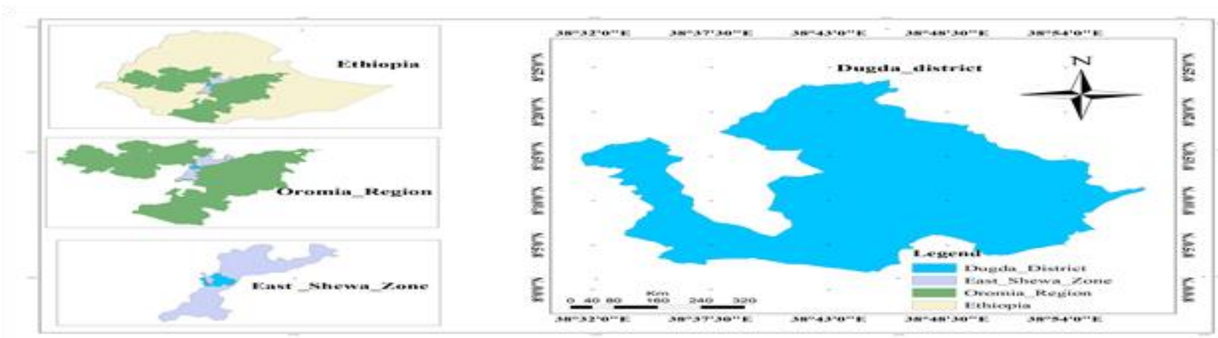

Figure 1. Location Map of Dugda District

Biochar Material Collection

Calotropis Procera was used as feedstock (biochar material), and this invasive alien plant species were abundant at the roadside, agricultural and grazing land in the districts. This material was collected by cutting with a bow saw into small pieces (Photo 1).

Photo a: *Calotropis Procera; b: Small piece of material; C; Conventional Biochar making at Field; d: Biochar*

Biochar Preparation

Calotropis Procera biochar was prepared conventionally at 225^0c for 18 hours using conventional process of pyrolysis based on the recommendation of (Warnock *et al., 200*7 and Sohi *et al.*, 2010) Periodically the ignition was controlled by taking a temperature reading. After the smoking was stopped the mound was opened and allowed to cool to room temperature. The biochar was crushed mechanically by pestle and mortar into small granules and passed through a 2 mm sieve to have the same particle size and easily mix in the soil.

Biochar Characterization

Biochar analysis (%OC and Total nitrogen) was undertaken at Horticoop Ethiopia (Horticulture PLC Soil and Water Analysis Laboratory). The other parameters were analyzed at Batu Soil Research Center. pH was measured using FAO potentiometer using a ratio of 1: 2.5 (w/v) biochar to distilled water after shaking for an hour in a mechanical shaker using a digital pH meter using a glass-calomel combination electrode (Van Reeuwijk, 1993). %Total nitrogen in the sample was determined by the Kjeldahl distillation method (Bremner, 1996). Available phosphorus in biochar was extracted by the Olsen method (Olsen *et al*., 1954) and measured on a spectrophotometer. The Walkley and Black (1934) wet digestion method was used to determine percent organic carbon content. The exchangeable cations (Ca^{2+}, $K^{1+,}$ Mg^{2+}, and Na^{1+}) of biochar were determined after leaching the biochar with 1N NH4OAC at the pH7 method. Sodium and potassium contents in the extract were determined by flame photometry (Rowell, 1994). Exchangeable cations (Ca and Mg) were determined using ammonium acetate extract-EDTA titration.

Soil Analysis

The particle size distribution of the soils was analyzed according to the procedure outlined by Bouyoucos (1962) with the help of the hydrometer method. Soil reaction (pH), electrical conductivity (EC), available phosphorus, % Total nitrogen, % organic carbon, CEC, and Exchangeable bases of soil were measured with the same procedures used for the analysis of biochar.

Treatments and Experimental Design

The treatments were set based on the nitrogen equivalency of biochar material. Accordingly, the number of biochar treatments was organized and arranged in a randomized complete block design with three replications (Table 1 and 2). Nitrogen equivalency was determined using a simple mathematical calculation which 1.02 % nitrogen substitutes which equivalent to 4.5 ton ha^{-1} (Table 2).

Table 1: Treatment Combination.

TREATMENTS	DESCRIPTION
1	No application
2	25%Biochar + (75% UREA + 100% PC)
3	50%Biochar +(50% UREA + 100% PC)
4	75%Biochar+(25% UREA + 100% PC)
5	100%Biochar+(Zero % UREA + 100% PC)
6	100% UREA +100% PC
7	100% Biochar alone

Table 2: Nitrogen Equivalency from Biochar

%N IN BIOCHAR	N EQUIVALENCY FROM UREA KG/HA	N EQUIVALENCY T/HA
1.02	4509.8	4.5

Application of Phosphorus fertilizer was calculated using phosphorus critical (10 ppm) and Phosphorus requirement factor (1.4-4.6) determined by (Dejene *et al*., 2019) for Maize crop on Andosol soil type in Dugda and Adami Tullu. Then, the amount of Phosphorus to be applied was calculated using the equation below.

Rate of phosphorus fertilizers to be applied (Pkg/ha) = (Pc-Po) x Pf

Where Po is the initial soil P values of the site, Pc is the critical value for P for a given crop, and Pf is the required factors of Pf or a given crop

The test crop was maize (Melkassa_2). The Gross plot size was 3m x 3m accommodating 5 rows each spaced 0.75m. 1.50m and 1m spacing was maintained between blocks and plots, respectively. Maize was planted with the rate of 25 kg ha^{-1} following the recommended spacing of 75cm*25cm (row to plant). One-third of N was applied in the form of urea at sowing while the remaining two-thirds were applied where the plant reached 35 days age.

Data Collection and Measurements

Nutrient contents of biochar, soil physical and chemical properties, growth parameter and yield components, and yield data were collected from each plot.

Plant height was measured from the ground level to the top-most leaf of 5 randomly selected plants, from two central rows by using a measuring tape.

The number of kernels per cob was calculated by counting the number of a kernel in five cobs of the two central rows of each subplot and then their average was calculated.

1000 grain weight was determined based on the weight of 1000 seeds sample from the cobs of the two central rows of each subplot and weighing with an electronic balance and the yield was adjusted to 12.5% moisture level.

The grain yield was taken by husking and cleaning the grain yield from the net plot area and converted to in kg ha^{-1}. The yield was adjusted to 12.5% moisture.

Harvest index was calculated as the ratio of grain yield to the aboveground dry biomass yield expressed as a percentage.

$$\textbf{HI (\%)} = \frac{\textit{Grain yield/plot}}{\textit{Above ground dry biomass/plot}} * 100$$

Data Analysis

Soil and yield data were subjected to analysis of variance (ANOVA), using Statistic analysis System (SAS) software package Version 2002. The differences among the treatments were compared by the Duncan Multiple Range Test at the $P < 0.05$ probability level.

Partial Budget Analysis

The dominance analysis procedure as described in CIMMYT (1988) was used to select potentially profitable treatments from the range that was tested. The discarded and selected treatments using this technique were referred to as dominated and un dominated treatments, respectively. For each pair of ranked treatments, % marginal rate of return (MRR) was calculated using the formula:-

$$\textbf{MRR (\%)} = \frac{\text{Change in NB (NBb} - \text{NBa)}}{\text{Change in TCV (TCVb} - \text{TCVa)}} \times 100$$

❖ Where NB_a = NB with the immediate lower TCV, NB_b = NB with the next higher TCV, TCV_a = the immediate lower TCV and TCVb = the next highest TCV.

Results and Discussion

Soil Physicochemical Properties

Table 3: pre-planting of some Initial soil physicochemical properties

SITES	SAND %	SILT %	CLAY %	CLASS	EC DSM^{-1}	PH
1	61	32	7	SL	0.053	6.29
2	63	28	9	SL	0.063	6.57
3	67	26	7	SL	0.058	6.43
4	45	34	21	SL	0.061	6.77
5	47	32	21	SL	0.065	6.86
6	59	26	15	SL	0.079	7.01
7	47	32	21	SL	0.084	6.89
AVG	55.57	30	14.43	SL	0.066	6.69

The soil test results have been revealed that the particle size distribution of the experimental soils classified as sandy loam according to the soil textural triangle. According to the rating of Tekalign (1991), the soil pH of experimental sites was classified as slightly acidic to neutral (6.29-7.01) which is suitable for crop growth. The electrical conductivity of experimental soils was categorized under salt-free (0.053-0.084 dsm^{-1}).

Table 4: pre-planting of some Initial soil chemical properties

SITES	**AV.P**	AV.K (MG KG-	OC %	CEC	NA	K	CA	MG
	(mgKg $^{-1}$			Cmol$_c$/kg soil				
1	5.36	64.5	0.10	12.33	0.24	1.83	10.98	7.12
2	6.20	70.5	0.11	21.16	0.20	2.02	11.77	4.28
3	6.76	54.0	1.17	10.12	0.28	1.55	12.84	4.28
4	5.56	63.5	1.95	23.92	0.26	1.80	8.05	5.35
5	5.16	73.5	0.88	22.08	0.20	2.86	12.84	9.63
6	5.88	102	1.37	25.21	0.26	2.79	16.19	10.7
7	7.24	103	0.10	23.74	0.48	2.19	17.12	7.49
MEAN	5.73	75.87	0.79	19.79	0.27	2.15	12.82	6.98

The pre-soil testing result indicated that available phosphorus values were categorized under medium values (5.16 -7.24 mg kg^{-1}) according to the rating of (Olsen *et al*., 1954). As rated by Tekalign (1991) soil organic carbon of the experimental soil was categorized as very low to moderate (0.1-1.95%). The average Cation Exchange Capacity (CEC) of 19.79 cmolc kg^{-1} soil was rated as moderate according to Hazelton p. and B.Murphy (2007).

Biochar Characterization

Table 5: Some physicochemical properties of Biochar

PARAMETERS	BIOCHAR
EC $_{WATER\ 1:2.5}$ DS M^{-1}	1.81
PH$_{WATER1:2.5}$	7.89
ORGANIC CARBON (%)	27.74
TOTAL NITROGEN (%)	1.02
AV.P MG KG^{-1}	168.68
AV.K MG KG^{-1}	20.3
CATION EXCHANGE CAPACITY (CEC CMOL$_C$/ KG BIOCHAR)	26.40
EXCHANGEABLE POTASSIUM (K^{+1} CMOL$_C$/ KG BIOCHAR)	10.12
EXCHANGEABLE CALCIUM (CA^{+2} CMOL$_C$/ KG BIOCHAR)	6
EXCHANGEABLE MAGNESIUM (MG^{+2} CMOL$_C$/ KG BIOCHAR)	4.5
EXCHANGEABLE SODIUM (NA^{1+} CMOL$_C$/ KG BIOCHAR)	4.87

A Biochar nutrient content depends on the quality of the feedstock, and some physicochemical properties of biochar are explained in table 5). The value of pH (7.89) of biochar material was categorized as moderately alkaline as rated by Tekalign (1991). Similarly, 27.74% organic carbon and total nitrogen of 1.02% was found in biochar material

Soil physicochemical properties after harvest

Table 6: Biochar and NP effect on some post-harvest soil physic- chemical properties.

TREATMENT	EC DS M^{-1}	PH	%TN	AV.PMG KG^{-1}	%OC
CONTROL	0.15±0.13	6.67±0.34	0.07±0.06	6.30±3.46	0.23±0.07
25%BIOCHAR+75%UREA+ 100% PC	0.29±0.40	6.58±0.36	0.07±0.06	13.28±7.36	0.21±0.05
50%BIOCHAR+50%UREA+ 100% PC	0.17±0.15	6.52±0.39	0.05±0.04	14.35±7.48	0.21±0.07
75%BIOCHAR+25%UREA+ 100% PC	0.14±0.13	6.24±1.57	0.05±0.05	13.07±6.57	0.21±0.07
100%BIOCHAR+0%UREA+ 100% PC	0.11±0.07	6.35±1.60	0.05±0.05	12.45±6.39	0.21±0.08
100% UREA +100% PC	0.22±0.24	6.08±1.58	0.06±0.07	15.85±11.62	0.21±0.1
100% BIOCHAR ALONE	0.12±0.08	6.65±0.24	0.06±0.06	9.89±4.86	0.25±0.13

The value of available phosphorus was higher at the application 100% urea and 100 % phosphorus critical followed by 50% biochar and 100% phosphorus critical. The lowest was recorded on the control plot (Table 6). The applications of biochar and NP do not affect the percent organic carbon after harvest. The result disagrees with Ali Arif *et al*., (2015) and (Abdurahman *et al*., 2017).

Yield Components and Yield

Grain yield

The analysis of variance indicated that the grain yield of maize was highly significantly ($p < 0.001$) influenced by treatment combinations of biochar and NP fertilizers (Table 5). The highest grain yield (4723.3 kg ha^{-1}) was obtained in response to the application of 25% biochar application + 75% urea + 100% phosphorus critical while the lowest (1817 kg ha^{-1}) was obtained by control plot.

The analysis of variance indicated that the grain yield of maize was highly significantly ($p < 0.001$) influenced by treatment combinations of biochar and NP fertilizers (Table 5). The highest grain yield (4723.3 kg ha^{-1}) was obtained in response to the application of 25% biochar application + 75% urea + 100% phosphorus critical while the lowest (1817 kg ha^{-1}) was obtained by control plot. This result is parallel with (Zafar *et al*., 2018) who reported the highest (3860 kg ha^{-1}) grain yield by application of 10 ton ha^{-1} sugarcane bagasse biochar.

Biomass Yield

The analysis of variance indicated that the grain yield of maize was highly significantly ($p < 0.001$) influenced by treatment combinations of biochar and NP fertilizers (Table 5). The highest Biomass yield (12.58 ton ha^{-1}) was obtained in response to the application of 25% biochar application + 75% urea + 100% phosphorus critical while the lowest (8.68 ton ha^{-1}) was obtained by control plot. In line with this result

(Jeffrey *et al*., 2019) recorded the highest (9.166 ton ha-1) biomass yield of maize by applying 100% poultry litter biochar.

Ear length

The analysis of variance indicated that the grain yield of maize was highly significantly ($p < 0.001$) influenced by treatment combinations of biochar and NP fertilizers (Table 5). The highest Biomass yield (16.64 cm) was obtained in response to the application of 25% biochar application + 75% urea + 100% phosphorus critical while the lowest (14.64 cm) was obtained by control plot. In agreement with this result, Arif *et al*., 2012 reported the highest (16 cm) ear length by application of 30 ton ha^{-1} with recommended NPK fertilizers for maize crop.

TKW (thousand kernels weight)

The result revealed that there was a significant difference in TKW at ($p<0.05$ The maximum TKW (29.30gm) and minimum TKW (22.06 gm) was obtained at 25% biochar + 100%Pc + 75% urea and Control plot, respectively. The result was agreed with Gebremedhin *et al.* (2015) with similar treatment applications.

Table 7: Effect of Biochar and NP on grain yield and yield components

TREATMENTS	GY KG HA^{-1}	BM TON HA^{-1}	HI (%)	TKW (G)	PH (CM)	EL (CM)	NRPE
CONTROL	1817.8^{c}	8.68^{b}	25.56^{d}	22.06^{b}	187.28^{b}	14.64^{b}	12.80^{b}
25%BIOCHAR+ 75% UREA+ 100% PC	4723.3^{a}	12.58^{a}	41.92^{a}	29.30^{a}	$192.64b^{a}$	16.64^{a}	13.37^{ba}
50%BIOCHAR+50%UREA+ 100% PC	4072.8^{ba}	11.60^{ba}	40.88^{ba}	28.13^{a}	196.96^{ba}	15.06^{ba}	13.46^{ba}
75%BIOCHAR+25%UREA+ 100% PC	3762.10^{b}	9.98^{ba}	42.03^{a}	27.09^{a}	190.64^{ba}	14.91^{ba}	13.33^{ba}
100%BIOCHAR+100%PC	3771.20^{b}	12.08^{ba}	40.13^{ba} c	28.01a	208.18^{a}	15.95^{ba}	13.33^{ba}
100%UREA +100% PC	3885.3^{b}	10.65^{ba}	35.99^{c}	27.8^{a}	197.95^{ba}	15.02^{ba}	13.51^{ba}
100% BIOCHAR ALONE	3618.9^{b}	11.12^{ba}	36.63^{bc}	27.71^{a}	194.85^{ba}	15.11^{ba}	13.71^{a}
LSD	816	3.30	4.68	3.47	19.78	1.69	0.83
% CV	23.53	17.23	7.11	13.51	5.78	11.74	6.60

Means followed by the same letter with in the same column of the respective treatment are not significantly different ($P \leq 0.05$) according to Duncan Multiple range Test, PH= plant height, El=ear length, NRPE=number of row per ear, BM= biomass, GY= grain yield, TKW = thousand kernel weight, HI= harvested index CV = Coefficient of variation, LSD = Least Significant differences, NS = not significant.

Plant Height

Analysis of variance showed that the combined effect of NP and biochar rates were significant ($P <0.05$) influenced on plant height of maize. The maximum application rate of 100%biochar+100% phosphorus critical resulted in the highest plant height (208.18 cm) while no N fertilizer supplementation showed the shortest plant height (187.28 cm) (Table 5).

Number of Rows per Ear

Analysis of variance showed that the combined effect of NP and biochar rates were significant ($P < 0.05$) affected on the number of rows per ear of maize (Table 8). The maximum application rate of 100%biochar alone resulted in the highest (13.71) number of rows per ear while no fertilizer application showed the smallest (12.80) number of rows per ear. This result is consistent with the finding of (Arif *et al*., 2012) who recorded the highest (13.67) number of rows per ear by application of 30 ton ha^{-1} with recommended NPK fertilizers for maize crop.

Partial budget analysis

Table 8: Partial budget on biochar and P fertilizer on maize in dugda district, 2020.

TRT	BCHR. QT HA^{-1}	TSP (KG HA^{-}	UREA (KG HA^{-}	ADJ. YLD KG HA^{-1}	GFB (ETB HA-1)	TVC (ETB HA^{-1})	NB (ETB HA^{-1})	MRR
1	0	0	0	1,818	23,631	-	23,631	-
2	11.25	100	75	4,723	61,403	8,641	52,762	107
3	22.5	100	50	4,073	52,946	13,894	39,053	D
4	33.75	100	25	3,762	48,907	19,146	29,761	D
5	45	100	0	3,771	49,026	24,399	24,627	4
6	0	100	100	3,885	50,509	3,388	47,121	693
7	45	0	0	3,619	47,046	22,500	24,546	D

NB: Trt 1: No application;2: 25%nitrogen equivalent biochar+ (75% UREA + 100% PC);3: 50%N equ biochar +(50% UREA + 100% PC); 4: 75%N equ biochar +(25% UREA + 100% PC); 5: 100% N equ biochar +(Zero % UREA + 100% PC);6: Recommended NP (100% UREA +100% PC);7: 100% biochar alone; Bchr = Biochar; TVC = Total variable cost; Ad GY = Adjusted grain yield;; TSP cost = 18.99 Birr kg^{-1}, UREA cost = 14.89 Birr $kg^{-1}$of N, TSP, maize grain = 13 Birr kg^{-1}, biochar cost = 5 Birr $kgha^{-1}$, MRR (%) = Marginal rate of return, D= Dominated treatment. Qt= Quintal

To identify treatments with the optimum return to the farmer's investment, marginal analysis was performed on non-dominated treatments. For a treatment to be considered worthwhile to farmers (100% marginal rate of return (MRR)) was considered as the minimum acceptable rate of return (CIMMYT, 1988). As indicated in table 8, the partial budget and dominance analysis showed that the highest net benefit 52,762 Birr ha^{-1} was obtained in the treatment that was treated with 25% nitrogen equivalent Biochar + (75% Urea + 100% PC) ;While the minimum net benefit was obtained on no application.

Conclusions and Recommendation

Integrated soil fertility management is critical to retain soil fertility and increase grain yield per acre. Organic (Biochar) supplement with NP fertilizer was carried out in Dugda District for determination of biochar nutrient characterization, effect on grain yield, and change in soil carbon restoration. The results of this experiment show that integrated application of biochar with NP fertilizer increase grain yield by 8.19% as compared to recommended NP (46N kg ha^{-1} and 100% phosphorus critical value) application. There was no residual soil organic carbon restored after harvest; however, there is increased soil available phosphorus.

Moreover, the economic analysis revealed that for a treatment to be considered as worthwhile to farmers (100% marginal rate of return) and sustainable soil productivity, application of 25%biochar + (75% urea + 100% Pc) is profitable which gave the highest (52762 Birr) net return with an acceptable (107%) marginal rate of return and recommended for farmers in Dugda district. Therefore based on the result obtained we recommend verification and demonstration integrated use of biochar made from *Calotropis procer*a with NP fertilizer in the dugda and neighboring districts for maize production.

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Characterization and Classification of problem Soils irrigated with different water sources of Adami Tullu District

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Abstract

Soil fertility degradation due to soil salinity is becoming a great problem for Soil production and productivity, especially in the central rift valley of Oromia, Ethiopia. Due to, this a field survey and soil morphological description, and laboratory analysis were carried out in Adami Tulu Jiddo Kombolcha District, central rift valley, Oromia, Ethiopia with the objectives of describing, characterizing, and classifying of salt affected soils and irrigation water source of the District to the standard classes. Irrigated area of the district was delineated based on irrigation water sources (Lake and Deep well) Accordingly, Three representative pedons (1 - 3) were opened from each areas irrigated with lake water, deep well water, and rain-fed agriculture (control. Then, forty five soil samples from profiles depths and nine soil samples from surface land were collected and described accordingly. The results indicated that textural class of of Land irrigated with Ground, lake and rain fed water were sandy loam except two pedons of land irrigated with lake water which was loamy sand. Electrical conductivity ranges from 0.173-1.795 dSm^{-1}, pH ranges from 7.20-9.92, OC ranges from 0.81%- 3.35%, TN ranges from 0.02%-0.17%, available phosphorus ranges from 0.32ppm- 28.02ppm for land irrigated with ground water, Similarly Ec ranges from 0.139-0.832dsm^{-1} pH ranges from 7.56-9.2, OC ranges from 0.89%- 2.81%, TN ranges from 0.02%-0.17%, available phosphorus ranges from 0.34ppm- 35.1ppm for land irrigated with lake water. Moreover, Ec ranges from 0.121-5.843dS m^{-1} pH ranges from 7.22-9.40, OC ranges from 0.81%- 3.17%, TN ranges from 0.02% - 0.12%, and available phosphorus ranges from 0.6ppm- 33.06ppm for rain fed agriculture. On the other hand the Electrical conductivity and soil reaction were 0.33dsm^{-1} and 8.19 for ground water and 0.32dSm^{-1} and 7.98 for lake water respectively. The overall results have been indicated that soils irrigated with deep wells have a maximum amount of pH than Lake Water and rain-fed. Some of the analyzed physicochemical parameters (pH, EC, cations, anions, and TDS) of water quality of ground and lake water were used for irrigation purposes in the studied area categories under permissible limits. However, the values of the water quality parameter of groundwater were much greater than the lake water. Therefore using ground water for Irrigation purposes can add cations and anions to the soil. These additions of ionic elements will increase the inherent ionic elements of the soil with the long-term use of groundwater. Hence, using groundwater for irrigation purposes needs great consideration of irrigation water management in the district.

Keywords: *Characterization, Classification; Pedon; Groundwater; Lake Water; surface sample*

Introduction

Soil degradation is a serious problem in the production and productivity of crops in many subs Saharan Africa (FAO, 1999). It is a process that lowers the current or the potential capability of the soil to produce (quantitatively or qualitatively) goods or services (FAO, 1999). There are different forms of soil degradation which are chemical, biological, and physical. Each form has its causes, for instance, chemical soil degradation could be soil salinization, nutrient depletion, or excessive leaching. Salinization is the process of accumulation of excess salts in the root zone resulting in partial or complete loss of soil productivity

In many areas of African countries, soil fertility depletion becoming a serious problem due to increased soil salinity on agricultural lands (Beets, 1989; Skoupy, 1991). Accordingly, in Ethiopia, shortage of rainfall, low soil fertility due to salinity is highly contributing to low agricultural productivity. Soil salinity is a problem in irrigated lands, particularly where saline water (poor quality irrigation water); a huge amount of fertilizer application, and inadequate drainage have contributed to rising groundwater tables leading to salinity-induced land degradation (Qureshi *et al*., 2013; Sarwar *et al*., 2015).

Salt affected soils are categorized into three main groups; namely saline, sodic, and saline-sodic (Gonzalez *et al.*, 2004). When soils contain excess concentration of water-soluble salts like Cations (Ca^{++}, Mg^{++}, and Na^{+}) and Anions (Cl^{-} , $SO4^{-}$) we call it Saline (Denise, 2003). Saline soils are recognized by white crust on the surface. Electrical conductivity is less than or equal to 4 mhos/cm. The pH is less than 8.5 and SAR is lessthan13 (Pam, 2002). Soils that contain a large amount of total soluble salt and exchangeable sodium are called saline-sodic (Jim, 2002). Sodic soils are low in soluble salts than saline or saline-sodic soils but high in exchangeable sodium (Jim, 2002; Pam, 2002). These soils contain ($HCO3^{-}$), and $CO3^{-}$ the dominant anion (Qadir & Schubert, 2002).

Nowadays, from the sub-region of the East African country, 11million hectares (Mha) of Salt affected soils are found in Ethiopia, of which 8Mha have combined salinity and alkalinity problems, and 3Mha have dominantly alkalinity problems (Sissa, 1985; Tamirie, 1994 and Meron, 2007). The semi-arid and arid lowlands and valleys in Ethiopia have major problems of salinity and alkalinity (Gebreselassie., 1993 Meron, 2007). Some Authors (Meron, 2007, Kafeyalew *et al*., 2011; Firew *et al*., 2015; Sissay, 1985; Taddese G and Bekele E 1996) reported that the rapid increase of salinity problems in many areas including; Meki, Ziway, Amibara, Melka Sadi, and MelkaWerer in individual and state irrigation farmlands. Since agriculture in Ethiopia is rain-fed, the country is facing repeated drought problems due to a shortage of rainfall. Having this in mind to tackle this drought problem rain fed agriculture has been supplemented by irrigation is indispensable.

Based on this, at present, the Ethiopian government planned and executes irrigation development in different areas mainly in the rift valley to increase agricultural productivity (Edossa *et al*., 2013). Now a day, in the area of Dugda and Adami Tullu Jido Kombolcha districts, irrigation development is going and expanding. But due to low precipitation, high evaporation, low leaching, and expansion of irrigation development soil salinity/secondary salinization are becoming a problem in these agricultural lands (Meron, 2007, Kafiyalew *et al*., 2011 and Edossa *et al*., 2013). As a result production per hectare is declined (Kafiyalew *et al*., 2011). Salinity is one of the most environmental factors limiting the productivity of crop plants because most of the crop plants are sensitive to salinity caused by high concentrations of salts in the soil (Hasanuzzaman *et al*., 2013). But the intensity and the severity of the problem as well as the type of the problem (salinity type) were not identified for the area. Therefore, this study was designed to fill the gap having the following objective.

Objectives

❖ To characterize and classify the soils and irrigation water source of the study area to the standard classes.

❖ To generate thematic maps using GIS to be used for further management decisions.

Materials and Methods

Description of the Study Area

The study was conducted in Adami Tullu Jido Kombolcha which is one of the districts in the Oromia Region, Ethiopia, which is located in the Great Rift Valley. The district is bordered from the South by West Arsi Zone with which it shares the shores of Lakes Abijatta and Langano, from the West by the Southern Nations, Nationalities and Peoples Region, from the North by Dugda District, from the Northeast by Hara-Dambal, and from the East by Arsi Zone. The main town of the district is Batu which is situated 165 km south of Addis Ababa. Adami Tullu has a latitude and longitude of 7°52′N 38°42′E with an elevation of 1636 meters above sea level.

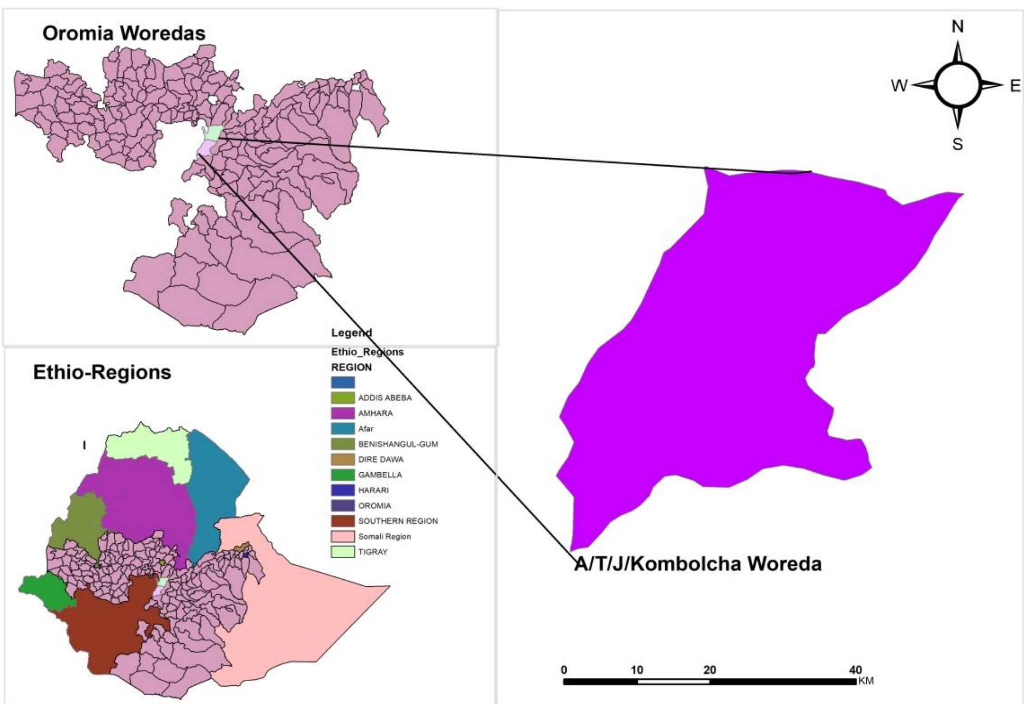

Figure 1: Location map of AdamiTullu Jiddo Kombolcha district

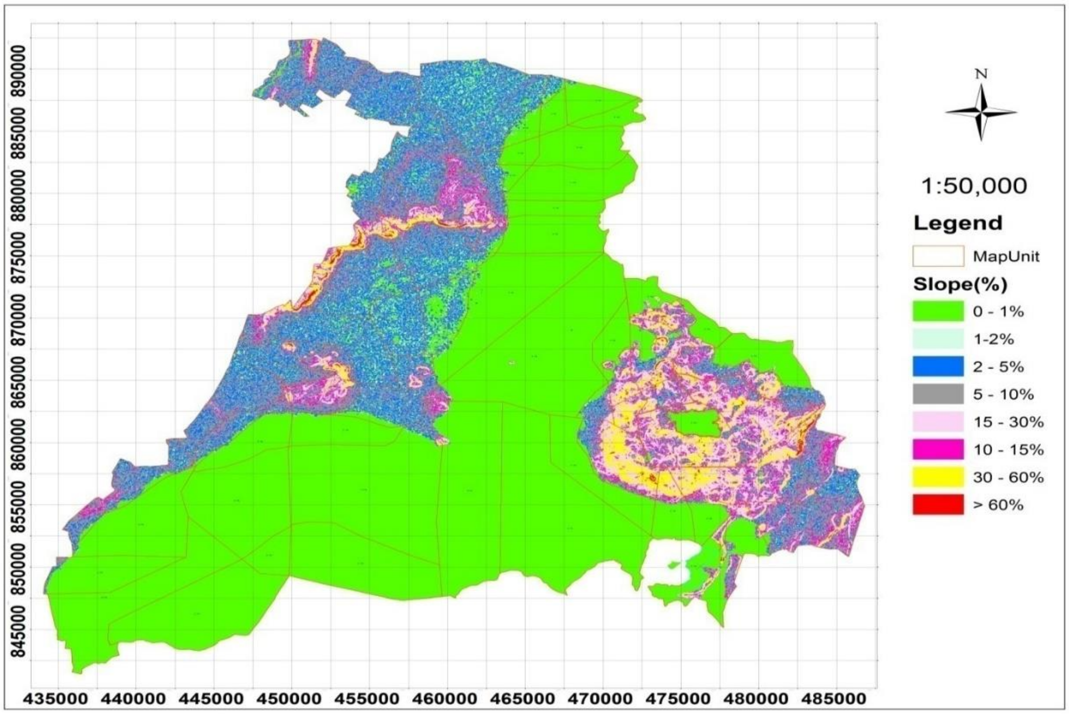

Figure 2: Slope class of Adami Tullu Jiddo Kombolcha district

Climate

The area is characterized by a uni-modal rainfall pattern. The mean annual rainfall was 677.84mm and the mean min and max temperature was 14.4and 27.8^{o}c. The area is dominantly a flat topography stretching from Modjo - Meki - Batu; it covered with lacustrine alluvium soil deposits (Behailu, 2007; Kefiyalew *et al*., 2011).

Land Use and Vegetation

The farming system of the area is a crop-livestock production system. Major crop production of the district is dependent on rainfall except for a limited irrigation area that is suited to river and lack. The land cultivated by oxen and rarely tractor plowing has been practiced. A survey result of the area in the district shows that 27.2% is arable or cultivable, 21.6% pasture, 9.9% forest, 15.7% swampy, and the remaining 25.6% is considered degraded or otherwise unusable (source).

Major crops grown in the main rain season are Maize (*Zea mays* L.), wheat *(TriticumaestivumL.*), teff (*Eragrostis tef* (Zucc). Major vegetable crops grown using irrigation are Onion, tomato, Cabbage, Kale, and pepper. While major tree species grown in the district are Acacia *tortolis, Acacia albida, Acacia Senegal, and Croton macrostachyus, Balanities Egyptian.*

Soil Types of the District

According to FAO, 2006, the dominant soil type of the study area are Vitric Andosols, The soils are derived from the parent material known as basalt, ignimbrite, lava, gneisses, volcanic ash, pumice, riverine and lacustrine alluvium (EGMOA,1975).

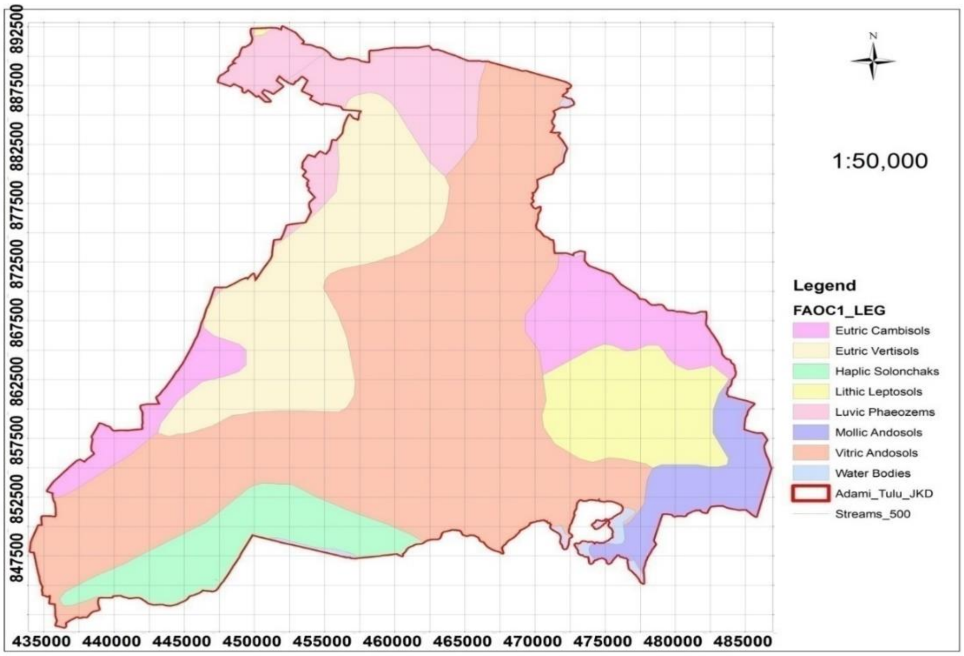

Figure 3: Soil types of AdamiTullu Jiddo Kombolcha District

Area Delineation of Irrigated Lands

Initially, a general visual reconnaissance survey of the area was carried out to have a general view of the variations in the study area. Ground control points were taken by GPS and irrigated areas were delineated by using Arc GIS (Figure, 4). Representative soil profiles sampling sites were identified based on landform, irrigation, and cultivation history including sources of irrigation water (Figure 4).

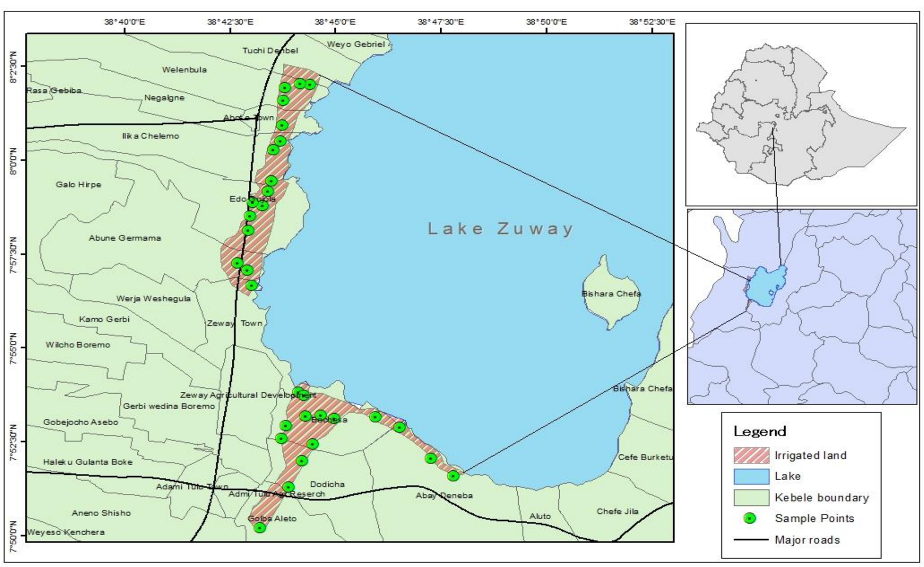

Figure 4: Delineated Irrigated area of Adami Tullu Jiddo Kombolcha District

Soil Sampling, Profile Sampling, Profile Description, and Surface Soil sampling.
The study sites were conducted in four different kebeles found in the Adami Tulu Jido Kombolchaa district known as Bochesa, Ido-Gojola, Desta Abijata, and Dodecha. A total of Nine (9) representative soil profiles of 2*1.5*2m deep were opened from land irrigated with two water sources (Groundwater, Lake Water) and Rainfed. Each soil profile was described by using soil field description guidelines (FAO, 2006). Description of the pedons was done according to soil survey investigation reports (USDA, 1972), guidelines for soil profile description (FAO, 2006). Soil colors have been determined using the Munsel color chart (Munsell Color Campany, 1975). orty-five (45) soil samples were collected from the whole area of the identified horizon. Additionally, surface random composite soil samples (0-20cm depth) were collected from the area, surrounding the pedons. Four (4) water samples were collected from 2 water sources (ground and Lake Water).

Table 1: Coordinate and Elevation of Pedons in Adami Tullu Jiddo Kombolcha district, 2019.

#	Pedon	Alt.(m)	Coordinates		Specific site
			X	Y	
1	LIP1	1651	0469521	0881016	Edo Gojola
2	LIP2	1637	0471193	0872563	Bochessa
3	LIp3	1639	0470200	0870399	Edo Gojola
4	GIPI	1632	0469273	0881611	Edo Gojola
5	GIP2	1643	0471300	0871490	Bochessa
6	GIP3	1603	0460730	0852793	DestaAbijata
7	RP1	1658	0469146	0880099	Edo Gojola
8	RP2	1662	0471303	0871412	Bochessa
9	RP3	1645	0471024	0869701	Dodecha

NB: LIP1: Profile from land irrigated with lake water; GIP1: profile land irrigated with groundwater; RP1: Profile land irrigated with rain fed.

Materials Used
Munsell Color chart, profile description sheet, Soil Auger, Core sampler, spatula, meter tape, plastic hammer, HCl % 0.5

Data Collected

Soil Physical and Chemical Properties
After the arrival of collected and leveled profiles and surface soil samples as well as water samples to the laboratory, it was analyzed for different required physical and chemical parameters. The particle size

distribution of the soils was analyzed according to the procedure outlined by Bouyoucos (1962) with the help of the hydrometer method. The bulk density of the soil was estimated from undisturbed soil samples which were collected by using a core sampler following the procedures used by Black (1965). Each core sample was oven-dried and the bulk density was calculated by dividing the mass of the oven-dry soil by the respective volume as it existed naturally under field conditions.

Soil reaction (pH) and electrical conductivity (EC) were determined by 1:2.5soils: water ratio using a digital pH meter (Van Reeuwijk, 1993). Percent total nitrogen in the samples was determined by the modified Kjeldahl method (Bremner, 1996). Available phosphorus in the soils was extracted by the Olsen method (Olsen *et al*., 1954) and measured on a spectro-photometer. Available K was measured by flame photometer, (Bray & Kurtz, 1945). The Walkley and Black (1934) wet digestion method was used to determine soil organic carbon content and percent soil organic matter was obtained by multiplying percent soil organic carbon by a factor of 1.724 following the assumptions that organic matter is composed of 58% organic carbon.

Exchangeable cations were extracted with 1N NH4OAC at pH7. Soil CEC was determined using ammonium acetate and ethanol as outlined by Chapman (1965). Sodium and potassium contents in the extract were determined by flame photometry (Rowell, 1994). Calcium and magnesium contents were obtained by atomic absorption spectrophotometer. Cation exchange capacity (CEC) was determined using the ammonium distillation method. Exchangeable sodium percentage (ESP) was calculated by using the equation below:

ESP = (Exchangeable Na/CEC) × 100

The percent base saturation of the soils was calculated as the percentage of the sum of exchangeable cations (Ca, Mg, K and Na) to the CEC (Bohn *et al.*, 2001).

Water Sampling and Laboratory Analysis

Irrigation water sources are Lake and ground well in the district. Four representative ground and Lake Water samples were collected from borehole and surface canal by using a 1-liter polyethylene plastic bottle. The collected samples were stored in a laboratory refrigerator for the analysis of physicochemical quality parameters including Electrical conductivity (EC), pH, Cations (Na^+, K^+ Ca^{++} Mg^{++}), Anions (Cl^-, CO_3^{2-} and HCO_3^-), Total dissolved solids(TDS) and total hardness

pH and EC were read on a pH-meter and conductivity-meter, respectively. Carbonates and Bicarbonates were determined by the titration method. The Cl^- was determined by barium sulfate turbidimetric or gravimetric method, Total dissolved solids (TDSs) were estimated by weighing the solid residue obtained by the evaporation of a measured volume of water samples to dryness (Chopra and Kanwar, 1980).

Results and Discussions

Morphological Characteristics of Land Irrigated with Ground Water

Three pedons (profile1, 2 and3) were opened from land irrigated with groundwater; each pedon was morphologically characterized by using FAO, 2006 soil characterization and classification Method. Textural composition, cutans, consistence, horizon boundary, soil colors, profile development, etc have been used as the basis of the soil morphological characteristics.

Table 2: Selected Morphological Characteristics of Land Irrigated with Ground Water

DEPTH(CM)	PEDON 1
0-15	2.5Y4/2 (moist); Clear boundary; no mottles; sandy loam texture; no Coarse fragment; no structure; no crack; no Cutans; no Cementation; no mineral nodules; Low sized fine roots; no pores; and a low sign of carbonates.
15-40	Clear boundary; 2.5Y4/3(moist); no mottles; sandy loam texture; no crack; no structure; no crack; no Cutans; no mineral nodules; very fine roots; no pores; and a low sign of carbonates.
40-70	clear boundary; 2.5Y6/3(moist); no coarse fragment; no structure; no Cutans; no Cementation; no mineral nodules; very low fine roots; no carbonates; no pores. Medium sign of carbonates.
70-100	Diffused boundary; 2.5Y8/1(moist); no mottles; sandy loam texture; Pumas Coarse fragment; no structure; no crack; no Cutans; no Cementation; no mineral nodules; no fine roots; no pores; and no sign of carbonates
100-110	Diffused boundary; 2.5Y8/4(moist); no mottles; Impermeable layer; no structure; no Cutans; strong cementation; no mineral nodules; no roots; no pores; no fine roots; no pores; no sign of carbonates;
>110	Diffused boundary**;** 5Y6/3(moist); no coarse fragments; no structure; no crack; no Cutans; No cementation; no mineral nodules; no roots; no pores; no carbonates.
DEPTH (CM)	PEDON 2
0-102	2.5YR4/2(moist); no mottles; no Coarse fragment; no structure; no crack; no Cutans; no Cementation; no mineral nodules; no fine roots; no pores; and the medium sign of carbonates.
102-200	Clear boundary; 7.5YR4/3(moist); no mottles; no crack; no structure; no Cutans; no mineral nodules; low fine roots; no pores; and the low sign of carbonates.
DEPTH (CM)	PEDON 3
0-36	10YR3/4(moist); no mottles; no Coarse fragment; massive structure; no crack; no Cutans; No Cementation; no mineral nodules; high fine roots; rare small pores; no sign of carbonates.
36-70	10YR3/6(moist); no mottles; no Coarse fragment; no crack; no Cutans; no Cementation; no mineral nodules; abundant fine roots; rare small pores and no sign of carbonates.
70-90	2.5Y5/3(moist); no mottles; low Coarse fragment; no crack; no Cutans; no Cementation; no mineral nodules; low abundant fine roots; no pores and a high sign of carbonates.
90-137	2.5Y6/3 (moist); no mottles; no Coarse fragment; no crack; no Cutans; high Cementation; no mineral nodules; no fine roots; no pores and the medium sign of carbonates.
137-148	Gely2 7/5BC(moist); no mottles; no Coarse fragment; no crack; no Cutans; no Cementation; no mineral nodules; no fine roots; no pores and no sign of carbonates.
148-193	2.5Y6/4(moist); no mottles; no Coarse fragment; no crack; no Cutans; high Cementation; no mineral nodules; no fine roots; no pores and the high sign of carbonates.
193-200	Gely26/10B (moist); no mottles; no Coarse fragment; no crack; no Cutans; no Cementation; no mineral nodules; no fine roots; no pores no sign of carbonates

The result indicated that the maximum depth of the pedons was 200cm and the minimum was 110cm. Accordingly, the number of horizons in each pedon, maximum was seven (7) and the minimum was two (2). These might be due to soil-forming factors and the shallowness of the soil (Table 2). Similar findings were reported by Mulat A. *et al*, 2018 and Kiflu *et al*., 2016 at Tendho sugarcane production farm and the south-central Ethiopia rift valley of Ziway and Alage, respectively.

Morphological Characteristics of Land Irrigated with Lake Water.

Three pedons were opened from land irrigated with lake water. The three pedons were morphologically characterized by the FAO, 2006 profile description method. The maximum depths of the pedons were 200cm. In the first pedon, there are five horizons, in the second pedon three horizons while four horizons are in the third pedons. These differences might be due to the soil-forming factors (time, Climate, etc). The soil of the lake embankment may be collective (Table 3)

Table 3: Selected morphological characteristics of Land irrigated with lake water (L1P1)

DEPTH(CM)	PEDON 1
0-15	10YR3/2(moist); no mottles; no Coarse fragment; no structure; no crack; no Cutans; no Cementation; no mineral nodules; no fine roots; no pores; and a very low sign of carbonates.
15-50	Clear boundary; 10YR4/3(moist); no mottles; no crack; no structure; no Cutans; no mineral nodules; low fine roots; no pores; and a low sign of carbonates.
50-85	Clear boundary; 10YR5/4(moist); no coarse fragment; no structure; no Cutans; no Cementation; no mineral nodules; low to medium-sized fine roots; no pores. low sign of carbonates.
85-110	10YR5/4(moist); no mottles; sandy loam texture; no structure; no crack; no Cutans; no Cementation; no mineral nodules; low to medium abundant fine roots; no pores: and a medium sign of carbonates.
110-200	2.5Y6/3(moist); no mottles; no structure; no crack; no Cutans; no Cementation; no mineral nodules; no fine roots; no pores; and a high sign of carbonates
DEPTH (CM)	PEDON 2
0-60	7.5YR5/2(dry); 2.5YR3/2(moist); no mottles; no Coarse fragment; no crack; no Cutans; No Cementation; no mineral nodules; less fine roots; no pores; no sign of carbonates
60-110	7.5YR6/2(dry); 10YR4/2(moist); no mottles; large abundant Coarse fragment; no crack; no Cutans; no Cementation; no mineral nodules; medium abundant fine roots; no pores and no sign of carbonates.
110-200	7.5YR 8/1(dry); 10YR5/3 (moist); no mottles; low abundant Coarse fragment; no crack; no Cutans; high Cementation; no mineral nodules; low abundant fine roots; no pores and the high sign of carbonates.
DEPTH (CM)	PEDON 3
0-30	Clear boundary**;** 10YR3/4(moist); no mottles; sandy loam texture; no Coarse fragment; no structure; no crack; no Cutans; no Cementation; no mineral nodules; Low sized abundant fine roots; no pores; and the low sign of carbonates.
30-60	Clear boundary; 10YR6/3(moist); no mottles; sandy loam texture; no crack; no structure; no crack; no Cutans; no mineral nodules; very fine roots; no pores; and a high sign of carbonates.
60-150	Clear boundary; no coarse fragment; no structure; no Cutans; no Cementation; no mineral nodules; no fine roots; no pores. high sign of carbonates Pumice
150-200	2.5YR7/3(moist); no mottles; sandy loam texture; no structure; no crack; no Cutans; no Cementation; no mineral nodules; no fine roots; no pores; and the high sign of carbonates

Morphological Characteristics of Rain Fed Agricultural Land.

Under rain-fed agricultural land, three pedons were opened; these pedons were morphologically different horizon-wise. The first and third pedons have been forming eight distinct horizons while the second pedon has four horizons. In all pedons, there were clear boundaries and color within the horizon of the pedons (Table 4).

Table 4: Selected morphological characteristics of rain-fed agricultural land (R1P1)

DEPTH(CM)	PEDON 1
0-25	Clear boundary**;** 10YR3/4(moist); no mottles; sandy loam texture; no Coarse fragment; no structure; no crack; no Cutans; no Cementation; no mineral nodules; Low sized abundant fine roots; no pores; and a very low sign of carbonates.
25-53	Clear boundary; 10YR4/2(moist); no mottles; no crack; no structure; no crack; no Cutans; no mineral nodules; very fine roots; no pores; and a low sign of carbonates.
53-97	Clear boundary; 10YR7/2(moist); no coarse fragment; no structure; no Cutans; no Cementation; no mineral nodules; no fine roots; no pores. Very high sign of carbonates.
97-126	10YR 5/2(moist); no mottles; sandy loam texture; no pores; no structure; no cracks; no Cutans; no Cementation; no mineral nodules; no fine roots; no pores; and a high sign of carbonates.
126-134	Gely17N(moist); no mottles; no structure; no crack; no Cutans; no Cementation; no mineral nodules; no fine roots; no pores; and no sign of carbonates.
134-156	5YR6/2(moist); no mottles; sandy loam texture; no structure; no crack; no Cutans; no Cementation; no mineral nodules; no fine roots; no pores; and no sign of carbonates
156-167	Gley28/10B(moist); no mottles; no structure; no crack; no Cutans; no Cementation; no mineral nodules; no fine roots; no pores; and no sign of carbonates
167-200	2.5Y6/4(moist); no mottles; sandy loam texture; no structure; no crack; no Cutans; no Cementation; no mineral nodules; no fine roots; no pores; and a high sign of carbonates
	PEDON 2
0-50	5YR5/2(dry); 10YR3/1(moist); no mottles; large-sized with few abundances of Coarse fragment; no crack; no Cutans; high Cementation; no mineral nodules; abundant fine roots; no pores and no sign of carbonates.
50-115	7.5YR5/3(dry); 2.5YR3/1(moist); no mottles; no Coarse fragment; no crack; no Cutans; no Cementation; no mineral nodules; medium abundant fine and large roots; no pores and no sign of carbonates.
115-155	10YR6/2(dry); 5Y3/2(moist); no mottles; no Coarse fragment; no crack; no Cutans; high Cementation; no mineral nodules; low abundant fine roots; no pores and no sign of carbonates.
155-200	10YR7/2(dry); 2.5Y3/2 (moist); no mottles; no Coarse fragment; no crack; no Cutans; high Cementation; no mineral nodules; abundant fine roots; no pores and no sign of carbonates
	PEDON3
0-35	7.5YR5/3(dry); 2.5YR2.5/1(moist); no mottles; no Coarse fragment; no crack; no Cutans; No Cementation; no mineral nodules; No fine roots; no pores; the low sign of carbonates.

35-70	7.5YR7/2(dry); 2.5YR3/1(moist); no mottles; no Coarse fragment; no crack; no Cutans; no Cementation; no mineral nodules; medium abundant fine and large roots; no pores and no sign of carbonates
70-94	10YR5/3 (moist); no mottles; no Coarse fragment; no crack; no Cutans; high Cementation; no mineral nodules; low abundant fine roots; no pores and a high sign of carbonates.
94-107	10YR8/1(dry); 5YR7/1 (moist); no mottles; high abundance of Coarse fragment; no crack; no Cutans; high Cementation; no mineral nodules; abundant fine roots; no pores and a low sign of carbonates.
107-120	10YR8/2(dry); 2.5Y5/3 (moist); no mottles; no Coarse fragment; no crack; no Cutans; no Cementation; no mineral nodules; abundant fine roots; no pores and no sign of carbonates.
120-140	2.5Y7/2(dry); 7.5YR5/5 (moist); no mottles; pumice Coarse fragment; no crack; no Cutans; No Cementation; No mineral nodules; abundant fine roots; No pores and a low sign of carbonates.
140-162	2.5Y8/1(dry); 2.5Y6/4(moist); no mottles; no Coarse fragment; no crack; no Cutans; high Cementation; no mineral nodules; no fine roots; no pores and the medium sign of carbonates.
162-200	2.5Y6/4(dry); 2.5Y5/2 (moist); no mottles; no Coarse fragment; no crack; no Cutans; high Cementation; no mineral nodules; no fine roots; no pores and no sign of carbonates.

Soil physical Characteristics of Land irrigated with Groundwater, Lake Water, and Rain Fed

Particle size distribution of soils samples taken from different horizons of profiles opened in irrigated land with groundwater was grouped into sandy clay loam, sandy loam, and sand textural classes (Table, 5). The particle size distribution of the soils of pedons1, 2 and 3 had similarities (Sandy Loam) throughout the profile except in sandy clay loam at 0-15cm layer (pedon 1), 36-70, and 148-193cm depth (pedon 3). The result revealed that soil particle size distribution of land irrigated with groundwater higher number of sand proportions was observed. Soil textural class categorized under sandy loam except in the depth of 110-200cm; and 60-110cm on the second and Third profile (Table 5).In the same manner, Sandy loam, sandy clay loam, and sand soil textural classes were observed on rain-fed agricultural land. In general, the sand content in all opened pedons (>70%) and silty/clay ratios were greater than 0.43 (Table 6). Mulatv *et al*., 2018 and Meron (2007) reported the soil around Adami Tullu was relatively young with a high degree of weathering. This might be due to the high occurrence of sedimentation and erosion, the parent materials are composed of volcanic rocks, with alkaline lavas, ashes, and ignimbrites in soil-forming time.

Table 5: Soil particle distribution of profile sample of land Irrigated with groundwater, Lake Water, and Rainfedat AdamiTullu, 2019

Land Irrigated with Groundwater					
Pedon	Depth(cm)	% sand	%silt	%clay	Class
Profile 1					
	0-15	59	21	20	SCL
	15-40	61	21	18	SL
	40-70	63	25	12	SL
	100-110	81	13	9	SL
	>110	71	21	8	SL
		67	20	13	Sandy loam
Profile2					
	0-102	81	15	4	SL
	102-200	85	11	4	SL
		83	13	4	Sandy loam
Profile3					
	0-36	83	11	6	SL
	36-70	57	31	12	SCL
	70-90	83	11	6	SL
	90-137	57	37	6	SC
	137-148	83	13	4	SL
	148-193	57	27	16	SCL
	193-200	97	1	4	S
		73.85	18.71	7.71	Sandy loam

Table 6: Soil particle distribution of profile sample of land Irrigated with Lake Water at AdamiTullu, 2019.

Land irrigated with lake water					
Profile 1					
	0-30	59	23	18	SL
	30-60	61	21	12	SL
	150-200	59	23	18	SL

		60	22	16	Sandy loam
Pofile2					
	0-15	79	15	6	SL
	15-50	85	11	4	SL
	50-85	85	11	4	SL
	85-110	85	11	4	SL
	110-200	93	5	2	S
		85	11	4	Loamy sand
Profile 3					
	0-60	75	19	6	SL
	60-110	95	3	2	S
	110-200	87	9	4	SL
		86	10	4	Loamy sand
Rain fed agricultural land					
Profile 1					
	0-25	59	23	18	SL
	25-53	67	23	10	SL
	53-97	61	21	18	SL
	97-126	73	17	10	SL
	126-134	65	35	0	SL
	134-156	55	15	30	SCL
	156-167	93	7	0	S
	167-200	57	17	26	SCL
		66	20	14	Sandy loam
Profile 2					
	0-50	75	17	8	SL
	50-115	77	15	8	SL
	115-155	77	15	8	SL
	155-200	73	15	12	SL
		76	16	9	Sandy loam
Profile 3					

	0-35	65	25	10	SCL
	35-70	67	27	6	SCL
	70-94	63	31	6	SCL
	94-107	61	35	4	SC
	107-120	67	29	4	SCL
	120-140	97	3	0	S
	140-162	81	15	4	SL
	162-200	83	13	4	SL
		73	22	5	Sandy loam

NB: SCL: sandy clay loam; SL: sandy loam; S: Sand

Soil Chemical properties of Land Irrigated with Ground water, Lake water, and rain fed

Electrical Conductivity and pH of Soil Irrigated with Ground Water Source

AS result indicated in Table 6, EC of the soil irrigated with groundwater source increased down the depth of profiles in all pedons (1,2 and 3). The maximum EC 1.795 ds/m was recorded in the first profile at the depth of 100-110cm while the minimum was 0.173ds/m that recorded at >110cm soil depth of the profile. Similarly, there was an increasing trend in EC in profiles 2 and 3 down the depth of the pedon(Table 6).

Soil pH in the studied pedons was ranged from 7.9 to 8.8 and 9.5-9.92in the first and second profile, respectively which can be described as moderately alkaline to very strongly alkaline (Jones. J, Benton, 2003). Whereas, it ranged from slightly alkaline (7.20-7.62) to strongly alkaline (8.89-9.4) in the third profile of land irrigated with groundwater (Table 6). The rise in Soil pH might be directly related to the concentration of HCO_3^- and high residue of Sodium carbonates.

Similarly, according to the standard stated by Tekalign (1991), the soil reaction of land irrigated with lake water sources was varied from moderately alkaline to strongly alkaline (7.56- 9.2). pH values similar from top to bottom in the depth, and increased from 8.66-9.2 in profile 2. Whereas on profile three no change from the top to the bottom of the pedon (Table,7). It was moderately alkaline to very strongly alkaline as rating described by Jones. J,Benton (2003).

Percent Exchangeable Sodium percentage (%ESP)

The exchangeable sodium percentage (ESP) is a measure of the amount of exchangeable Na relative to the total cation exchange capacity. As the ESP goes up, more exchangeable Na is available, and the greater the potential to be toxic to plants and soil. As indicated in Table 6, the values of ESP increase down the depth. However, it ranges from 11-49.8%; 30.67-46.36% in the first and second pedons. Even though some irregularities were observed, in the third pedon, in general, the result revealed that in all pedons opened inland irrigated with groundwater the value of ESP >15 implies that high amount of sodium in the profile(Table 6). The %ESP in the land irrigated with lake water have shown < %15 in all opened soil pedon (Table 7). Generally, it is possible to conclude that the values of %ESP in the land irrigated with groundwater is greater than rain-fed agriculture and lesser inland irrigated with lake water.

Cation Exchange Capacity (CEC) in Land Irrigated with Ground Water, Lake Water, and Rain Fed. The result revealed that, low to very high CEC inland irrigated with groundwater in surface and subsurface profiles of pedons. The values of CEC, in profile it was decreased as goes from surface to sub-surface layer of the profile (Table, 6). According to the rating of Booker (1991) low to very high values of CEC were observed in the upper and lower layer of the profile. This might be the soil have high buffering capacity according to Hazelton and Murphy (2007). In table 7 the result should that CEC inland irrigated with lake water varied from 29.69-38.99; 10.50-15.40 and 11.70-22.20 cmol (+) Kg^{-1} in profiles 1, 2, and 3 respectively. The maximum values of 38.99 cmol (+) Kg^{-1} were observed in profile 1 in the subsurface layer of land irrigated with lake water. However, the minimum value was recorded in profile 2 of the subsurface layer (85-110cm). Generally, the value of CEC in profiles 1, 2, and 3 were rated from high, medium and very high (Landon, 1991).

CEC in rain-fed agricultural land varies from medium to very high Categories as Landon (1991) stated. The maximum CEC was observed in profile 1(50.3cmol (+) kg^{-1}, the lowest values of CEC were recorded in profile 3 (Table, 8). This is in line with Kiflu *et al.*, (2016). CEC in Zeway soils ranged from 32.55 to 49.29 cmol kg^{-1}. According to Landon (2014), this range is above the satisfactory value (15-25 cmol kg^{-1}) for agricultural lands.

Tables 6: EC, pH, organic carbon (OC), Total nitrogen (%TN), available phosphorus (P), available potassium, Exchangeable bases (Ca, Mg, Na, K), and CEC land irrigated with groundwater at Adami Tullu.2019.

Pedon	Depth(cm)	EC ds/m	pH	% OC	% TN	AvP(mg kg^{-1})	cmol(+)/Kg					%ESP
							Ca	Mg	K	Na	CEC	
Profile Sample land irrigated with Groundwater												
Profile 1	0-15	0.703	7.9	3.35	0.17	28.02	15.47	3.82	5.44	7.02	41.21	17.03*
	15-40	0.792	8.12	2.54	0.08	4.96	22.57	2.91	4.79	5.96	35.96	16.57*
	40-70	0.944	8.09	2.9	0.09	4.26	24.57	3.46	5.84	3.83	33.94	11.28
	100-110	1.795	8.11	2.36	0.05	3.36	16.02	4.73	8.90	12.30	40.60	30.30*
	>110	0.173	8.8	2.1	0.02	3.46	7.64	2.91	7.26	14.72	29.69	49.58*
Profile 2	0-102	0.245	9.5	1.7	0.03	2.2	22.4	0.80	3.58	5.46	17.80	30.67*
	102-200	0.651	9.92	1.43	0.02	1.32	18.8	0.80	5.03	4.59	9.90	46.36*
Profile 3	0-36	0.525	8.20	1.52	0.09	2.22	6.4	1.60	1.96	3.17	17.60	18.01*
	36-70	0.548	7.90	1.61	0.08	7.02	6.4	0.80	1.46	1.70	10.10	16.83*
	70-90	0.723	7.20	1.25	0.06	1.5	28.8	1.20	1.07	0.46	17.70	5.97
	90-137	0.587	7.25	0.81	0.08	1.26	31.2	1.60	3.31	0.78	11.70	6.67
	137-148	0.521	7.62	1.43	0.08	0.6	7.6	2.00	1.60	0.72	11.40	6.32
	148-193	0.821	8.89	1.25	0.06	0.32	23.6	1.20	4.99	9.96	21.40	46.54*
	193-200	0.898	9.4	1.16	0.11	0.86	2.4	0.00	2.16	3.67	4.60	79.78*

NB:*= %ESP greater than>15

Tables 7: EC, pH, organic carbon (OC), Total nitrogen (%TN), available phosphorus (P), available potassium, Exchangeable bases(Ca, Mg, Na, K), and CEC land irrigated with lake water in Adami Tullu.2019.

Pedon	Depth(cm)	EC dsm^{-1}	pH	% OC	% TN	Avp(mg Kg^{-1}	cmol(+)/Kg					%ESP
							Ca	Mg	K	Na	CEC	
					Profile sample land irrigated with lake water							
Profile 1	0-30	0.817	8.34	2.81	0.17	35.1	15.47	3.28	5.09	6.19	34.54	17.92*
	30-60	0.729	8.38	2.63	0.12	11.52	22.02	2.18	3.98	5.93	29.69	19.97*
	60-150	Pumi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	150-200	0.165	8.33	2.01	0.05	7.5	18.38	2.37	4.89	6.67	38.99	17.11*
Profile 2	0-15	0.684	8.66	2.06	0.02	8.26	12.4	1.6	2.15	0.50	15.40	3.25
	15-50	0.832	8.6	1.61	0.02	1.76	17.6	2.4	1.74	0.13	12.10	1.07
	50-85	0.803	8.73	1.52	0.05	1.24	24.8	2	1.65	0.63	12.50	5.04
	85-110	0.316	8.83	0.89	0.02	0.86	22.4	0.8	0.91	0.72	10.50	6.86
	110-200	0.310	9.2	0.89	0.02	0.34	19.2	1.6	2.62	1.48	14.90	9.93
Profile 3	0-60	0.423	7.56	1.88	0.05	2.4	26	2.8	2.81	1.74	22.20	7.84
	60-110	0.139	7.81	1.34	0.11	25.88	28	1.2	2.28	1.89	17.80	10.62
	110-200	0.336	7.78	1.34	0.03	11.06	22	3.2	3.34	0.26	11.70	2.22

NB: LIP1: Profile from land irrigated with lake water; GIP1:profile land irrigated with groundwater; RP1: Profile land irrigated with Rainfed

Tables 8: EC, pH, organic carbon (OC), Total nitrogen (%TN), available phosphorus (P), available potassium, Exchangeable bases (Ca, Mg, Na, K), and CEC Rain-fed agricultural land in Adami Tullu.2019.

Pedon	Depth(cm)	EC dsm^{-1}	pH	% OC	% TN	AvP(mg kg^{-1})	Cmol(+)/Kg					%ESP
							Ca	Mg	K	Na	CEC	
Profile Sample from Rainfed												
Profile 1	0-25	0.555	7.22	2.99	0.2	33.06	14.92	2.37	4.91	0.978	31.71	3.08
	25-53	0.464	7.27	2.72	0.12	4.76	16.74	2.18	3.91	1.76	41.01	4.29
	53-97	0.997	7.37	2.1	0.05	5.22	21.48	3.64	4.72	4.09	34.54	11.84
	97-126	1.178	8.60	3.17	0.22	2.68	22.75	4.91	3.85	5.74	20.02	28.67
	126-134	0.238	7.59	1.92	0.05	1.24	3.28	1.09	0.70	0.35	13.74	2.55
	134-156	2.411	7.53	0.89	0.06	2.64	7.64	4.00	8.79	16.57	50.30*	32.94
	156-167	1.388	8.20	1.07	0.03	10.56	1.82	0.73	1.84	3.76	14.65	80.86
	167-200	5.843	9.40	1.34	0.02	5.68	1.82	1.09	7.16	26.74	48.88*	54.71
Profile 2	0-50	0.680	8.12	1.97	0.03	5.22	17.2	0.8	2.88	0.15	44.2*	0.34
	50-115	0.249	8.30	2.50	0.02	2.34	22.8	0.8	2.15	0.63	44.9	1.40
	115-155	0.131	8.38	2.24	0.05	3.76	18.4	3.6	1.78	3.93	41.6	9.45
	155-200	0.285	8.78	2.06	0.08	9.46	15.2	1.6	1.52	4.65	39.2	11.86
Profile 3	0-35	0.191	8.34	2.86	0.11	1.82	8.4	2	1.80	0.20	17.40	1.15
	35-70	0.171	8.47	2.59	0.08	2.92	4.8	0.8	1.36	0.22	14.10	1.56
	70-94	0.249	8.55	2.5	0.05	2.52	9.2	0.8	1.84	0.17	9.70	1.75
	94-107	0.228	8.74	2.68	0.08	1.00	17.6	1.2	2.15	0.28	7.10	3.94

	107-120	0.233	8.90	2.59	0.05	9.94	19.2	1.2	2.08	1.09	9.10	11.98
	120-140	0.121	9.10	1.97	0.05	0.6	5.6	1.6	0.43	0.26	3.40**	7.65
	140-162	0.387	7.65	1.34	0.02	1.22	5.6	0.8	1.46	3.41	7.30	46.71
	162-200	0.156	8.20	0.81	0.02	0.62	22.4	3.2	3.08	11.20	22.4	50.00

Surface Sample

Table 9: EC, pH, Avp_ppm, AVK_ppm, %OC, CEC, Exchangeable bases, % SAR and ESP from a Surface sample from land Irrigated from groundwater, Lake water, and Rainfed agricultural land in AdamiTullu district,2019.

Surface sample	EC ds/m	pH	Avp(mg Kg^{-1}	%_OC	Cmol(+)/Kg					% ESP
					CEC	Ca	Mg	Na	K	
GWSS	0.233	8.18	28.34	1.44	22.4	15.04	6.58	1.65	2.8	10.06
	0.393	8.17	25.8	2.16	26.8	20.20	2.82	2.1	3.9	7.84
	0.367	8.21	24.4	0.82	24.4	17.86	7.52	2.37	2.51	15.39
Mean	**0.330***	**8.19****	**26.18**	**1.47**	**24.53**	**17.70**	**5.64**	**2.04**	**3.07**	**11.10*****
LW SS	0.173	8.13	18.97	1.23	28.00	28.2	3.76	0.82	3.97	2.93
	0.395	7.99	26.42	1.33	32.4	21.62	11.28	1.54	2.19	4.75
	0.396	7.81	18.58	1.23	38.4	30.42	11.28	1.00	5.41	2.60
Mean	**0.320***	**7.98****	**21.32**	**1.26**	**32.93**	**26.75**	**8.77**	**1.12**	**3.86**	**3.43*****
RSS	0.445	7.35	54.12	1.13	16.4	12.22	5.64	1.48	1.86	9.02
	0.037	7.83	19.84	2.87	19.00	13.16	3.76	0.78	1.89	6.00
	0.168	7.68	5.16	1.03	24.6	13.86	16.92	0.65	3.42	2.64
Mean	**0.220***	**7.62****	**26.37**	**1.68**	**20.00**	**13.08**	**6.77**	**0.97**	**2.39**	**5.89*****

NB: GWSS: groundwater-surface sample; LWSS lake water surface sample; RSS: Rainfed surface sample

Table 10: Chemical composition of Ground and Lake Water source in Adami Tullu Jiddo Kombolcha District.

Water Source	**Sites**	**EC µS/cm**	**pH**	**Cations (meq/L)**				**Anions (meq/L)**		**TDS(mg/L)**
				Na^+	**K^+**	**Ca^{++}**	**Mg^{++}**	**Cl^-**	**HCO_3^{1-}**	
Ground	1	2.78	8.3	8.23	0.71	Trace	2.29	4.80	1.01	1560
Ground	2	3.10	8.5	9.7	0.52	Trace	0.82	0.90	1.22	1660
Mean		**2.94**	**8.4**	**8.9**	**0.62**	**Trace**	**1.56**	**2.85**	**1.12**	**1610**
Lake	3	0.62	7.7	3.24	0.43	Trace	2.47	0.6	0.32	480
Lake	4	0.62	7.8	3.33	0.48	Trace	0.82	3.40	0.33	460
Mean		**0.62**	**7.75**	**3.29**	**0.46**	**Trace**	**1.65**	**2.0**	**0.33**	**470**
FAO permissible limit (1985)		0-3000	6.0-8.5	0-40	0-2	0-20	0-5	0-30	0-10	0-2000

NB: Sites 1and 3: Bochesa ; 2: Dodicha; 4: Bulbula; meq/L= milli equivalent per litre;µS/cm= micro simen per centimeter; mg/L= milligram per liter

pH and Electrical conductivity of Ground and Lake water source.

The mean pH value of the groundwater from different sites is about 8.4(Table 11), the value it categories under permissible range according to FAO (1985, 2005, and 2013). Similarly, the value of pH of Lake water used for irrigation purposes is about 7.75(Table 11). It also categories under permissible range according to FAO (1985).

Cations, Anions and Total dissolved solids (TDS) of Ground and Lake Water

The mean values of cations (Na^+, K^+ Ca^{++} Mg^{++}), Anions (Cl^- and HCO_3^{1-}), and total dissolved solids(TDS) as listed in Table 11 are under the permissible limit according to FAO(1985).

Conclusions and Recommendations

Soil profile samples were collected from land irrigated with groundwater, Lake water, Rainfed, and surface sample characterized by morphological, physical, and chemical characteristics. Profile depth of land irrigated with groundwater varied from 110-200cm. whereas land irrigated with lake water and Rainfed maximum soil profile depth was 200cm in all opened pedons. Soil physical properties, soil textural class were categorized; Sandy loam, sandy clay loam, and Sand in all sampled pits. The parameters of salinity indicator of (EC, pH, and %ESP) were collected and compared to each Land (land Irrigated with groundwater, lake water, and Rainfed. The mean value of EC dsm^{-1} on land Irrigated with groundwater is much higher than land irrigated with lake water. While low in rain-fed agriculture. pH> 8.5 was observed on both lands irrigated with groundwater and lake water while <8.5 on rain-fed agriculture. > 15% ESP was recorded in land irrigated with groundwater and rain-fed agriculture. In general, based on the soil salinity indicator, land irrigated with groundwater is classified as sodic soil. Similarly, the sign of this problem was slightly observed in both land (land irrigated with Lake Water and Rainfed. Some of the analyzed physicochemical parameters (pH, ECw, cations, anions, and TDS) of water quality of ground and lake water were used for irrigation purposes in the studied area categories under permissible limits. However, the values of the water quality parameter of groundwater were much greater than the lake water. Therefore using groundwater for Irrigation purposes can add cations and anions to the soil. These additions of ionic elements will increase the inherent ionic elements of the soil with the long-term use of groundwater.

Therefore, to tackle this problem proper water management practice, Sodic soil reclamation methods which are, Green manuring & its mulching in the soil for increasing organic carbon in the soil and high degree use of Farm Yard Manure (FYM); Application of soil test based chemical fertilizers and micro-nutrients to ensure Care full and balanced use of fertilizers; Growing of suitable crops/horticultural/agroforestry species including food, fuel& fodder plantations depending upon soil and slope conditions should be practiced.

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Combined Effect of Conventional Compost and Phosphorus fertilizer on Soil fertility and yield of Bread Wheat at Lume District, East Shewa Zone, Oromia, Ethiopia

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Abstract

Soil fertility replenishment through the integrated use of Organic and inorganic input is important to maintain the soil ecosystem and increase productivity. The Experiment was carried out in the Lume district for two consecutive cropping Seasons (2019-2020) on a Farmers' field. The Objectives of the Experiment were to evaluate the combined effect of conventional compost with inorganic fertilizer on the yield of wheat, changes in soil chemical properties after harvest, to characterize and quantify conventional compost by their nutrient content, and to determine the nutrient equivalency of compost concerning inorganic fertilizer urea. Accordingly, in the first phase, conventional compost was prepared from locally available material (Animal manure, teff straw, maize ear leaf, maize stover, Cordia Africana, Croton maychrostachay, leaf of Calotropis procera, Forest soil, and Ash). Nutrient content of Compost and Composting materials were identified and Nitrogen Equivalency of compost was identified. In the second phase, seven treatments list of treatments were arranged on randomized complete block design with three replications. Wheat crop Kekeba variety was sawn with the rate of 150Kg ha^{-1}. Inorganic fertilizer TSP and urea were used as a source for Phosphorus and nitrogen respectively. Nitrogen in urea was balanced with Conventional compost. Agronomic data (plant height, spike length, seed per spike, TKW, grain, and Biomass yield) were collected from the total plot. One hundred twenty-six (126) soil samples were collected from the treated plots. The collected soil was submitted to the Batu soil research center for the analysis of different parameters (pH, Ec, Av. P, %OC, CEC, and Exchangeable bases). Data were analyzed by Fisher LSD at alpha 0.05. The result revealed that maximum yield was obtained the plot treated with 46N kg ha-1 +p critical followed by plot treated with 25% equivalent conventional compost +75% recommended urea + 100% phosphorus critical and 50% equivalent conventional compost +50%recommended urea +100% phosphorus critical which is 4096 kg ha^{-1}, 3424 kg ha^{-1} and 3173 kg ha^{-1} respectively. While the minimum grain yield was obtained from the control plot (1502kg ha^{-1}). Moreover, the economic analysis revealed that the highest net benefit 75,797 Birr ha^{-1} and the second-highest net benefit 61,1180 Birr ha^{-1} were obtained in the treatment that was treated with recommended 100%Pc and 100% urea, as well as 25% urea equivalent compost + (75% Urea + 100% PC) respectively. Therefore, for a treatment to be considered as worthwhile to farmers (100% marginal rate of return) and sustainable crop production and soil productivity, application of 25%urea equivalent compost + (75% urea + 100% Pc) is profitable and recommended for farmers in Lume district.

Keywords: bread wheat, Compost, phosphorus, soil fertility, yield

Introduction

Soil fertility depletion in smallholder farmers is the fundamental root cause for the reduction of per capita food production in Ethiopia (Mulugeta, *et al.*, 2014). Soil fertility problem is going more serious and it is aggravated by erosion, overgrazing, and no return of crop residues since farmers are using the FYM for firewood, less and unbalanced addition of inorganic fertilizer and less provision of alternative soil fertility improvement technologies (Wakene *et al*., 2007; Ajayi *et al*., 2007). To improve soil fertility and nutrient management at farmers' level integrated use of organic and inorganic fertilizer is crucial to increase production per household farmers (Abebe *et al*., 2013 and Ademba *et al*., 2014). Inorganic fertilizer is the priority but due to the escalating price, smallholder farmers' may apply fewer amounts (Tesfaye, 2012. and Ademba *et al*., 2014).).

It is believed that ISFM based crop production systems play important roles in restoring soil fertility and availability of plant nutrients, enhancing crop growth and productivity (Zeleke *et al*., 2010). Compost can be made from different plant and animal remains for soil fertility enhancement through nutrient recycling. Compost application increase organic matter, Improve aggregate stability, Reduce bulk density, Increase water holding capacity, Increase Cation exchange capacity, Enhance the soil microbial community and Provide nutrients to the soil (Flavel and Murphy, 2006). The nutrient supply potential of compost was studied in western Oromia in the Bako area. According to this study 5ton, compost ha^{-1} supplies 171kg N, 41.1kg P, and 11.42kg K nutrients to the soil (Wakene Negassa *et al*., 2001).

According to Abebe *et al*., (2013), integrated use of 12t ha^{-1} FYM with 28/12 N/P_2O_5 saves 75% cost of commercial fertilizer for the smallholder farmers. Similarly, according to Tesfaye (2012), the application of 20-30t ha^{-1} cattle manure resulted in saving 33.3% and 66.6% of the recommended NP fertilizers, respectively. Habtamu Admas (2015) also stated that the combined effect of compost and inorganic fertilizer supplies more nutrients to the soil. For example, a plot treated with 120kgN, 10t compost, and 30kg sulfur ha^{-1} supplies the highest total nitrogen, available phosphorus, and sulfur than the control. Similarly, the plot treated with 60kgN and 10t compost ha^{-1} supplies the highest organic carbon and CEC.

Organic additions to the soil have been considered as an important input to maintain the soil ecosystem. But, the Application of inorganic fertilizer year to year without the addition of organic matter might be considered as soil fertility decline and production reduction. Soils of the study area lost their inherent fertility status therefore it needs external input to replenish fertility. Combined uses of organic and inorganic fertilizers are the backbone of the integrated soil fertility management approach, which is known to increase nutrient use efficiency and reduce environmental stress (Bationo, 2008).

Therefore for sustaining production integrated soil fertility replenishment is critical.

Objectives

- To evaluate and recommend the best combination of conventional compost with inorganic fertilizer on yield of wheat and changes in soil chemical properties after harvest.
- To characterize and quantify conventional compost by its nutrient content.
- To determine the nutrient equivalency of compost for inorganic fertilizer.

Materials and Methods

Description of the study area

The study was conducted in Lume district, East Shoa Zone of Oromia Whose capital town is located 73 kilometers far from Finfine (Addis Ababa) to the East. Geographically Lume district located between 8^0

24’300” to 8^0 49’30” North and 39^0 01'00" to 39^0 17'00" East. The Elevation ranges from 1590 to 2512 meters above sea level, whereas the average elevation is 1909 meters above sea level.

According to FAO (2006) soil classification, soil of the Lume district is grouped into seven soil types, which are mainly dominated by Eutric Vertisol (44.84%), mollic andosols (21.69), and Ludovic Phaeozems (14.76). Generally, major land uses are grouped into four that include Agricultural land (93.13%), Plantation forest (2.76%), settlements (2.34%), and flower farms (1.77%).

Methodologies

Site selection for Pit

The sites were selected purposively based on the availability of Composting material and water for compost making.

Compost Pit Preparation

The pit was prepared with the size of L*W*D (1m*1.5m*1m).

Composting Material Collection

Locally available Composting material(Animal manure, Maize Stover, Forest Soil, Ash, Teff straw, Green leaf (*Croton macrostachyus, Cordia Africana, Calotropis procera, weed, Field peas(atara),* were collected from the surrounding compounds. Then, weighing the materials and added to the pit layer by layer.

Compost Making

Following the procedure of Hilu *et al*., 2011 and (Shah *et al*., 2015) each composting material was weighted and added in the pit sequential, Layer1, layer2, Layer 3, until the heaps were about 1meter tall. Three Ventilation holes and two testing sticks were placed at the center to check the decomposition process. At the bottom, 4kg maize Stover up to 10cm thick and the three layers 30cm deep were laid. In layers 1,2,3 equal amount(177kg) of Composting materials(Forest soil(12kg), Animal manure (84kg); Ash(12kg); pea residue(7kg); Leaf (Croton, Cordia and Calotropis (46kg), Teff straw(16kg) were pulled together and form a layer. In addition 20lt of water was sprinkled in each layer (Figure 1).

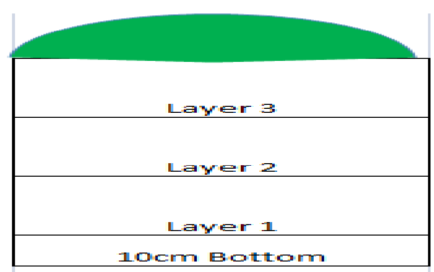

Figure 2: Compost Pile in the pit

Nutrient contents determination of compost materials before decomposition.

Samples of composting material were brought to the laboratory for identifying nutrients before composting. Each material was oven-dried at 65^oc for 24hrs. After getting constant weight it was grounded by Piestel and Mortar. Accordingly stored to sample box up to parameters were analyzed.

Soil and Compost Analysis

After 90 days of decomposition, the piled materials were shrinks to 45cm depth in the pit. To keep the uniformity and representativeness of the compost, samples were withdrawn from 0-15, 15-30, and 30-45cm depth from the pit for nutrient analysis. The samples were submitted to Horticop Ethiopia for analysis of Ammonium nitrate, Nitrate nitrogen, and % total nitrogen. The result of % total nitrogen was pulled together and calculated nitrogen equivalency from the average value (Table 1).

Soil Analysis

Pre planting soil samples were collected from the experimental field while after harvest was also collected from compost treated plots and analyzed at Batu Soil Research Center. The particle size distribution of the soils was analyzed according to the procedure outlined by Bouyoucos (1962) with the help of the hydrometer method. Soil reaction (pH) and electrical conductivity (EC) were determined by 1:2.5 soils: water ratio using a digital pH-meter (Van Reeuwijk, 1993). Ammonium nitrogen and nitrate nitrogen were determined by 1:5 steam distillation %Total nitrogen in the samples was determined by the modified Kjeldahl distillation method (Bremner, 1996). Available phosphorus in the soils was extracted by the Olsen method (Olsen *et al*., 1954) and measured on a spectrophotometer. Available K was measured by flame photometer, (Bray & Kurtz, 1945). The Walkley and Black (1934) wet digestion method was used to determine soil organic carbon content and percent soil organic matter was obtained by multiplying percent soil organic carbon by a factor of 1.724 following the assumptions that organic matter is composed of 58% organic carbon.

Exchangeable cations were extracted with 1N NH4OAC at pH7. Soil CEC was determined using ammonium acetate and ethanol as outlined by Chapman (1965). Sodium and potassium contents in the extract were determined by flame photometry (Rowell, 1994). Calcium and magnesium contents were obtained by atomic absorption spectrophotometer. Cation exchange capacity (CEC) was determined using the ammonium distillation method.

Treatments and Experimental Design

The treatments will have four levels of equivalent conventional compost and recommended Phosphorus critical (optimum46N +P-critical). The treatments were being arranged on randomized Complete Block Design (RCBD) with three replications. The test crop was bread wheat “variety Kekeba “The plot size was 4m*3m. The land was prepared by plow oxen; it was planted with 20cm row spacing.

Table 1. Description of treatment of Compost application at Lume District

Treatment	Description
1	No application
2	25% compost equivalent +(75% UREA + 100% PC)
3	50% compost equivalent N+ (50% UREA +100% PC)
4	75%compost equivalent N + (25% UREA +100% PC)
5	100%Compost equivalent N(Zero % UREA+ 100% PC)
6	100% UREA + 100% PC
7	100%Compost alone

PC= Phosphorus Critical;

Data Collection
Agronomic data plant height, thousand seed weight, spike length, aboveground biomass yield, and grain yield were collected.

Data Analysis
All Soil and Yield data were subjected to analysis of variance (ANOVA), using Statistic Analysis System (SAS) Software package Version 2002. The differences among the treatments were compared by using the Duncan Multiple Range Test (DMRT) at the $P < 0.05$ probability level. Partial budget analysis was employed for Economic analysis of the treatments.

Economic Analysis
For economically feasible treatments partial budget analysis was employed. Dominance and marginal rate of return were carried out to estimate economic parameters; the marketable wheat yield was valued based on average farm gate price collected from the local markets during the two (2019-2020) years of production immediately after harvest where the average wheat price was 20 Birr kg^{-1}. The average cost of TSP, Urea, and Conventional compost were 18.99, 14.89, and 1 Birr kg^{-1}, respectively.

In the partial budget analysis, total variable cost, gross field benefit, net benefit, and marginal rate of return were employed. Total variable cost refers to the sum of all costs of variable inputs (fertilizers) and management practices. The gross field benefit ha^{-1} was obtained as the products of the real price and the mean wheat yield for each treatment adjusted to 10% whereas the net benefit ha^{-1} is the difference between the gross field benefit and total variable cost (CIMMYT, 1988). The dominance analysis procedure, which was used to select potentially profitable treatments, comprised ranking of treatments in ascending order of total variable cost from the lowest to the highest cost to eliminate treatments costing more but producing a lower net benefit than the next lowest costing treatment was undertaken. For each pair of ranked non-dominated treatments, a marginal rate of return was also calculated in percent. The percent marginal rate of return between any pair of undominated treatments denoting the return per unit of investment for crop production was analyzed. The marginal rate of return (%) was calculated (CIMMYT, 1988).

$$\textbf{MRR (\%)} = (\Delta NB/\Delta TVC)*100$$

Results and Discussions

Some Soil Physiochemical Properties and Conventional Compost Before Planting
The experiment was undertaken on 12 (twelve) sites in the Lume district. Soils of experimental sites were collected from farmers' fields and analyzed at the Batu soil research center. TSP (Triple supper phosphate) was used as a source of phosphorus fertilizer; it was calculated based on the available initial phosphorus by using the following formula:-

P applied Kg/ha= (Pc-Po)*Pf *whereas:-*

- P applied:- Phosphorus to be applied
- Pc: phosphorus Critical (19);
- Po: phosphorus initial and Pf: phosphorus factor (4.92).

Table 2. Some soil Nutrient content and Particle size distribution of before planting Lume, 2019.

OC%	**TN%**	**CMOL KG^{-1}**					**% SAND**	**%SILT**	**%CLAY**	**CLASS**
		CEC	Ca	Mg	K	Na				
1.58	0.25	16.65	10.75	2.38	1.76	0.26	42.00	33.00	25.00	SCL

**NB: SCL: Sandy Clay Loam

Sites that have phosphorus values below the critical limits were selected for experimental sites (Table 3). Soils of the experimental site have a sandy clay loam textural class. The total N (0.25%) and Organic Carbon (1.58%) were ranged in moderate according to Tekalign (1991). Available p was in the very low, low, and medium-range (<5, 5-9 and 10-17mg kg^{-1}) Cottenie (1980). The CEC of soil was categorized as medium according to London (1991). The value of exchangeable Ca and Na were in the low range while Mg and K were medium and very high range respectively (FAO, 2006)

Table 3. Class of soil initial available phosphorus of experimental sites according to Cottenie (1980)

SITES	**AV. P (PPM)**	**CATEGORIES**
1	3.08	Very low
2	7.04	low
3	8.98	low
4	10.74	High
5	7.86	low
6	12.12	medium
7	8.08	low
8	10.96	medium
9	12.88	medium
10	11.04	medium
11	6.99	low
12	9.12	low
	9.07	

Sites=1: FTC; 2: Dechassa Jote; 3:Worku Dechassa; 4: Girma Tullu; 5:FTC Tede Dildima; 6:Amsalu Bedhadha; 7:Girma Wolde; 8: Tesfaye Dechassa; 9:Dereje Haile; 10: Shimeles Girma; 11: Dechassa_1; 12: Worku_1.

Nutrient Content of Composting Material

Conventional Compost is made from different available organic materials. Animal manure, Maize stover, teff straw, and residue of field peas are waste organic materials found in the agricultural ecosystem and some green leaves (Cordia, *Croton, and Calotropis*) were used for conventional compost making. Farmers are Conventional they collected and pile near the homestead for decomposition. Composting materials were analyzed and some nutrient content organic carbon and %TN before decomposition were identified.

The higher %organic carbon was found to be on maize Stover (49.29%) while the lower organic carbon was on Animal manure (33.88%) (Table 4). % Total nitrogen in the composting material varies from 1.11% in Animal manure were as to 5.68% in the leaf of *Cordia Africana*. The variation of nutrients in composting material might be due to the nutrient mining potential reserved in the leaf of the plants.

Table 4: Total nitrogen, Organic carbon, and Exchangeable bases of composting material in Lume district, 2019.

COMPOSTING MATERIAL	%OC	%TN	CMOL KG^{-1}			
			Ca	Mg	K	Na
ANIMAL MANURE	33.88	1.11	10.63	3.75	9.96	1.63
MAIZE STOVER	49.29	1.45	4.00	2.75	9.32	0.28
TEFF STRAW	44.28	1.14	5.25	0.75	8.64	1.00
THE RESIDUE OF FIELD PENS	43.72	1.25	6.00	2.00	12.93	1.70
LEAF OF *CROTON (BEKENISA)*	35.36	5.11	1.75	4.00	10.31	0.00
LEAF OF *CORDIA AFRICANA*	36.29	5.68	8.5	2.25	8.86	0.20
LEAF OF *CALOTROPIS PROCERA*	40.93	4.97	2.75	3.00	10.72	2.17
	33-49	1.11-5.68	1.75-10.63	0.75-4	8.64-12.93	0-2.17

Nutrient Concentration in Conventional Compost

Five Composite Compost samples were collected from 0-15cm, 15-30cm, and 30-45cm depth from each

PIT	DEPTH(CM)	PH: H_2O	NH4N (PPM)	NO3N PPM	TN %	OC %	C: N	AV. PMG KG^{-1}	CMOL KG^{-1}				
									CEC	Na	K	Ca	Mg
1	0-15	7.04	39.23	25.22	0.52	0.25	0.48	9.66	36.4	5.10	8.60	16.20	6.48
	15-30	7.12	48.34	35.03	0.56	0.20	0.36	9.06	32.40	4.69	8.64	14.58	4.86
	30-45	7.21	43.44	44.14	0.87	0.22	0.25	9.62	32.00	5.16	8.42	12.96	5.67
2	0-15	7.30	35.38	35.03	0.87	0.35	0.40	6.62	41.60	4.90	12.7	12.15	10.53
	15-30	7.42	41.34	42.39	0.89	0.36	0.40	8.62	42.20	4.47	11.4	15.39	8.10
	30-45	7.37	48.34	38.88	0.77	0.35	0.45	7.96	40.80	4.38	11.5	18.63	6.48
AVERAGE		7.24	42.67	40.11	0.75	0.29	0.39	8.59	37.57	4.78	10.3	14.99	7.20

pit. The samples were subjected to analysis for Ammonium Nitrogen, Nitrate- Nitrogen, percent total nitrogen, %OC, Available phosphorus, CEC, and Exchangeable bases. The average values are indicated in Table 5. The total nitrogen obtained from conventional composts was 0.745%. According to (Tolera *et al.*, 2020) the concentration of total nitrogen obtained matured conventional was found to be ideal and optimal. The average value of % organic carbon obtained from the matured conventional compost was found to be 0.29%. Available phosphorus obtained from the matured conventional compost was 8.59 mg kg^{-1}

Table 5. Nutrient Content of Conventional compost Prepared from different composting material in Lume district, 2019.

Table 6. Nitrogen Equivalency Converted from Compost

%N IN CONVENTIONAL COMPOST	N EQUIVALENCY FROM UREA	N EQUIVALENCY T/HA
0.745	6174.49	6.174

Soil pH

According to Jones, J. Benton (2003), the Soil pH of all treated plots was slightly alkaline (7.4-7.8) (Table 7). After harvest medium to high values of available phosphorus, residues were registered on T2, T3, T4, T5, and T6 according to Cottenie (1980).

Organic Carbon

According to Tekalign (1991) pre soil organic carbon(1.58%) is under medium class and similarly post harvested treated experimental plots also ranges (1.19 – 1.37% OC) which were categorized under moderate rates which indicates that the soil has medium potential to maintain and supply mineralize nitrogen to the plants during growth.

Table 7. Some soil chemical properties after harvest

TRT	DESCRIPTION	EC MMHOS CM-1	PH	AV.P (MG KG^{-1})	OC %
1	No application	0.11±0.05	7.60±0.49	12.16±5.84	1.21±0.34
2	25%compost equivalent +(75% urea + 100% PC)	0.12±0.06	7.59±0.48	17.27±8.12	1.19±0.34
3	50% compost equivalent N+ (50% UREA +100%PC)	0.13±0.06	7.63±0.47	18.05±10.33	1.38±0.64
4	75%compost equivalent N + (25% UREA +100%PC)	0.11±0.06	7.63±0.49	18.45±8.93	1.21±0.25
5	100%Compost equivalent N(Zero % UREA+ 100% PC)	0.12±0.06	7.69±0.53	17.64±11.80	1.25±0.31
6	100% UREA + 100% PC	0.12±0.06	7.62±0.48	18.94±13.14	1.20±0.33
7	100%Compost alone	0.13±0.06	7.63±0.44	12.81±6.69	1.37±0.27

Electrical Conductivity

The Electrical conductivity of the post harvested treated plots ranges 0.11 to 0.13 mmhos/cm and therefore EC of all treated composts are low according to rating of Horneck *et al.* (2011), which indicates the suitability of the soil for the proceeding crop production.

Available P

The average of available initial soil phosphorus of study area was 9.05 ppm and which is categorized under medium class according to (Olsen *et al*., 1954). However, post-harvest available soil phosphorus of almost all study plot were shifts to the high available soil phosphorus class except the control and a plot treated with compost alone(Table 7). This indicated that, applications of compost with inorganic fertilizer left some nutrient residues for the next crop production and secure sustainable soil productivity.

Wheat Grain Yield and Yield Components

The analysis of variance showed that grain yield; plant height, spike length, and seed per spike were highly significantly (p< 0.001) affected by the application of Conventional compost and NP fertilizers (Table 8). While, other yield components were not significantly affected by treatments applied.

Table 8. Grain yield, plant height, spike length, and seed/ spike as influenced by Conventional compost and NP fertilizers at Lume district.

TREATMENTS	PH (CM)	SL (CM)	NSPS	GYLD KG HA-^{1}
NO APPLICATION	63.66^{d}	6.11^{c}	30^{b}	1502^{c}
25%N CC + (75% UREA + 100% PC)	77.05^{ba}	6.86^{ba}	35.67^{a}	3424^{ba}
50%N EQU. CC +(50% UREA + 100% PC)	74.47^{bc}	6.80^{ba}	33.78^{a}	3173^{b}
75%N EQU. CC+(25% UREA + 100% PC)	71.39^{c}	6.43^{bc}	32.33^{ab}	3004^{bc}
100% N EQU CC + 100% PC)	65.95^{d}	6.15^{c}	29.33^{b}	2941.2^{bc}
RR NP (100% UREA +100% PC)	79.30^{a}	6.97^{a}	35.54^{a}	4096^{a}
100% COMPOST ALONE	66.49^{d}	6.18^{c}	29.62^{b}	3027^{bc}
CV (%)	12.65	13.26	22.09	24.37
LSD	4.58	0.44	3.63	781.62
P-VALUES	<.0001	<.0001	<.0001	0.0019

PH= plant height, SL= Spike length, NSPS= Number of seed per spike, GYld= Grain yield, N= Nitrogen, Pc= Phosphorus critical, N equ. CC= Nitrogen equivalent conventional compost, RR NP = Reccomended rate of nitrogen and Phosphorus, N CC= nitrogen equivalent conventional compost.

Plant Height

Analysis of variance showed that the combined effect of NP and compost rates were highly significant (P <0.001) influenced on plant height of bread wheat. The highest plant height (79.30 cm) was recorded by application rate of 100% urea+100% phosphorus while the shortest plant height (63.66 cm) was resulted by control plot (Table 8). This result is parallel with the finding of (Lakew, 2019) who recorded the highest (88.86 cm) plant height by application of 60.5N/23 P Kg ha^{-1} for bread wheat

Spike Length

Analysis of variance showed that the combined effect of NP and compost rates were highly significant (P <0.001) influenced on spike length of bread wheat. The highest spike length (6.97 cm) was recorded by application rate of 100% urea+100% phosphorus while the shortest plant height (6.11 cm) was resulted by control plot (Table 8). This result is parallel with (Worku *et al*., 2022) who reported The longest spike length (7.61 cm) from the plot treated by 250 kg/ha NPS fertilizer rate which was statistically at par with (150, 200) kg/ha NPS for food barley.

Number of Seed per Spike

Analysis of variance showed that the combined effect of NP and compost rates were highly significant ($P < 0.001$) influenced on the number of seeds per spike of bread wheat. The highest number of seeds per spike (35.67) was recorded by application rate of 50% N equal conventional compost + (50% Urea + 100% Pc) while the shortest plant height (30) was recorded by control plot (Table 8). The result is in agreement with the finding of (Admasu and Tadesse, 2018) who reported the Higher (46) number of seed spike^{-1} of bread wheat by application of recommended rate of N and P from inorganic fertilizer, and 33: 33: 33 % RR VC (recommended vermin compost): RR C (recommended urea equivalent vermin compost): RR IF (recommended rate of inorganic fertilizer NP).

Grain Yield

Analysis of variance showed that the combined effect of NP and compost rates were highly significant ($P < 0.001$) influenced on grain yield of bread wheat. The highest grain yield (4096) was recorded by application rate of 100% urea+100% phosphorus which was statistically at par with (3424 kg ha^{-1}) which was recorded by treatment treated with 25% nitrogen equivalent conventional compost+ (75% UREA + 100% PC) while the shortest plant height (6.11 cm) was resulted by control plot (Table 8). In line with the finding of (Shah *et al.*, 2009) who recorded maximum (3248 kg ha^{-1}) grain yield of wheat from treatment applied with 25% N was applied from poultry manure and 75% from mineral fertilizer. This result is also parallel with the finding of (Alemu *et al*., 2016) who recorded the highest grain yield of Teff from a plot treated with 64/46 N/P_2O_5 kg ha^{-1} and 7.5 tons ha^{-1} of compost.

Partial Budget Analysis

Table 9: Partial budget on Conventional Compost and P fertilizer on wheat in Lume district

TRT	CC QT HA^{-1}	TSP (KG HA^{-1})	UREA (KG HA^{-1}	AD GY (KGHA^{-1})	GFB ETB HA^{-1}	TVC ETB HA^{-1}	NB ETB HA^{-1}	MRR
1	0	0	0	1,502	30040	0	30040	0
2	15.5	244	75	3,424	68480	7300	61180	622
3	31	244	50	3,173	63460	8478	54982	D
4	46.5	244	25	3,004	60080	9656	50424	D
5	62	244	0	2,941	58824	10834	47990	D
6	0	244	100	4,096	81920	6123	75797	747
7	62	0	0	3,027	60540	6200	54340	D

NB: Trt 1: No application;2: 25%nitrogen equivalent conventional compost+ (75% UREA + 100% PC);3: 50%N equ conventional compost +(50% UREA + 100% PC); 4: 75%N equ conventional compost+(25% UREA + 100% PC); 5: 100% N equ conventional compost +(Zero % UREA + 100% PC);6: Recommended NP (100% UREA +100% PC);7: 100% Compost alone; CC = Conventional compost; TVC = Total variable cost; Ad GY = Adjusted grain yield; GFB = Gross field benefit; NB = Net benefit; TSP cost = 18.99 Birr kg^{-1}, UREA cost = 14.89 Birr kg-1of N, TSP, wheat grain = 20 Birr kg^{-1}, compostr cost = 1 Birr kgha^{-1}, MRR (%) = Marginal rate of return, D= Dominated treatment. Qt= Quintal

To identify treatments with the optimum return to the farmer's investment, marginal analysis was performed on non-dominated treatments. For a treatment to be considered worthwhile to farmers (100% marginal rate of return (MRR)) was considered as the minimum acceptable rate of return (CIMMYT, 1988). As indicated in table 9, the partial budget and dominance analysis showed that the highest net benefit 75,797 Birr ha^{-1} and the second net benefit 61,180 Birr ha^{-1} were obtained in the treatment that were treated with recommended 100% Pc and 100% urea, and 25% urea equivalent compost + (75% Urea + 100% PC) respectively; While the lowest (30040 Birr ha^{-1}) net benefit was obtained on control plot.

Conclusion and Recommendation

Integrated uses of organic and inorganic fertilizer have the potential to increase grain yield and soil fertility. The effect of Conventional compost and inorganic phosphorus fertilizer was carried out on 12 sites on the grain yield of wheat in the Lume district (2019-2020). Conventional Compost has been prepared at FTC's. The Nitrogen Equivalency of compost was determined and adjusted by Urea Fertilizer. The combined application of Conventional compost to phosphorus fertilizer increase wheat grain yield and soil phosphorus values. Moreover, the economic analysis revealed that the highest net benefit 75,797 Birr ha^{-1} and the second-highest net benefit 61,1180 Birr ha-1 were obtained in the treatment that was treated with recommended 100%Pc and 100% urea, as well as 25% urea equivalent compost + (75% Urea + 100% PC) respectively. Therefore, for a treatment to be considered as worthwhile to farmers (100% marginal rate of return) and sustainable crop production and soil productivity, application of 25%urea equivalent compost + (75% urea + 100% Pc) is profitable and recommended for farmers in Lume district.

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Soil Test based Crop Response Phosphorus Calibration Study on Bread Wheat (TriticumAestivum L.) in Dugda District, East Shewa Zone, and Oromia, Ethiopia

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Abstract

Nutrient mining due to sub-optimal fertilizer use on one hand and unbalanced fertilizer use on the other have favored the emergence of multi-nutrient deficiency in Ethiopian soils. Therefore, the study was conducted on twenty-six farmers' fields in Dugda District of East Shewa Zone of Oromia, during the main cropping seasons of 2018-2020. These studies were conducted to determine the economically optimum rate of nitrogen fertilizer in the first year Phosphorus critical (Pc) and phosphorus requirement factor (Pf) in the second year respectively. The treatments consisted of factorial combinations of three levels of TSP (0, 100, and 200) kg ha^{-1} with six levels of nitrogen (0, 23, 46, 69 92, and 115) kg ha^{-1} that gave a total of eighteen treatments. However, in the second two consecutive years, the experiment was conducted to determine phosphorus critical (Pc) and phosphorus requirement factor (Pf), and the treatments consisted of six levels of phosphorus (0, 10, 20, 30, 40, and 50) kg ha^{-1} combined with a single level of nitrogen (69 kg ha^{-1}) that gave a total of seven treatments. The experiments were laid out in randomized complete block design (RCBD) with two replications and the gross plot size was 4 m x 5 m (20 m^2) were used to determine optimum nitrogen in the first year and 4m x 5m (20 m^2) and phosphorus critical (Pc) and also harvested from 4m^2 plot areas. The analysis of variance indicated that Plant height, spike length, number of seeds per spike, biomass yield, and grain yield were highly significantly (p <0.01) influenced by the main effect of nitrogen fertilizer rates. However except for the number of seed per spike, TSP fertilizer significantly (p<0.05) affect plant height and the number of seed per spike as well as highly significantly (p <0.01) biomass and grain yield of bread wheat. The highest (68.76 cm) plant height, the highest (41.02) seed per spike, the highest (8867 kg ha^{-1}) biomass, and the highest (3293 kg ha^{-1}) grain yield were recorded by 200 kg TSP ha^{-1}. The highest (71.79 cm) plant height, the highest (9483 kg ha^{-1}) biomass, and the highest (3603 kg ha^{-1}) grain yield were recorded by 69 kg N ha^{-1}. However, the highest (6.867 cm) spike length and the highest (41.79) numbers of seed per spike were recorded by 115 kg N ha^{-1}. Moreover, from all tasted parameters the lowest values were recorded by control plots. The economic analysis revealed that for a treatment to be considered as worthwhile to farmers (100% marginal rate of return) application of 69 kg N ha^{-1}) is profitable which gave the highest (98871 Birr) net return with an acceptable (4607%) marginal rate of return and recommended for farmers in Dugda district. On the other hand, the analysis of variance indicated that Plant height, spike length, number of seeds per spike, biomass yield, and grain yield were highly significantly (p <0.01) influenced by soil test-based phosphorus fertilizer application. The result indicated that the highest (83.9 cm) plant height, the highest (9900 kg ha^{-1}) biomass, and the highest (39980 kg ha^{-1}) grain yield were recorded by 50 kg P ha^{-1}. Moreover, 10ppm phosphorus critical (Pc) and 6.45ppm phosphorus requirement factor (Pf) were identified for bread wheat production for the farmers of Dugda District.

Key words: - Applied phosphorus, bread wheat, Cate and Nelson graph, TSP, Nitrogen, Phosphorous critical (Pc) phosphorus requirement factor (Pf), Soil and Yield.

Introduction

Wheat is a type of cereal crop cultivated for its grain and used worldwide as a staple food. The many species of wheat together make up the genus Triticum; the most widely grown is common wheat (*Triticum aestivum*) (James, 2014). Ethiopia is also one of the largest wheat producers in Sub-Saharan Africa and approximately 80% of the wheat area is planted to bread wheat (Asfaw et al. 2013). In Ethiopia wheat is mainly grown in the highlands, which lie between 6 and 16° N latitude and 35 and 42° E longitude, at altitudes ranging from 1500 to 2800 m above sea level and mean minimum temperatures of 6°C to 11°C. In Arsi, Bale, and Shewa Zones, the soil, moisture, and disease conditions within the range of 1900-2300m altitude zone are favorable for the production of early and intermediate maturing varieties of bread wheat. This is estimated to comprise 25% of the total wheat production area, while the remaining 75% falls in the 2300-2700 m altitude zone (MOA, 2016).

Ethiopia is not self-sufficient in wheat and has a substantial gap primarily due to inefficient transfer of technology and the lack of necessary inputs and blanket type fertilizer application based on soil color characteristics rather than on soil test results and crop requirements. According to the report of the Food and Agriculture Organization of the United Nations (FAOSTAT, 2021) world total, wheat production in 2019 was estimated at 765 million tons from a total of 215 million hectares area harvested; with an average yield of 3547 kg ha^{-1}. However, in Ethiopia, wheat production in 2019 was estimated at 5.3 million tons from 1.7 million ha area harvested with an average yield of 2970 kg ha^{-1}. According to this report despite the large area under wheat in Ethiopia, the average yield of wheat is 19.4 % far below the world's average yield.

Each type of plant is unique and has an optimum nutrient range as well as a minimum required level. Below this minimum level, plants start to show nutrient deficiency symptoms. Excessive nutrient uptake can also cause poor growth because of toxicity. Therefore, the proper amount of application and the placement of nutrients are important (Silva and Uchida, 2000). Moreover, Sonon and Zhang (2014) reported that soil test calibration is specific for each crop type and they may also differ by soil type, climate, and the crop variety and relates soil test measurement in terms of crop response (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. The farmers in most parts of the country in general and in the study area, in particular, were applied fertilizers based on blanket recommendation (100 kg ha^{-1} Urea and 100 kg TSP ha^{-1} rather than soil test-based crop response fertilizers application method. Due to this soil test based crop response phosphorus calibration study was conducted for bread wheat with the following objectives:-

- ❖ To determine economically optimum N fertilizer for bread wheat in Dugda District.
- ❖ To determine Phosphorus critical and phosphorus requirement factor for bread wheat.

Materials and Methods

Description of the Experimental Site

The experiment was conducted on a Farmers' field in Dugda District, East Shewa Zone of Oromia Regional State, central Ethiopia, for three consecutive years (2018 -2020). It is located in the Great Rift Valley. Dugda is bordered on the southeast by Lake Zuway, on the south by Adami Tullu Jido Kombolcha, on the west by the Southern Nations, Nationalities and Peoples Region, on the northwest by the Southwest Shewa Zone, on the north by the Bora District. Meki is the town of Dugda district and it has a latitude and longitude of 8°9′N 38°49′E/ 8.150°N 38.817°E with an elevation of 1636 meters above sea level.

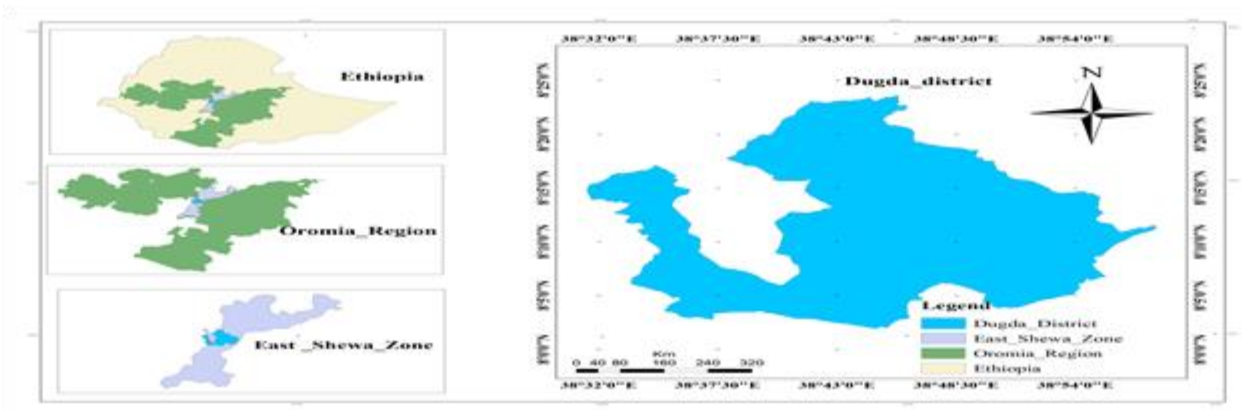

Figure 1. Location Map of Dugda District

Experimental Materials

- ✓ Bread wheat variety (Qaqaba) was used for the study area.
- ✓ TSP (46% P_2O_5),
- ✓ Urea (46% N) were used

Treatments and Experimental Design

In the first year, the experiment was conducted to determine optimum nitrogen rate and the treatments consisted of factorial combinations of three levels of TSP (0, 100, and 200) kg ha^{-1} with six levels of nitrogen (0, 23, 46, 69 92 and 115) kg ha^{-1} that gave a total of eighteen treatments. However, by using the determined optimum Nitrogen (69 kg ha^{-1}) at the first year; phosphorus critical (Pc) and phosphorus requirement factor (Pf) were determined in the second two consecutive years. So the treatments consisted of six levels of phosphorus (0, 10, 20, 30, 40, and 50) kg ha^{-1} combined with a single level of nitrogen (69 kg ha^{-1}) that gave a total of seven treatments. The experiments were laid out in randomized complete block design (RCBD) with two replications and the gross plot size was 4 m x 5 m (20 m^2) were used and also harvested from 4 m^2 plot areas.

Management of the Experiment

The experimental fields were prepared following the conventional tillage practice which includes three times plowing before sowing of the crop. As per the specification of the design, a field layout was prepared;

the land was leveled and made suitable for crop establishment. Sowing was done in mid-July of 2018, 2019, and 2020 using a seed rate of 150 kg ha^{-1}. A full dose of Triple supper phosphate and TSP as per the treatment and one-third of N alone was applied at sowing time. The remaining two-thirds of N alone were top-dressed at the mid-tillering crop stage. during experimenting, other necessary agronomic management practices such as fungicide (Natura) sprayed for yellow rust and herbicide (Palas) sprayed to control both grass leaf and broadleaf were carried out uniformly for all treatments.

Data Collection and Measurement

Yield Components and Yield Parameters

Plant height (cm) Plant height was measured from the soil surface to the tip of a spike (awns excluded) from 10 randomly tagged plants from the net plot area at physiological maturity

Number of seed per spike: The mean number of seeds per spike was recorded as an average of 10 randomly taken spikes from the net plot area.

Thousand Kernel Weight:

Thousand kernels weight was determined based on the weight of 1000 kernels sampled from the grain yield of each net plot by counting using an electronic seed counter and weighed with electronic sensitive balance. Then the weight was adjusted to 12.5% moisture content.

Spike length (cm):- was measured from 10 randomly selected wheat heads per plot at harvesting time

Above ground dry biomass yield: The aboveground dry biomass yield was determined from plants harvested from the net plot area after sun drying to a constant weight and expressed in kg ha^{-1}.

Grain yield: The grain yield was taken by harvesting and threshing the grain yield from net plot area. The yield was adjusted to 12.5% moisture content and expressed as yield in kg ha^{-1}.

Harvest index (HI): The harvest index was calculated as ratio of grain yield per plot to total above ground dry biomass yield per plot expressed as percent.

Soil Sample collection and analysis: - After 21 day's composite soil samples were collected from each plots by using soil auger from a depth of 0-20cm and analyzed for phosphorus

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 grain yield values on the Y-axis. 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).

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

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

The data subjected to analysis of variance (ANOVA) as per the experimental design using GenStat (15th edition) software (GenStat, 2012). The Least Significance Difference (LSD) at 5% level of probability was used to determine differences between treatment means.

Partial Budget Analysis

The dominance analysis procedure as described in CIMMYT (1988) was used to select potentially profitable treatments from the range that was tested. The discarded and selected treatments using this technique were referred to as dominated and un dominated treatments, respectively. For each pair of ranked treatments, % marginal rate of return (MRR) was calculated using the formula:-

$$\textbf{MRR (\%)} = \frac{\text{Change in NB (NBb}-\text{NBa)}}{\text{Change in TCV (TCVb}-\text{TCVa)}} \times 100$$

- Where NB_a = NB with the immediate lower TCV,
- NB_b = NB with the next higher TCV,
- TCV_a = the immediate lower TCV and
- TCV_b = the next highest TCV.

Result and Discusion

Thousand Kernels Weight and Harvest Index

The analysis of variance indicated that different rates of TSP and nitrogen fertilizers did not significantly ($p < 0.05$) influence thousand kernels weight and harvest index of bread wheat crop at the study area (Table 1).

Table 1. Plant height, Spike length, number of seed per spike, Biomass and grain Yield of bread wheat as influenced by main effect of TSP and nitrogen fertilizers rates.

TREATMENT	PH(CM)	SPL(CM)	NSPS	BM (KG	GY(KG HA^{-1})
TSP (KG HA^{-1})					
0	65.55^{b}	6.547	38.54^{b}	7042^{b}	2612 ^{b}
100	68.12^{a}	6.684	39.99^{ab}	8325^{a}	3077^{a}
200	68.76^{a}	6.736	41.02^{a}	8867^{a}	3293^{a}
LSD (0.05)	2.388	NS	1.952	890.4	287.5
N (KG HA^{-1})					
0	60.28^{c}	6.333^{c}	37.18^{b}	5417^{d}	1864 ^{d}
23	68.40^{b}	6.386^{c}	39.84^{ab}	7417^{c}	2668 ^{c}
46	68.19^{b}	6.539^{bc}	39.47^{ab}	7900^{bc}	3003 ^{bc}
69	71.79^{a}	6.822^{ab}	39.54^{ab}	9483^{a}	3603^{a}
92	68.86^{ab}	6.867^{a}	41.27^{a}	9000^{ab}	3376^{bc}
115	67.33 ^{b}	6.867^{a}	41.79^{a}	9250 ^{a}	3449 ^{a}
LSD (0.05)	3.377	0.2974	2.760	1259.3	406.6
CV (%)	4.1	3.7	5.7	12.8	11.7

Means followed by the same letter with in the same column of the respective treatment are not significantly different ($P \leq 0.05$) according to fishier Test, PH= plant height, SPL= spike length, SPS= seed per spike, BM= biomass, GY= grain yield, , CV = Coefficient of variation, LSD = Least Significant differences, NS = not significant

Plant Height

The analysis of variance indicated that plant height was not affected by the interaction effect of TSP and nitrogen. However, it significantly ($p < 0.05$) and highly significantly ($p < 0.01$) influenced by the main effect of TSP and nitrogen respectively (Table 1). Increasing the amount of both TSP and N rates increased significantly plant height. The maximum application rate of TSP (200 kg ha^{-1}) resulted in the highest plant height (68.76 cm). Similarly, the highest plant height (71.79 cm) was recorded in the highest (69 kg ha^{-1}) N rate while no fertilizer application recorded the shortest plant height (Table 1). In agreement with this result Diriba *et al*., (2019) reported the highest (95.5 cm) plant height by application of 300 kg ha^{-1} blended TSPB and 100kg urea fertilization.

Spike Length

The analysis of variance indicated that different rates of nitrogen fertilizer was highly significantly ($p < 0.01$) influenced spike length of Bread wheat crop. However, this parameter was not influenced by both the main effect of TSP and the interaction effect of TSP and nitrogen (Table 1). The maximum application rate of 115 kg N ha^{-1} resulted in the highest (6.867 cm) spike length. While no fertilizer application has recorded the shortest spike length (6.333 cm) (Table 1). This result is consistent with (Tilahun *et al*., 2021 who reported the highest (7.367 cm) spike length by application of 150 kg N ha^{-1} for bread wheat. This result is also in line with (Lemi and Negash, 2020) who recorded the highest (8.73cm) spike length for Ogolcho variety at 100/100 kg ha^{-1} NPSZnB/Urea application.

Number of Seed per Spike

The analysis of variance indicated number of seed per spike was not affected by interaction effect of TSP and nitrogen. However it was significantly ($p < 0.05$) influenced by the main effect of each TSP and nitrogen (Table 1). The result indicated that there was constant rate of increments on the number of seed per spike, as the rate of each TSP and N enhanced from the lowest rate to the highest rate of fertilizer application. The result showed that, highest (41.02) and (41.79) number of seed per spike were recorded by the maximum application rate of 200 kg TSP ha^{-1} and 115 kg N ha^{-1} respectively While nil fertilizer application was recorded the smallest number of seed per spike (Table 1). This result is consistent with the finding of (Tilahun *et al*., 2021) who reported the highest (39.94) number of seed per spike by application of 200 kg NPS ha^{-1} for bread wheat. This result is also in parallel with the finding of Dinkinesh *et al*., (2020) who reported the highest (42.7) number of seed per spike by application of 183 kg ha^{-1} blended NPSB for durum wheat.

Biomass Yield

The analysis of variance indicated Biomass was not affected by the interaction effect of TSP and nitrogen fertilizer rates. However, it was highly significantly ($p < 0.01$) influenced by the main effect of each TSP and nitrogen fertilizers (Table 1). Biomass Yield has been increasing as the rate of TSP and N increased from the lowest rate to the highest application rates. The result showed that the highest (890.4 kg ha^{-1}) and (9483 kg ha^{-1}) biomass yields were recorded by the maximum application rate of 200 kg TSP ha^{-1} and 69 kg N ha^{-1} respectively. While nil fertilizer application was recorded the smallest biomass yield per all plots (Table 1). The result is in parallel with Dinkinesh *et al*., (2020) who reported the highest (11772 kg ha^{-1}) biomass yield by application of the highest (183 kg ha^{-1}) NPSB for durum wheat varieties. Similarly, (Eyasu *et al*., 2020) reported that application of 200 kg NPSZnB resulted in the highest 16.9 tone ha^{-1} biomass yield of wheat.

Grain Yield

Grain yield, biomass yield, seed per spike, spike length, plant height of bread wheat significantly responded ($p<0.001$) to P fertilizer application rate. Grain yield significantly ($p<0.001$) affected by P rate. Thus the application of 50 kg P ha^{-1} gave a significantly higher grain yield. Moreover, the determination of Pc defined by the Cate Nelson method for the study area was 10 ppm with a mean relative yield response of about 66%. The soil available phosphorus vs phosphorus fertilizer of the district was ranges 6.39 and 12.26 ppm for 0 and 50 kg P ha^{-1} respectively. The P requirement factor (Pf), is computed from the difference between available soil test P values from plots that received 0-50 kg P ha^{-1}. Where the available p vs. p fertilizer applied were ranges 6.39 to 12.26 ppm for 0 and 50 kg P ha^{-1} respectively. Where the Pf of the district were ranged from 3.98 to 8.40 and the overall average Pf of all treatments was 6.45 for the study area.

Partial Budget Analysis

To identify treatments with the optimum return to the farmer's investment, marginal analysis was performed on non-dominated treatments. For a treatment to be considered worthwhile to farmers (100% marginal rate of return (MRR)) was considered as the minimum acceptable rate of return (CIMMYT, 1988).

Table 2. Partial budget and marginal analysis for TSP and N rate of bread wheat

UREA (KG HA^{-1})	TSP (KG HA^{-1})	ADJUSTED YIELD DOWN WARDS BY 10% (KG HA^{-1})	GROSS BENEFIT (BIRR HA^{-1})	TOTAL VARIABLE COST (BIRR HA^{-1})	NET RETURN (BIRR HA^{-1})	MRR %
0	0	1,450	43,506	-	43,506	-
0	100	1,508	45,248	2,000	43,248	D
0	200	2,075	62,253	3,600	58,653	D
50	0	1,824	54,734	1,100	53,634	921
50	100	2,575	77,252	2,700	74,552	D
50	200	2,804	84,110	4,300	79,810	D
100	0	2,259	67,784	1,800	65,984	1,764
100	100	2,808	84,245	3,400	80,845	3,959
100	200	3,041	91,224	5,000	86,224	D
150	0	2,975	89,258	2,500	86,758	8,702
150	100	3,268	98,028	4,100	93,928	3,023
150	200	3,486	104,571	5,700	98,871	4,607
200	0	2,538	76,127	3,200	72,927	D
200	100	3,285	98,550	4,800	93,750	2,788
200	200	3,294	98,816	6,400	92,416	D
250	0	3,059	91,782	3,900	87,882	9,743

Where, TSP cost = 16 Birr kg^{-1}, UREA cost = 14 Birr kg^{-1}of N, TSP, bread wheat grain per ha = 30 Birr kg^{-1}, TSP and Urea application cost = 400 Birr ha^{-1}, MRR (%) = Marginal rate of return, D= Dominated treatment.

As indicated in table 2, the partial budget and dominance analysis showed that the highest net benefit 98,871 Birr ha^{-1} was obtained in the treatment that was treated with 150 kg ha^{-1} urea and 200 kg TSP ha^{-1} while the lowest net benefit 43,506 Birr ha^{-1} was obtained in the control treatment.

Determination of Phosphorus critical concentration and P-requirement factor

The Cate_Nelson graphical method was employed to determine the phosphorus critical point for bread wheat in a Dugda district. Accordingly, the phosphorus critical concentration above which the responses of the crop become minimal was 10ppm for bread wheat production (Fig 1).

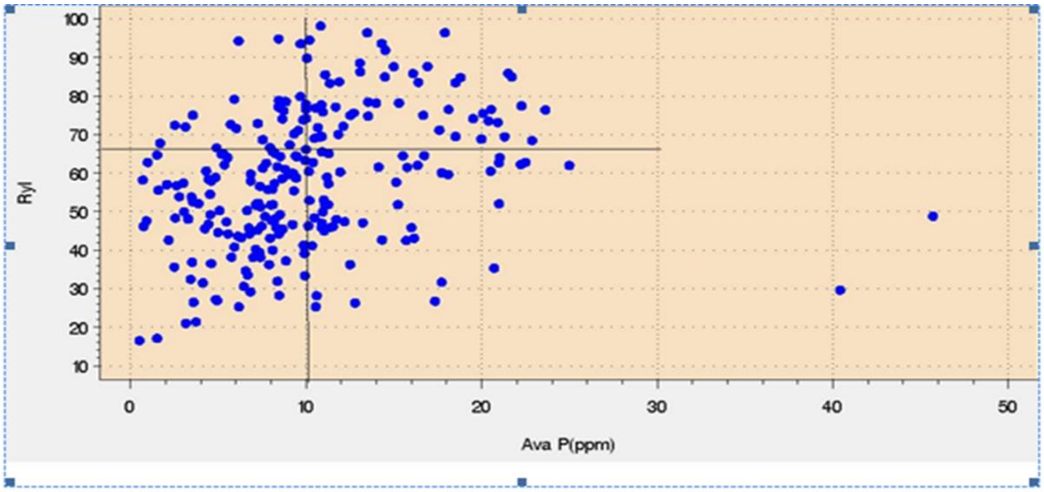

Fig : Phosphorus critical concentration for Bread wheat at Dugda District, 2021.

Table 3: Determination P-requirement factor in Dugda District

TREATMENTS KG P HA^{-1}	OLSEN - P (PPM) Range	Average	P INCREASE OVER CONTROL	P REQUIREMENTS FACTOR KG P^{-1} (PPM)/ Δ P
0	0.92-10.06	6.39	-	-
10	1.60-22.24	8.90	2.51	3.98
20	1.52-23.64	10.21	3.82	5.23
30	3.88-21.72	10.98	4.59	6.54
40	1.70-22.88	11.15	4.76	8.40
50	1.00-25.00	12.56	6.17	8.10
	MEAN			6.45

Phosphorus requirement factor (Pf) is the amount of phosphorus in kg needed to raise the soil phosphorus by 1ppm for bread wheat crop at Dugda district was 6.45 (table 3).

Table 4: Mean grain yield and yield components as influenced Phosphorus fertilizer application.

P-APPLIED KG HA^{-1}	N KG HA^{-1}	PLANT HEIGHT(CM)	SPIKE LENGTH(CM)	SEED/ SPIKE	BM TON HA-^{1}	GY QT. HA-^{1}
0	0	69.89c	6.24c	35.13b	6.20c	20.69b
10	69	80.67b	7.07b	40.99a	8.93b	35.61a
20	69	82.77a	7.16a	41.85a	9.48ba	38.48a
30	69	83.26a	7.16a	41.79a	9.56ba	39.08a
40	69	83.82a	7.23a	41.79a	9.88a	39.97a
50	69	83.91a	7.00ba	42.47a	9.90a	39.98a
LSD(0.05)		2.30	0.24	2.23	1.01	4.24
CV (%)		5.88	7.84	12.43	25.65	27.02

Grain yield, biomass yield, seed per spike, spike length, plant height of bread wheat significantly responded ($p<0.001$) to P fertilizer application rate. Grain yield significantly ($p<0.001$) affected by P rate. Thus application of 50 kg P ha^{-1} gave significantly higher grain yield. Moreover, the determination of Pc defined by the Cate Nelson method for the study area was 10 ppm with mean relative yield response of about 66%. The soil available phosphorus vs. phosphorus fertilizer of the district was ranges 6.39 and 12.26 ppm for 0 and 50 kg P ha^{-1} respectively. The P requirement factor (Pf), computed from the difference between available soil test P values from plots that received 0-50 kg P ha^{-1}. Where the available p vs. p fertilizer applied were ranges 6.39 to 12.26 ppm for 0 and 50 kg P ha^{-1} respectively. Where, the Pf of the district were ranges 3.98 to 8.40 and the overall average Pf of all treatments was 6.45 for the study area.

Conclusion and Recommendation

Ethiopia is also one of the largest wheat producers in Sub-Saharan Africa and approximately 80% of the wheat area is planted to bread wheat (Asfaw *et al*. 2013). However, according to the report (FAOSTAT, 2019), its productivity has been 19.38 % far below the world's average yield. This is might be due to the blanket way of fertilizer application in type (only DAP and Urea) and amount without considering agro-ecology and crop types. Such practice leads to inefficient use of fertilizers by wheat since the amount to be applied can be more or less than the crop requires. Therefore, soil test-based crop response and site-specific P fertilizer application with newly introduced fertilizers such as TSP are very important for fertilizer recommendations to improve the trend and increase crop yield. Therefore, this study was conducted to determine the economically optimum rate of nitrogen fertilizer in the first year and the treatments have consisted of factorial combinations of three levels of TSP (0, 100, and 200) kg ha^{-1} with six levels of nitrogen (0, 23, 46, 69 92 and 115) kg ha^{-1} that gave a total of eighteen treatments. However, in the second two consecutive years the experiment was conducted to determine phosphorus critical (Pc) and phosphorus requirement factor (Pf and the treatments consisted of six levels of phosphorus (0, 10, 20, 30, 40, and 50) kg ha^{-1} combined with a single level of nitrogen (69 kg ha^{-1}) that gave a total of seven treatments. The experiments were laid out in randomized complete block design (RCBD) with two replications and the gross plot size was 4 m x 5 m (20 m^2) were used to determine optimum nitrogen in the first year and 4m x 5m (20 m^2) and phosphorus critical (Pc) and also harvested from 4m^2 plot areas. The analysis of variance indicated that Plant height, spike length, number of seeds per spike, biomass yield, and grain yield were highly significantly ($p < 0.01$) influenced by the main effect of nitrogen fertilizer rates. However except for the number of seed per spike, TSP fertilizer significantly ($p<0.05$) affect plant height and the number of seed per spike as well as highly significantly ($p < 0.01$) biomass and grain yield of bread wheat. The highest (68.76 cm) plant height, the highest (41.02) seed per spike, the highest (8867 kg ha^{-1}) biomass, and the highest (3293 kg ha^{-1}) grain yield were recorded by 200 kg TSP ha^{-1}. The highest (71.79 cm) plant height, the highest (9483 kg ha^{-1}) biomass, and the highest (3603 kg ha^{-1}) grain yield were recorded by 69 kg N ha^{-1}. However, the highest (6.867 cm) spike length and the highest (41.79) numbers of seed per spike were recorded by 115 kg N ha^{-1}. Moreover, from all tasted parameters the lowest values were recorded by control plots. The economic analysis revealed that for a treatment to be considered as worthwhile to farmers (100% marginal rate of return) application of 69 kg N ha^{-1}) is profitable which gave the highest (98871 Birr) net return with an acceptable (4607%) marginal rate of return and recommended for farmers in Dugda district. On the other hand, the analysis of variance indicated that Plant height, spike length, number of seeds per spike, biomass yield, and grain yield were highly significantly ($p < 0.01$) influenced by soil test-based phosphorus fertilizer application. The result indicated that the highest (83.9 cm) plant height, the highest (9900 kg ha^{-1}) biomass, and the highest (39980 kg ha^{-1}) grain yield were recorded by 50 kg P ha^{-1}. Moreover, 10ppm phosphorus critical (Pc) and 6.45 ppm phosphorus requirement factor (Pf) were identified for bread wheat production for the farmers of Dugda District.

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Verification of Soil Test Crop Response Based Phosphorus Fertilizer Recommendation for Teff in Debre Libanos District, North Shewa Zone, Oromia

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Abstract

*The field experiment was conducted to verify the determined optimum amount of nitrogen (92 kg N ha $^{-1}$), critical P concentration (15 ppm) and P requirement factor (6.1) for tef production in Debre Libanos District. The experimental field was arranged with 3 treatments. The trial was carried out in randomized complete block design (RCBD) with seven replications over different farmer's field. Control (without fertilizer), blanket recommendation (100kg Urea and100kg DAP) and soil test based fertilizer recommendation with recommended nitrogen 92 kg ha $^{-1}$ were used as a treatment. The gross plot area was 10 * 10m and the space between plots was 0.7m. The required amount of seeds was weighed per plot by considering the recommended rate of tef seed per hectare. The result from this study indicate that an optimum rate of nitrogen (92 Kg N/ha) and soil test based phosphorus fertilizer recommendation was highly significantly influence plant height, panicle length, biomass and grain yield of tef. The highest plant height (82 cm) panicle length (27.78 cm), biomass yield (4613kgha^{-1}) and grain yield (1588 kg ha $^{-1}$) was recorded from the application of soil test based fertilizer recommendation in conjunction with recommended optimum Nitrogen. The results of the economic analysis showed that the maximum net return was obtained due to soil test based phosphorus fertilizer recommendation .As a result determined Pc and Pf through site specific soil test crop response based fertilizer study could be profitable for tef production in the study area and other areas having similar soil type and agro-ecology..*

Key words: Verification, optimum rate of nitrogen, soil test based, treatment, phosphorus fertilizer

Introduction

Tef, Eragrostis tef (Zucc.) Trotter is the major Ethiopian cereal grown for thousands of years (D'Andrea, 2008) and currently grown on 2.5 million ha annually, and accounts for 30 per cent of total acreage and 19 per cent of gross cereal production (CSA, 2008). It is the only cultivated cereal in the genus Eragrostis (Abebe, 2001). Tef is a highly versatile crop with respect to adaptation to different agro-ecologies, widely grown from sea level up to 2800 m above sea level (a.s.l.) under various rainfall, temperature, and soil conditions (Ketema, 1997; 1993). The crop has both its origin and diversity in Ethiopia (Vavilov, 1951) and plays a vital role in the country's overall food security. In addition, the straw is an important cattle feed source, and the high market prices of both its grains and the straw make it a highly valued cash crop for tef-growing smallholder farmers. However, the average mean grain yield of tef in this part of the country is below 1000 kg ha^{-1} (Mebratu *et al*., 2016) and variable, mainly due to nutrient stress.

In Sub-Saharan Africa (SSA), low and declining soil fertility due to net nutrient extraction by crops is responsible for low agricultural productivity and food insecurity (Nakhumwa and Hassan, 2012). Moreover, the rampant soil degradation and the consequent decline of its productivity due to loss essential plant nutrients is among the underlying reasons for poor crop yield (Bekunda *et al.*, 2012) and food insecurity (Sanchez, 2002). Over 50% of the highlands in general and cropped areas of Ethiopia are in an advanced stage of land degradation (Elias, 2002). Sub-Saharan Africa accounted for 3 percent of world fertilizer consumption in 2013 as compared to Asia that consumes 58.5 percent of the world total, the bulk of which is used in East Asia and South Asia (FAO, 2015). In terms of per hectare fertilizer application Asia is in the first place in fertilizer application per hectare (150.7 kg ha^{-1}) (Hossain, and Singh, 2000). While farmers in Sub-Saharan Africa estimated to have used 11 kg nutrients/ha in 2013, i.e. only 10% of the global average (Drechsel et al., 2000).

Therefore, there are still large areas where farmers use little fertilizer and mine their soil nutrient reserves. According to (Stoorvogel and smalling, 1993) the annual average nutrient loss for Sub-Saharan Africa was 26 kg N, 3 kg P, and 19 kg K ha^{-1} yr^{-1} the yearly equivalent of US$ 4 billion worth of fertilizers (Drechsel *et al*., 2000). Because of all decline in the soil fertility is one of the major bottlenecks to agricultural production, productivity in the world particularly in Africa and specifically in Ethiopia (Giday et al., 2014). Therefore, greater use of mineral fertilizers is crucial to increasing food production and slowing the rate of soil degradation in Ethiopia since severe soil nutrient depletion is a major bottleneck for boosting production and productivity of tef.

Phosphorous (P) is one of most limiting plant nutrients in the tropics (Brady and Weil, 1999) .it required in the early stages of growth (Grant *et al.*, 2001), which is necessary for many plant processes including synthesis of phospholipids, energy transfer, and enzyme activation (Hawkesford, 2012) for optimum crop production. Inadequate P availability is a major limitation to plant growth and development (Schachtman *et al.*, 1998) and consequently global crop production (Raghothama and Karthikeyan, 2005). It is estimated that 30–40% of global agricultural soils are limited by P availability and it is second only to nitrogen (N) in limiting agricultural productivity (Vance et al., 2003). Phosphorous is deficient in about 70% of the soils in Ethiopia (Mamo, and Haque, 1991). One of major constraints that are responsible for low yield is P deficiency (Balesh *et al*., 2005). According to Regassa and Agegnehu, (2011) the soils of the highlands are marginally to severely deficient in P.

The Blanket fertilizer recommendations currently applied was released several years ago in Ethiopia, does not consider the differences in agro-ecological environments, and is not suitable for the current production systems and for the foreseeable future (Ketema, 1997). Since the spatial and temporal fertility variations in soils were not considered, farmers have been applying same P fertilizer rate to their fields regardless of soil fertility differences. For this reasons, the blanket recommendation will make inefficient use of these expensive nutrients which contribute to the depletion of scarce financial resources, increased production costs and potential environmental risks (Tarekegne and Tanner, 2001).

Sound soil test calibration is essential for successful fertilizer program and crop production. Soil test based P-fertilizer calibration study on teff was conducted in Debre Libanos district during 2010 to 2012 cropping season to determine P-critical value, P-requirement factor and N-level for the district. Accordingly, FiARC has developed soil test based Pc (15 ppm) and Pf (6.10) for tef with 92 kg N ha^{-1} in Debre Libanos district. Thus for further demonstration and scale up the achievement should be verified for the district and develop phosphorus fertilizer recommendation guide line for all tef growing areas in the district. Therefore the objective of this study was to verify the determined nitrogen level, phosphorus critical value and phosphorus requirement factor determined for teff at the district.

Materials and Methods

Description of the Study Area

The experiment was conducted in Debre Libanos Districts of North Shewa Zone, Oromia. The district is located at 89 km from the capital Addis Ababa. Geographically the district is located between 09^{0} 36’0’’ to 09^{0} 45’0” North and 038^{0} 45’00’’ to 39^{0}0’00’’ East. The altitude ranges between 1500 and 2700 (m.a.s.l). Agro ecologically 75% of the district is highland 15% is midland and 10% is lowland. The main rainy season of the study area is between May and September in which mean annual rainfall is about 1000 mm that ranges from 800 to 1200 mm. The maximum and minimum annual temperature is 23^{0}C and 15^{0}C, respectively.

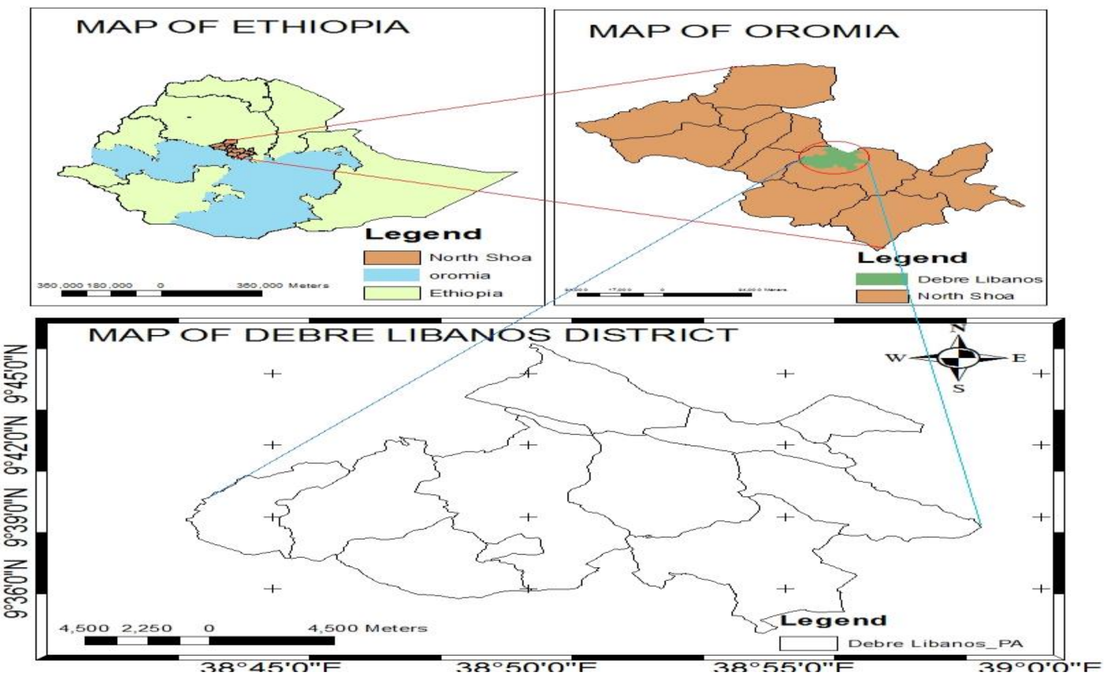

Fig. 1. Map of the study area

Site Selection, Soil Sampling and Analysis Methods

Tef production potential kebeles (small administrative unit) were selected from the District. Before planting 20 surface composite soil samples were collected from each field for analysis at a depth of 0-20 cm in a zig zag methods. Soil samples were collected using auger. The collected surface soil samples from the experimental field were air dried, grinded and allowed to pass through 2 mm sieve for further analysis in the laboratory (FAO, 2008). The collected soil samples were analyzed for pH (H_2O) in the suspension of 1: 2.5 soil to water ratio using pH meter (Rhoades, 1982) and Available P was determined by the Olsen’s method using a spectrophotometer (Olsen *et al.*, 1954). Then 7 farmer’s field was selected based on the analyzed soil sample results in which the soil pH above 5.5, available soil phosphorus below critical phosphorus (Pc) considering willingness of the farmers to handle the experimental field

Experimental Procedures

The experimental field was arranged with 3 treatments. The trial was carried out in simple adjacent arrangement with seven replications over the farmers. The treatment were includes control (without fertilizer), Blanket recommendation (100kg DAP & 100kg urea) and soil test based fertilizer recommendation with recommended Nitrogen 92 kg ha^{-1}. The gross plot area was 10 * 10m and the space between plots was 0.7m. The required amount of seeds was weighed per plot by considering the recommended rate (25kg/ha) of tef seed per hectare. Urea and DAP (Di ammonium Phosphate) was used as source of nitrogen and phosphorus containing fertilizers. A tef variety (Kora) was used. Uniform field management practices for all plots were conducted. The determined P-critical value (15 ppm) and phosphorous requirement factor (6.10) was used to calculate the rate of fertilizer to be applied. Thus, Phosphorus fertilizer rate was calculated by using the formula given below;

Rate of P-applied = (Pc-Pi) * Pf

Where;

Pc: Critical phosphorus concentration;

P: Initial available P

Pf: Phosphorus requirement factor which was derived from the calibration study

Data Collection

Tef grain yield was harvested at the ground level from the net plot area and weighed for biomass data. Then plant height and panicle length was measured at harvest. After threshing, grain yield were cleaned and weighed. The straw yield was determined by subtracting the grain yield from the total above ground biomass yield for each respective treatment. Economic data such as production cost (input cost), gross income and net income based on the current market price of the yield and input was recorded.

Data Analysis

All data recorded and collected were subjected to analysis of variance (ANOVA) using GenStat 18th edition software program. The comparisons among treatment means were employed by using Least Significance Difference (LSD) at 5% significant level.

Economic Analysis

Partial budget analysis was done to identify economic feasibility among the treatments. The average open market price (Birr kg^{-1}) of tef, at field level and fertilizers was used for analysis. For a treatment to be considered a worthwhile option to farmer, the minimum acceptable rate of return (MRR) should be 100 % (CIMMT, 1988), which is suggested to be realistic. This enables to make recommendations from marginal analysis. Marginal rate of return (MRR) were calculated by using the formula given blow;

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

Result and Discussions

Soil Reaction (pH) and Available Phosphorus of Experimental Field

The analyzed soil samples indicated that, the soil pH (H_2O) of the study area is (6.01), which is moderately to slightly acidic with the value ranged from 5.87 to 6.29 according to the ratings suggested by Tekalign, 1991. Thus, the pH of the experimental soil was within the range for productive soils. The available phosphorus content of soils is 4.71ppm, which is very low to low with the value ranged from 2.78 to 6.94 ppm according to the rating given by Cottenie, 1980. Therefore, the soil of the study areas needs application of phosphorus containing fertilizers for crop production.

Table 1. Soil pH and Available Phosphorus of experimental field

Site	Soil pH	Available Phosphorus (ppm)
1	5.89	3.74
2	5.94	5.6
3	5.92	6.94
4	6.29	2.78
5	5.87	5.48
6	6.15	4.27
7	5.98	4.17
Mean	6.01	4.71
SD	0.16	1.38

Where: SD = Standard Deviation

Response of Grain Yield of tef to treatment

The analysis of variances indicated that, there was a highly significant variation ($p < 0.01$) among the treatments on plant height, spike length, biomass and grain yield. Accordingly, the highest plant height (82 cm) and panicle length (27.78 cm) was recorded from the application of soil test based fertilizer recommendation. While the lowest plant height (46.56 cm) and panicle length (17.67 cm) was registered from the treatments without fertilizer application. In addition, the maximum biomass yield (4673 kg ha $^{-1}$) and grain yield (1588 kg ha $^{-1}$) was recorded from the soil treated with the soil test based fertilizer recommendation. The results clearly showed that, tef yield and yield components were significantly increased with the application of 92 Kg N ha $^{-1}$ and site specific fertilizer recommendation over the blanket fertilizer recommendation. The results of this study are consistent with findings of Gidena, 2016; Legesse, 2017; Kefyalew *et al*., 2018 who reported that the highest values on yield and yield component of tef was recorded under the application of site specific fertilizer recommendation over blanket recommendation.

Table 1. Effects of blanket and soil test based Fertilizer recommendation on plant height, panicle length, biomass and grain yield of tef.

Treatment	Plant height (cm)	Panicle length (cm)	Biomass (kg ha^{-1})	Grain Yield (kg ha^{-1})
Without fertilizer	46.56^{b}	17.67^{b}	2160^{b}	764^{b}
Blanket Recommendation	77.72^{a}	24.58^{a}	3886^{a}	1031^{b}
Soil test based fertilizer recommendation	82^{a}	27.78^{a}	4613^{a}	1588^{a}
$LSD_{0.05}$	8.597	3.36	889.2	278.1
CV(%)	5.5	6.4	17.1	19.2

Where: LSD= Least Significant Difference, CV (%) = Coefficient of Variation

Partial Budget Analysis

To estimate the economical significant of the different fertilizer rates, partial budget analysis were employed to calculate the Marginal rate of return (MRR) to investigate the economic feasibility of fertilizers. Based on actual unit prices during the year 2020 harvesting season farm gate price of 43 ETB (Ethiopian Birr) per kg of teff, 16.35 and 15.01 Birr per kg of DAP and Urea, respectively were used to calculate variable cost. The economic analysis showed that the highest net income (61106.35 ETB per ha) and marginal Rate of Return (393.64%) was obtained from soil test based fertilizer recommendation (Table 3). Thus, the MRR showed that it would yield 3.94 birr for every birr invested. Therefore, soil test based fertilizer recommendation record the highest MRR that is in acceptance range. So, farmers and other end users in the study area advised to use this soil test crop response-based recommended fertilizer which is cost effective, economically feasible and environmentally safe.

Table 3. Partial budget analysis for verification of tef in Debre Libanos District

Treatment	Variable Input (Kg ha^{-1})		Unit price(ETB)		TVC	Output (Kg ha^{-1})	Unit price (ETB)	Gross Income (ETB ha^{-1})	Net Income (ETB ha^{-1})	MRR (%)
	DAP	Urea	DAP	Urea						
without fertilizer	0	0	0	0	0	764	43	32852	32852.00	
Blanket fertilizer	100	100	16.35	15.01	3135.52	1031	43	44333	41197.48	266.16
STBPFR	398.62	44.02	16.35	15.01	7177.65	1588	43	68284	61106.35	393.64

Where: ETB = Ethiopian Birr, TVC = Total Variable Cost, MRR = Marginal Rate of Return

Conclusion and Recommendations

The field experiment was conducted to verify the determined optimum amount of nitrogen (92 kg N ha $^{-1}$), critical P concentration (15ppm) and P requirement factor (6.1) for tef production in Debre Libanos district. An optimum rate of nitrogen (92 Kg N/ha) and soil test based phosphorus fertilizer recommendation was highly significantly influence plant height, panicle length, biomass and grain yield of tef. Accordingly, the highest plant height (82 cm) panicle length (27.78 cm), biomass yield (4673 kg ha $^{-1}$) and grain yield (1588 kg ha $^{-1}$) was recorded from the application of soil test based fertilizer recommendation in conjunction with recommended optimum nitrogen. The economic analysis also showed that the highest net benefit (61,106.35 ETB) was obtained from site specific soil test based fertilizer recommendation with marginal rate of return 393.64% which is greater than the acceptable minimum rate of return (100%). Therefore, site specific soil test based crop response fertilizer recommendation could be recommended and thus the determined Pc and Pf for tef production could be demonstrated and scaled up in study area (Debre Libanos district) and verified in other districts in the zones those having similar soil type and agro-ecology.

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Determination of NPS Fertilizer Rate Based on Calibrated Phosphorus for Yield of Tef in Girar Jarso District, North Shewa Zone, Oromia, Ethiopia

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Abstract

Appropriate soil fertility management practices based on the actual limiting nutrients and crop nutrient requirement for a given crop is economic and judicious use of fertilizers for sustainable crop production. Moreover, application of balanced fertilizers and nutrient requirements of the crop is the basis to produce more crop yield from the land under cultivation. Accordingly, field experiment was conducted in 2019 & 2020 main cropping season to determine NPS fertilizer rate in relative to determined P-critical and P-requirement factor for tef and to estimate the economically feasible NPS fertilizer rate for higher yield of tef in Girar Jarso district. Accordingly the result of study indicated that, plant height, panicle length, biomass and grain yield was highly significantly ($P<0.01$) affected by NPS fertilizer rate. The highest plant height (86.32cm), panicle length (32.51cm), biomass yield (8626kg ha^{-1}) and grain yield (1622 kg ha^{-1}) of tef was recorded from the application of 100% P-critical from NPS fertilizer rate supplemented with recommended Nitrogen whereas, the lowest value was recorded from the field without fertilizer which was significantly inferior to all other treatments. Furthermore, the economic analysis depicted that, application of NPS fertilizer at the rate of 100% P-critical in NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}) for the production of tef was more economically beneficial for the district. In conclusion, farmers and other end users could be advised to use 100% PC from NPS fertilizer rate with recommended nitrogen for tef production in the district and other area having similar soil type and agro- ecology.

Keywords: NPS fertilizer rate, recommended Nitrogen, Phosphorus critical, yield

Introduction

Tef (Eragrostistef), a cereal crop that belongs to the grass family Poaceae, is endemic to Ethiopia and has been widely cultivated in the country for centuries (Tekluand Tefera 2005). Tef is adaptable to a wide range of ecological conditions in altitudes ranging from near sea level to 3000 msl and even it can be grown in an environment unfavorable for most cereal, while the best performance occurs between 1100 and 2950 m a.s.l in Ethiopia (Hailu and Seyfu, 2000). Almost two thirds of the Ethiopian population use teff as their daily staple food. It is estimated that per capita consumption grew by 4 percent over the last 5 years (ATA, 2013c).Tef is considered an economically superior good, relatively more consumed by urban and richer consumers (Berhane *et al.* 2011; Minten *et al*. 2013).

Growth in average incomes and faster urbanization in Ethiopia are likely to increase the demand for teff over time (Berhane *et al.* 2011). Even though, Ethiopia is a center of origin and diversity of tef and has the above-mentioned importance and coverage of large area, its productivity is very low to feed the demand of its people and market. These is due to low soil fertility and suboptimal use of mineral fertilizers in addition to weeds, lack of high yielding cultivars, erratic rainfall distribution in lower altitudes, lodging, water logging, low moisture, and low soil fertility conditions (Fufa, 1998). On the other hand, under conditions where most growth requirements are available and in organic matter rich soils, application of fertilizers without knowing its fertility status causes yield and fertilizer losses (Tekalign *et al.*,2001). There are different blanket fertilizer recommendations for various soil types of Ethiopia for tef cultivation. This is due to its cultivation in different agro ecological zones and soil types, having different fertility status and nutrient content. Accordingly, N/P recommendation rates by the Ministry of Agriculture were set at 55/30, 30/40, and 40/35 N/P kg ha^{-1} for tef crop on Vertisols, Nitosols, and Cambisols, respectively across the country (Seyfu, 1993). However, 100 kg DAP ha^{-1} and 100 kg urea ha^{-1} were set by the Ministry of Agriculture and Rural Development later (Kenea *et al*., 2001).

Those blanket recommendations brought generally, an increase in yield of improved cultivars ranging from 1700 to 2200 kg/ha (Seyfu, 1997). Accordingly, the average national yield in the year 2010 reached 1200 kg/ha (CSA, 2010). However, the recommendations do not work for all Production aspects of various soil types of different regions. Tef responds to fertilizers especially to N highly in all its yield components. N is essential for carbohydrate use within plants and stimulates root growth and development as well as uptake of other nutrients (Tisdale *et al*., 1993; Brady and Weil, 2002).
Soil test based application of plant nutrient helps to realize higher response ratio and benefit: cost ratio as the nutrients are applied in proportion to the magnitude of the deficiency of a particular nutrient and correction of the nutrients imbalance in soil helps to harness the synergistic effects of balanced fertilization. Location specific fertilizer recommendations are possible for soils of varying fertility, resource conditions of farmers and level of target yield conditions of similar soil classes and environment (Ahmed *et al*., 2002).

Since, Ethiopia is moving from blanket recommendations to soil test based fertilizer recommendations, Fitche Agricultural Research Center was conduct a research to determine critical phosphorus concentration and phosphorus requirement factors for tef in Girar Jarso District, North Shewa Zone. However, the effect of NPS fertilizer rate was not determined for tef in the study area. Thus, based on the determined Pc (18 ppm) and Pf (3.03), optimum NPS fertilizer rate determination was carried out in the study area with the objectives; to determine NPS fertilizer rate in relative to determined P-critical and P-requirement factor for tef and to estimate the economically feasible NPS fertilizer rate for higher yield of tef in Girar Jarso District.

Material and Methods

Description of the Study Area

The study was conducted in Girar Jarso District North Shewa Zone Oromia, Ethiopia. The district is located at 112 km from the capital Addis Ababa. Geographically the district is located between 09038’52.8’’N to 10000’10.8’’N latitude and $38^0$34'22.8"E to $38^0$50'20.4"E longitude. The elevation ranged from 1300 and 3419 meters above sea level. The mean annual rain fall is 1200mm According to Fitche Station Meteorological data (Haile Mariam, 2014). The maximum and minimum mean temperature of the area is 35^0C and 11.5^0c respectively.

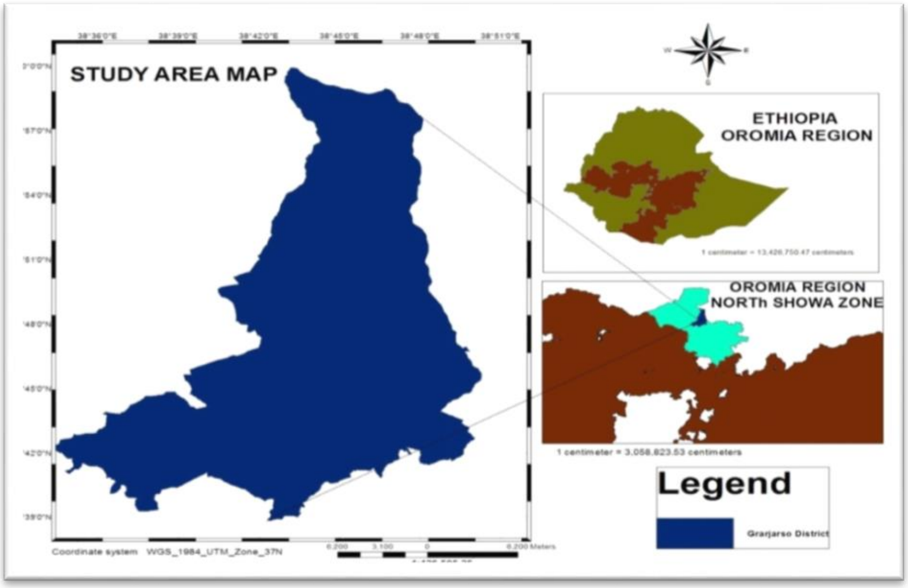

Figure 1: Location map of Girar Jarso district.

Site Selection, Soil Sampling and Analysis Methods

Tef production potential kebeles (small administrative unit) were selected from the district. Accordingly, the 11 farmer's fields were selected based on their willingness to handle the experimental fields. Before planting, 45 surface composite soil samples were collected in duration of two years from 45 farmer's fields for analysis at a depth of 0-20 cm in a zig zag methods. Soil samples were collected using auger. The collected surface soil samples from the experimental field were air dried, grinded and allowed to pass through 2 mm sieve for further analysis in the laboratory (FAO, 2008). The collected soil samples were analyzed for the pH (H_2O) in the suspension of a 1: 2.5 soil to water ratio using a pH meter (Rhoades, 1982) and available P was determined by the Olsen's method using a spectrophotometer (Olsen *et al.*, 1954). Then the farmer's field was selected based on the analyzed soil sample results in which the soil pH above 5.5 and available soil phosphorus below critical phosphorus (Pc) was selected for the experiments.

Experimental Design and Treatments

The experimental field study was arranged with a total of 6 treatments in a randomized complete block design (RCBD) in three replications. The recommended Nitrogen (92 kg ha^{-1}) for the district was used. The gross plot size was 3m * 4m and the space between block and plot was 70cm and 30cm respectively. The net plot size was 2 * 2m. The required amount of seeds was weighed per plot by considering the recommended rate of tef seed per hectare. Urea, NPS, and DAP (Di ammonium Phosphate) was used as source of Nitrogen and Phosphorus containing fertilizers. Uniform field management practices for all plots were conducted. A tef variety (kora) was used as test crop.

The treatments were;

T1 = Control (without fertilizers).
T2 = 25% P-critical from NPS fertilizer +Recommended Nitrogen
T3 = 50% P-critical from NPS fertilizer + Recommended Nitrogen
T4 = 75% P-critical from NPS fertilizer + Recommended Nitrogen

T5 = 100% P-critical from NPS fertilizer + Recommended Nitrogen
T6 = 100% P-critical from DAP fertilizer + Recommended Nitrogen

The determined P-critical value (18 ppm) and phosphorous requirement factor (3.03) was used to calculate the rate of phosphorus fertilizer to be applied. Thus, Phosphorus fertilizer rate was calculated by using the formula given below;

$$\text{Rate of P-applied} = (Pc - Pi) * pf$$

Where

Pc: Critical phosphorus concentration; P: Initial available P; Pf: Phosphorus requirement factor which was derived from the calibration study

Data Collection

Tef grain yield was harvested at the ground level from the net plot area and weighed for biomass data. Then plant height and panicle length was measured at harvest. After threshing, grain yield were cleaned and weighed. The biomass yield was determined by addition of the grain yield and the straw yield for each respective treatment. Economic data such as production cost (input cost), gross income and net income based on the current market price of the yield and input was recorded.

Data Analysis

All data recorded and collected were subjected to the analysis of variance (ANOVA) using GenStat 18th edition software program. The comparisons among treatment means were employed by using of Least Significance Difference (LSD) at 5% significant level.

Economic Analysis

Partial budget analysis was done to identify economical feasibility among the treatments. The average open market price (Birr kg^{-1}) of tef, price of fertilizers was used for analysis. For a treatment to be considered a worthwhile option to farmer, the minimum acceptable rate of return (MRR) should be 100 % (CIMMT, 1988), which is suggested to be realistic. This enables to make recommendations from marginal analysis. Marginal rate of return (MRR) were calculated by using the formula given blow;

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

Result and Discussions

Soil Reaction (pH) and Available Phosphorus of Experimental Field

The soil was moderately to slightly acidic in reaction with the pH (H_2O) value of 6.6, which is value ranged from 5.56 to 5.9 according to the ratings suggested by Tekalign, 1991. Thus, the pH of the experimental soil was within the range for productive soils. The available phosphorus content of soils before planting was 7.37pmm, which is low to medium according to the rating given by Cottenie, 1980. Therefore, the soil of the study areas needs application of phosphorus containing fertilizers for crop production.

Table 1. Soil pH and Available Phosphorus of the experimental fields

Site	Soil pH	Available phosphorus (ppm)
1	6.33	8.2
2	6.77	7.1
3	6.21	3.17
4	6.86	9.23
5	6.03	8.65
6	7.16	5.86
7	6.4	8.13
8	6.84	5.92
9	6.79	5.28
10	6.44	14.77
11	6.73	4.74
Mean	6.60	7.37
SD	0.34	3.07

Where: SD = Standard Deviation

Response of yield and yield component of tef to NPS Fertilizer Rate

Plant Height and Panicle Length

Plant height and Panicle length revealed significantly ($P<0.05$) influenced by NPS fertilizer rate. The highest plant height (86.32cm) and Panicle length (32.51cm) of tef was recorded from the application of 100% P-critical from NPS fertilizer rate supplemented with recommended nitrogen. The lowest plant height (55.6 cm) and panicle length (20.61 cm) was recorded from the field without fertilizer which was significantly inferior to all other treatments (Table 2). The increase in plant height with increasing NPS fertilizer could be attributed due to sufficient supply of nutrient which in turn contributed to increased vegetative growth since nitrogen plays crucial role in the structure of chlorophyll and P involved in the energy transfer for cellular metabolism. This result was in agreement with the findings of (Giday *et al*., 2014; Feyera *et al*., 2014 and Wakjira, 2018) reported that, application of blended fertilizers was on par with blanket recommendation of fertilizers and gave significantly higher plant height and panicle length on tef. Furthermore, according to Feyera *et a*l., 2014 balanced fertilization application and efficient utilization of nutrient leads to high photosynthetic productivity and accretion of dry matter, eventually increases spike length.

Biomass Yield

The analysis of variance indicated that the biomass yield was significantly affected by NPS fertilizer rate (Table 2). The highest biomass yield (8626 kg ha^{-1}) was obtained from the application of 100% P-critical from NPS fertilizer rate supplemented with recommended Nitrogen and the lowest biomass yield (3593 kg ha^{-1}) obtained from unfertilized plot (Table 2). The significant increase in biomass yield could be attributed due to the availability of macronutrients and some secondary nutrients formulated with the NPS fertilizer, which could increase the vegetative consequently the biomass yield. Similar significant increase in biomass yield was also observed for different application rate of NPS fertilizers which states that the increased in straw yield attributed due to the proportional vegetative growth especially plant height (Giday *et al.*, 2014; Feyera *et al*., 2014 and Wakjira, 2018).

Grain Yield

The statistical analysis showed that, the grain yield of tef was highly significantly ($P<0.05$) influenced by NPS fertilizer rate. The highest (1622 kg ha^{-1}) and the lowest (617 kg ha^{-1}) grain yield was obtained from the application of 100% P-critical from NPS fertilizer rate supplemented with recommended Nitrogen and unfertilized plot respectively (Table 2). Grain yield increased consistently and significantly in response to increasing the rate of NPS fertilizer from nil up to the highest. The increased in grain yield from NPS fertilizer might be facilitated the uptake of other essential nutrients which helps to boost plant growth and yield.

Table 2. Effects of NPS Fertilizer rate and recommended Nitrogen on yield and yield components of tef

Treatment	pH (cm)	PL (cm)	Biomass kg ha^{-1}	Grain yield kg ha^{-1}
Control(without fertilizer)	55.6^{e}	20.61^{f}	3503^{f}	617^{d}
25% P-critical from NPS fertilizer +Recommended Nitrogen	69.37^{d}	25.4^{e}	5642^{e}	1076^{c}
50% P-critical from NPS fertilizer +Recommended Nitrogen	74.67^{c}	27.17^{d}	6342^{d}	1225^{c}
75% P-critical from NPS fertilizer +Recommended Nitrogen	81.68^{b}	30.4^{b}	7978^{b}	1498^{ab}
100% P-critical from NPS fertilizer +Recommended Nitrogen	86.32^{a}	32.51^{a}	86264^{a}	1622^{a}
100% P-critical from DAP fertilizer +Recommended Nitrogen	78.23^{bc}	29.08^{c}	7283^{c}	1322^{bc}
$LSD_{0.05}$	3.937	1.313	551.31	186.3
CV (%)	7.3	6.6	11.2	29.8

Means with the same letter in columns are not significantly different at 5% level of significance's, PH=plant height, SL= Panicle length, CV=Coefficient of variation, LSD=Least Significance Difference

Partial budget analysis

Partial budget analysis showed that the highest net benefit (64722.06 ETB ha^{-1}) and the highest marginal rate of return (MRR) (760.18 %) was obtained from the fertilizer application of 100% P-critical from NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}). The lowest net benefit (26531.00 ETB ha^{-1}) was obtained from unfertilized plots (Table 3). The MRR was indicated that tef producers can get an extra of 7.61 ETB for 1.00 ETB investments in the NPS and N fertilizers application on the rates of 100% P-critical in NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}).Therefore, application of NPS fertilizer at the rate of 100% P-critical in NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}) for the production of tef was more economically beneficial and recommended for Girar Jarso District.

Table 3. Marginal Analysis of Bread Wheat Yield as influenced by NPS Fertilizer Supplemented by Nitrogen Rate

Treatment	Variable Input (Kg ha^{-1})		Unit price(ETB)		TVC	Output (Kg ha^{-1})	Unit price (ETB)	Gross Income (ETB ha^{-1})	Net Income (ETB ha^{-1})	MRR (%)
	DAP/NPS	Urea	DAP/NPS	Urea						
Control(without fertilizer)	0	0	0	0	0	617	43	26531	26531.00	
25% P-critical from NPS fertilizer +Recommended Nitrogen	51.36	178.78	16.04	15.01	3506.78	1076	43	46268	42761.22	462.82
50% P-critical from NPS fertilizer +Recommended Nitrogen	102.73	157.57	16.04	15.01	4012.66	1225	43	52675	48662.34	551.54
75% P-critical from NPS fertilizer +Recommended Nitrogen	154.09	136.35	16.04	15.01	4518.22	1498	43	64414	59895.78	738.45
100% P-critical from NPS fertilizer +Recommended Nitrogen	205.45	115.14	16.04	15.01	5023.94	1622	43	69746	**64722.06**	760.18
100% P-critical from DAP fertilizer +Recommended Nitrogen	169.72	133.59	16.35	15.01	4188.74	1322	43	56846	52657.26	623.73

Where: ETB = Ethiopian Birr, TVC = Total Variable Cost, MRR = Marginal Rate of Return, PC = Critical phosphorus, Rec. N = Recommended Nitrogen

Conclusion and Recommendations

Appropriate soil fertility management practices based on the actual limiting nutrients and crop nutrient requirement for a given crop is economic and judicious use of fertilizers for sustainable crop production. According to this study NPS fertilizer rate based on calibrated phosphorus significantly influences yield and yield component of tef which is at promising level to sustain soil fertility and to tackle the problems. Therefore, the study was conducted to determine the effect of NPS fertilizer rate in relative to determined critical phosphorus for tef in Girar Jarso District.

The analysis of variance depicted that, plant height, spike length, straw and grain yield was significantly ($P<0.05$) affected by NPS fertilizer rate. The highest plant height (86.32cm), panicle length (32.51cm), biomass yield (8626 kg ha^{-1}) and grain yield (1622 kg ha^{-1}) of tef was recorded from the application of 100% P-critical from NPS fertilizer rate supplemented with recommended Nitrogen whereas, the lowest value was recorded from the field without fertilizer which was significantly inferior to all other treatments. Furthermore, the economic analysis depicted that, application of NPS fertilizer at the rate of 100% P-critical in NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}) for the production of tef was more economically beneficial for the district.

Therefore, farmers could be advised to use 100% PC from NPS fertilizer rate with recommended nitrogen for tef production in the district. Demonstration and further scale up as well as verification at other district of similar soil type agro-ecology should be pre requisite.

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Y. Improvement in Grain Yield
Tekle, H. Tefera. “Genetic

Determination of NPS Fertilizer Rate Based on Calibrated Phosphorus for Yield of Bread Wheat in Degem District, North Shewa Zone, Oromia, Ethiopia

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Abstract

Ethiopian agriculture depended solely on fertilizer urea and diammonium phosphate (DAP) which is a source of N and P. The field experiment was conducted to determine NPS fertilizer rate in relative to determined P-critical and P-requirement factor for bread wheat production and to estimate the economically feasible NPS fertilizer rate for higher yield of bread wheat in Degem District. The experiment was laid out in randomized complete block design with three replication. The analysis of variances revealed that, the yield and yield components of bread wheat was very highly influenced ($P<0.01$) by different rates of NPS fertilizers. The result showed that the highest mean values of plant height (96.81 cm), spike length (7.5 cm), number of total tiller per plant (5.16), number of productive tillers per plant (4.16), biomass yield (14071 kg ha^{-1}) and grain yield (4173 kg ha^{-1}) of bread wheat was recorded from the application of 75 % P-critical from NPS fertilizer rate supplemented with recommended Nitrogen whereas, the lowest value was recorded from the field without fertilizer. Hence, farmers could be use 75 % critical phosphorus from NPS fertilizer rate with recommended nitrogen for bread wheat production in the district

Keywords: NPS fertilizer rate, yield, recommended nitrogen

Introduction

Wheat is an important crop that is grown on more acres globally than any other and provides a major share of the nutritional requirements for the growing world population (Shapiro, 2009). It is cultivated in Ethiopia on about 1.51 million hectares and delivers about 3.3 million tons of grain, which makes Ethiopia the largest wheat producer in sub Saharan Africa (CSA, 2013). However, Soil chemical degradation such as (soil acidity, salinity and sodicity, low levels of fertilizers), pesticides and improved seeds, moisture stress, are some of the major crop production constraints in Ethiopia (Taffesse *et al*., 2011).

For the last three decades, Ethiopian agriculture depended solely on imported fertilizer products, only urea and diammonium phosphate (DAP), sources of N and P. However, recently it is perceived that the production of such high protein cereals like wheat and legumes can be limited by the deficiency of S and other nutrients. In Ethiopia, major prone areas of S deficiency are the central highlands, because of their high crop production, which is driven by high market access in the big towns/cities in the center of the country. Reasons that lead to S deficiency in soils of central high lands include improved use of high analysis fertilizers that contain no S, intensive agriculture that leaves behind little organic matter (OM), and/or complete removal of OM for alternative uses, including farm yard manure (FYM), increased crop yields due to high yielding varieties, resulting in more S removal, and intensive cropping systems that include legumes and oil crops that mine more S etc.

Sulfur is a nutrient most overlooked in Ethiopian agriculture. In Ethiopia, incidental addition of S from low analysis sources is nil due to a shift to high analysis fertilizers. It is true that farmers and extensions can aim at increasing crop yields only in quantity by applying significantly higher amounts of NP from urea and DAP. But, in such conditions, failure to supplement S in balanced fertilizer programmers' can rapidly deplete available soil reserve leading to hidden S deficiency. Regardless of its importance, very little research is done on the status in soils and crops, and the available information/data are quite scanty. Furthermore, nitrogen and phosphorus are considered as the most deficient nutrients in soils of Ethiopia (Asnakew *et al*., 1991. This indicates that nitrogen and phosphorus are the most yield limiting factors of cereals including wheat production in Ethiopia. Soil fertility status also varies with in adjacent farms or plots mainly due to preceding individual farmer's soil management practices.

Therefore, developing site specific fertilizer recommendations that consider existing soil nutrient supply and recommend fertilizer based on crop nutrient demand to achieve target yield is required. Site and crop specific fertilizer recommendation is very useful for easy adoption of technologies as it better increases productivity as compared to the blanket recommendation. Site and crop specific recommendation is resulted from solving the real production constraints in the specific area. Since, Ethiopia is moving from blanket recommendations to soil test based fertilizer recommendations, Fitche Agricultural Research Center was conduct a research to determine critical phosphorus concentration and phosphorus requirement factors for bread wheat in Degem District, North Shewa Zone. However, the effect of NPS fertilizer rate was not determined for bread wheat in the study area. Thus, based on the determined Pc (22 ppm) and Pf (5.85), optimum NPS fertilizer rate determination was carried out in the study area with the objectives; to determine NPS fertilizer rate in relative to determined P-critical for bread wheat and to estimate the economically feasible NPS fertilizer rate for higher yield of bread wheat in Degem District.

Materials and Methods

Description of the Study Area

The experiment was conducted in Degem district of North Shewa Zone, Oromia, central high lands of Ethiopia. The district is located at 124 km of the capital Addis Ababa in the Northwest direction. The district is located between 9°34'0" to 10°03'0" North and 38°29'0" to 38°44'0" East and at an average elevation of 2878 m.a.s.l. The mean annual rainfall of the area is about 1150 mm that ranges from 900 to 1400 mm. The maximum and minimum annual temperature is 15^0C and 22^0C, respectively.

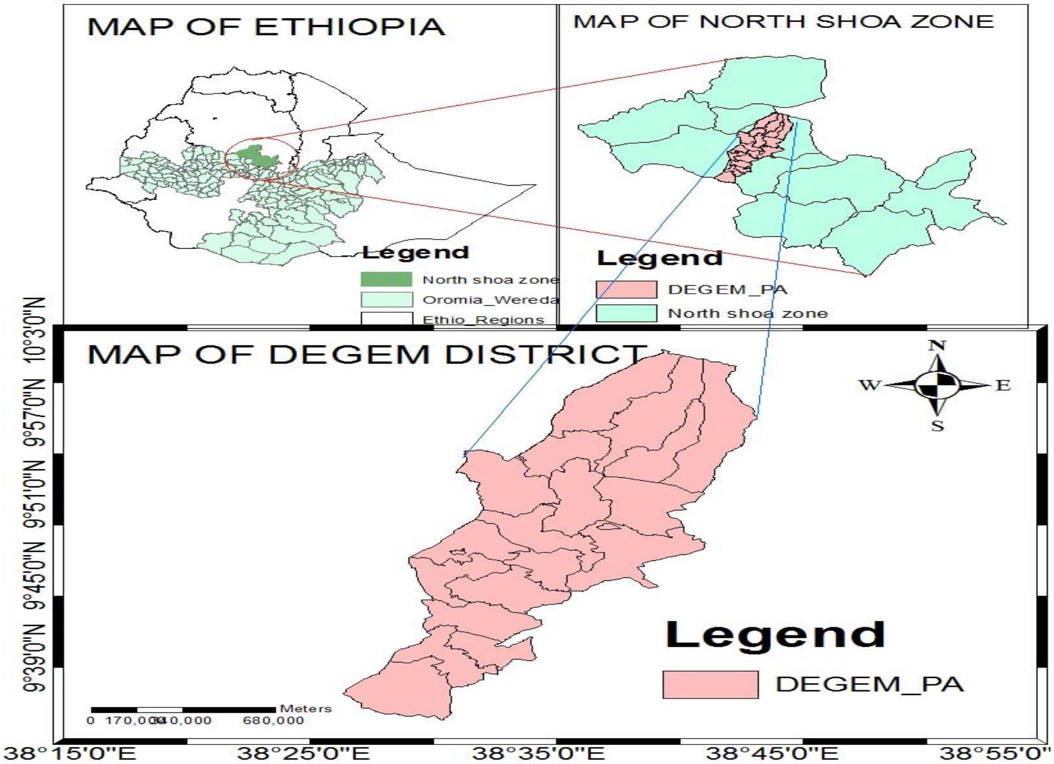

Figure 1: Location map of Degem district

Site Selection, Soil Sampling and Analysis Methods

Wheat production potential kebeles were selected with the office of Agriculture and Natural Resource Office of Degem District. Accordingly, the 9 farmer's fields were selected based on their willingness to handle the experimental fields. Before planting, 28 surface composite soil samples were collected from the farmers' field for analysis at a depth of 0-20 cm in a zig zag methods. Soil samples were collected using auger. The collected surface soil samples from the experimental field were air dried, grinded and allowed to pass through 2 mm sieve for further analysis in the laboratory (FAO, 2008). The collected soil samples were analyzed for the parameters of pH (H_2O) in the suspension of a 1: 2.5 soil to water ratio using a pH meter (Rhoades,1982) and available P was determined by the Olsen's method using a spectrophotometer (Olsen *et al*., 1954). Then the farmer's field was selected based on the analyzed soil sample results in which the soil pH above 5.5 and available soil phosphorus below critical phosphorus (Pc) was selected for the experiments.

Experimental Design and Treatments

The experimental field study was arranged with a total of 6 treatments in a randomized complete block design (RCBD) in three replications. The recommended nitrogen (92 kg ha^{-1}) for the district was used. The gross plot size was 3 * 4 and the space between block and plot was 70cm and 30cm respectively. The net plot size was 1.5 * 1.5 m. The required amount of seeds was weighed per plot by considering the recommended rate (150 kg ha^{-1}) of wheat seed per hectare. Urea, NPS, and DAP (Di ammonium Phosphate) was used as source of nitrogen and phosphorus containing fertilizers. Uniform field management practices for all plots were conducted. A bread wheat variety (Sanate) was used as test crop.

The treatments were;

T1 = Control (without fertilizers).
T2 = 25% P-critical from NPS fertilizer +Recommended Nitrogen
T3 = 50% P-critical from NPS fertilizer + Recommended Nitrogen
T4 = 75% P-critical from NPS fertilizer + Recommended Nitrogen
T5 = 100% P-critical from NPS fertilizer + Recommended Nitrogen
T6 = 100% P-critical from DAP fertilizer + Recommended Nitrogen

The determined P-critical value (22 ppm) and phosphorous requirement factor (5.85) was used to calculate the rate of phosphorus fertilizer to be applied. Thus, Phosphorus fertilizer rate was calculated by using the formula given below;

$$\text{Rate of P-applied} = (Pc - Pi) * pf$$

Where

Pc: Critical phosphorus concentration

P: Initial available P

Pf: Phosphorus requirement factor which was derived from the calibration study

Data Collection

Ten plants were randomly selected from the net plots area of each experimental unit for plant height and spike length measurements. Then the heights were measured from the selected plant from the ground to the tips of spike. Effective tillers were selected randomly from each plot at the time of harvesting and the spike was measured from the bottom of spike to the tip of the spike excluding of the awns. Number of total tillers per plant was measured from ten plant samples taken randomly from each plot at full tillering stage of crops by counting the total number of tillers and then the mean value was determined. Number of productive tillers was determined from those ten plant samples of spikes which can bear kernels at full tillering of the crop. The plants were harvested from the plot close to the ground level by hand; air dried in an open dry environment. The biomass and grain was determined by weighing using sensitive balance. Grain yield per plot was determined after carefully separating the grain from the biomass and finally concerted and expressed in kg per ha. Economic data such as production cost (input cost), gross income and net income based on the current market price of the yield and input was recorded.

Data Analysis

All data recorded and collected were subjected to analysis of variance (ANOVA) using GenStat 18th edition software program. The comparisons among treatment means were employed by using of Least Significance Difference (LSD) at 5% significant level

Economic Analysis

Partial budget analysis was done to identify economical feasibility among the treatments. The average open market price (Birr kg^{-1}) of bread wheat, price of fertilizers was used for analysis. For a treatment to be considered a worthwhile option to farmer, the minimum acceptable rate of return (MRR) should be 100 % (CIMMT, 1988), which is suggested to be realistic. This enables to make recommendations from marginal analysis. Marginal rate of return (MRR) were calculated by using the formula given blow;

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

Result and Discussions

Soil Reaction (pH) and Available Phosphorus of Experimental Field

The soil pH (H_2O) of the study area was moderately acidic with the value ranged from 5.56 to 5.72 according to the ratings suggested by Tekalign, 1991 (Table 1). Thus, the pH of the experimental soil was within the range for productive soils. The available phosphorus content of soils was very low to medium with the value ranged from 4.68 to 11.28 ppm according to the rating given by Cottenie, 1980. Therefore, the soil of the study areas needs application of phosphorus containing fertilizers for crop production.

Table 1. Soil pH and Available Phosphorus of Experimental field

Site	Soil pH	Available Phosphorus
1	5.59	10.21
2	5.72	5.73
3	5.66	4.68
4	5.72	6.89
5	5.71	6.57
6	5.63	4.73
7	5.59	4.78
8	5.60	11.21
9	5.56	4.78
Mean	5.64	6.62
SD	0.06	2.47

Where: SD = Standard Deviation, CV = Coefficient of variation

Response of Yield and Yield Components of Bread Wheat to NPS Fertilizer Rate

Plant Height

The result of analysis of variance showed that plant height was very highly significantly ($P < 0.01$) affected by the NPS fertilizer rate. Mean of the tallest plants height of 96.81 cm was recorded from the application of 75% PC from NPS supplemented with optimum N fertilizers while the shortest plants 65.25 cm were recorded from the plots without fertilizer application (Table 2). The result indicated that plant height increased with an increased up to optimum NPS fertilizer rate based on calibrated phosphorus supplemented by nitrogen fertilizer (Urea). The increment in plant height might be due to increase in cell elongation and vegetative growth attributed to different nutrient content of NPS fertilizer and the increasing of sulfur content caused a significant increase in wheat root and shoot growth as well as nutrient uptake. In conformity with this result, Melesse, 2017, Abebaw and Hirpa, 2018, Tilahun and Tamado, 2019, Abera *et al.,* 2021 and Tigist *et al.,* 2021 reported that increased application of balanced fertilizer significantly increased plant height of wheat.

Spike Length

The effect of NPS fertilizer was highly significantly ($P < 0.01$) influences spike length. The tallest (7.50 cm) and the shortest (4.95 cm) spike length was recorded from the application of 75% PC from NPS supplemented with optimum N fertilizers and unfertilized fields respectively (Table 2). The fertilizer application up to 75% PC from NPS showed increasing tendency of spike length with optimum nitrogen fertilizer. This might be due to an adequate and balanced nutrient supply especially nitrogen, phosphorus and sulfur available in the formulation of applied NPS fertilizer as in fact that it have a great role in cell division and grain filling there by it attributes to increased spike length. These results are in agreement with Diriba Shiferaw *et al.,* 2019, Abebe and Hirpa, 2018, reported that spike length was significantly affected by NPS fertilizer rate and the longest spike length was observed at the highest application of fertilizers.

Table 2. Effects of NPS Fertilizer rate and recommended Nitrogen on yield components of bread wheat

Treatment	PH (cm)	SL (cm)	NTTPP	NPTPP
100% P-critical from DAP fertilizer +Recommended Nitrogen	90.36[bc]	6.53[c]	3.62[d]	2.88[d]
100% P-critical from NPS fertilizer +Recommended Nitrogen	93.55[b]	6.94[b]	4.62[b]	3.71[b]
75% P-critical from NPS fertilizer +Recommended Nitrogen	96.81[a]	7.50[a]	5.16[a]	4.16[a]
50% P-critical from NPS fertilizer +Recommended Nitrogen	89.72[c]	6.36[c]	4.01[c]	3.19[c]
25% P-critical from NPS fertilizer +Recommended Nitrogen	84.75[d]	5.94[d]	3.03[e]	2.43[e]
without fertilizer	65.25[e]	4.95[e]	2.23[f]	1.63[f]
$LSD_{0.05}$	3.21	0.21	0.25	0.20
CV (%)	6.9	6.20	12.20	12.40

Means with the same letter in columns are not significantly different at 5% level of significance's, PH=plant height, SL= Spike length, CV=Coefficient of variation, LSD=Least Significance Difference, NTTPP = Number of total tillers per plant, NPT= Number of productive tillers per plant.

Total Number of Tillers per Plant

The analysis of variance showed that the number of total tillers per plant was very highly significantly (P< 0.01) affected by NPS fertilizer rates. Application of fertilizers at an application of 75% PC from NPS supplemented with optimum N fertilizers resulted in the highest (5.16) number of total tillers per plant and the minimum (2.23) number of total tillers per plant was recorded from unfertilized plots (Table 2). The increase in the numbers of tillers in response to increasing rate of balanced fertilizer indicated the importance of availability of balanced nutrients for better growth and development of wheat. The number of tillers per plant has a vital position in controlling yield of wheat. It is clear that the more the number of tillers is, the better will be the stand of the crop, which ultimately increases the yield. This result agrees with Bizuwork, 2018, Dinkinesh, 2018, Tigist *et al.,* 2021 reported that the highest number of total tillers was produced by plants treated with the highest rate of balanced fertilizers and the lowest was recorded from unfertilized plots.

Number of Productive Tillers per Plant

The analyzed result indicated that there was very highly significant (P < 0.01) variation among the NPS fertilizer rates. Application of fertilizers at an application of 75% PC from NPS supplemented with optimum N fertilizers resulted in the highest number of productive tillers per plant (4.16), and the minimum number of productive tillers per plant (1.63) was recorded from unfertilized plots (Table 2). The result in this study was in conformity with Diriba Shiferaw *et al.,* 2019, Tilahun and Tamado, 2019, Dinkinash *et al.,* 2020, who reported that the highest number of productive tillers, was obtained from the application of the highest rate of NPS fertilizers.

Biomass Yield

The analysis of variance revealed that the effect of NPS fertilizer was very highly significant (P < 0.01) affect the biomass yield. The highest biomass yield 14071 kg ha^{-1} was obtained at an application of 75% P-critical from NPS fertilizer with recommended Nitrogen and the lowest biomass yield of 3860 ton ha^{-1} was registered from the control plot (Table 3). The result is consistent with that of Bizuwork, 2018, Usman Kedir *et al.,* 2020, 2018, Diriba Shiferaw *et al.,* 2019 who reported increased in biomass yield of bread wheat with increased application of balanced fertilizers with nitrogen.

Grain Yield

The result showed that grain yield was very highly significantly (P < 0.001) influenced due to NPS fertilizer rate application. The highest grain yield (4173 kg ha^{-1}) was obtained from the application of 75% P-critical from NPS fertilizer rate supplemented with optimum recommended nitrogen while the lowest (1422 kg ha^{-1}) grain yield was recorded from the fields without fertilizers. The highest grain yield at the highest rates of NPS and nitrogen might be connected with provision of adequate plant nutrient requirement which results the induction of more productive tillers that directly correlated with the production of better yields. This result is in agreement with Usman Kedir et al., 2020, Tigist *et al.,* 2021, Abera *et al.,* 2021 who reported that, the maximum grain yield of bread wheat was recorded at the highest application of blended fertilizer rate.

Table 3. Effects of NPS Fertilizer rate and recommended Nitrogen on Biomass and grain yield of bread wheat

Treatment	Biomass yield (kg ha^{-1})	Grain yield (kg ha^{-1})
Control(without fertilizer)	5282^{e}	1422^{c}
25% P-critical from NPS fertilizer +Recommended Nitrogen	9056^{d}	2930^{b}
50% P-critical from NPS fertilizer +Recommended Nitrogen	11402^{c}	3338^{b}
75% P-critical from NPS fertilizer +Recommended Nitrogen	14071^{a}	4173^{a}
100% P-critical from NPS fertilizer +Recommended Nitrogen	12943^{b}	3959^{a}
100% P-critical from DAP fertilizer +Recommended Nitrogen	10736^{c}	3299^{b}
$LSD_{0.05}$	919.14	419
CV (%)	16.2	24.5

Means with the same letter in columns are not significantly different at 5% level of significance's, CV=Coefficient of variation, LSD=Least Significance Difference.

Partial Budget Analysis

The economic analysis showed that the highest net benefit (101570.65 ETB ha^{-1}) was obtained from the application of 75% Pc from NPS with recommended nitrogen, whereas the least net benefit (36972 ETB ha^{-1}) was obtained from the unfertilized treatment (Table 4). The highest marginal rate of return (MRR) (932.52 %) was obtained from the fertilizer application of 75 % P-critical from NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}). The MRR was indicated that bread wheat producers can get an extra of 9.33 ETB for 1.00 ETB investments in the NPS and N fertilizers application on the rates of 75 % P-critical in NPS fertilizer with recommended nitrogen fertilizer (92 kg N ha^{-1}). Therefore, application of NPS fertilizer at the rate of 75 % P-critical in NPS fertilizer with recommended nitrogen fertilizer (92 kg N ha^{-1}) for the production of bread wheat was more economically profitable.

Table 4. Marginal Analysis of Bread Wheat Yield as influenced by NPS Fertilizer Supplemented by Nitrogen Rate

TREATMENT	VARIABLE INPUT (KG HA^{-1})		UNIT PRICE(ETB)		TVC	OUTPUT (KG HA^{-1})	UNIT PRICE (ETB)	GROSS INCOME (ETB HA^{-1})	NET INCOME (ETB HA^{-1})	MRR (%)
	DAP/NPS	Urea	DAP/NPS	Urea						
CONTROL(WITHOUT FERTILIZER)	0	0	0	0	0	1422	26	36972	36972.00	
25% P-CRITICAL FROM NPS FERTILIZER +RECOMMENDED NITROGEN	439.24	28.12	16.35	15.01	7603.15	3299	26	85774	78170.85	541.87
50% P-CRITICAL FROM NPS FERTILIZER +RECOMMENDED NITROGEN	445.53	14.65	16.04	15.01	7367.70	3959	26	102934	95566.30	795.29
75% P-CRITICAL FROM NPS FERTILIZER +RECOMMENDED NITROGEN	398.78	35.29	16.04	15.01	6927.35	4173	26	108498	101570.65	932.52
100% P-CRITICAL FROM NPS FERTILIZER +RECOMMENDED NITROGEN	265.85	90.19	16.04	15.01	5618.64	3338	26	86788	81169.36	786.62
100% P-CRITICAL FROM DAP FERTILIZER +RECOMMENDED NITROGEN	132.93	159.51	16.04	15.01	4526.27	2930	26	76180	71653.73	766.23

Where: ETB = Ethiopian Birr, TVC = Total Variable Cost, MRR = Marginal Rate of Return, PC = Critical phosphorus, Rec. N = Recommended Nitrogen

Conclusions and Recommendations

Ethiopian agriculture depended solely on fertilizer urea and diammonium phosphate (DAP) which is a source of N and P. However, recently it is perceived that the production has been limited by the deficiency of Sulfur and other nutrients. Based the needs to supply limited nutrients at optimum rate, this study was initiated with the objectives to determine NPS fertilizer rate in relative to determined P-critical for bread wheat production and to estimate the economically feasible NPS fertilizer rate for higher yield of bread wheat in Degem district. The analysis of variances revealed that, the yield and yield components of bread wheat was very highly influenced ($P<0.01$) by different rates of NPS fertilizers based on calibrated phosphorus supplemented with optimum nitrogen in Degem district.

The analyzed result showed than the highest mean values of plant height (96.81 cm), spike length (7.5 cm), number of total tiller per plant (5.16), number of productive tillers per plant (4.16), biomass yield (14071 kg ha^{-1}) and grain yield (4173 kg ha^{-1}) of bread wheat was recorded from the application of 75 % P-critical from NPS fertilizer rate supplemented with recommended nitrogen whereas, the lowest value was recorded from the field without fertilizer.

The economic analysis showed that, the application of NPS fertilizer at the rate of 75 % P-critical from NPS fertilizer with recommended nitrogen fertilizer (92 kg N ha^{-1}) gave the highest the net income (101570.65 ETB ha^{-1}) with the highest marginal rate of return (932.52 %) are economically feasible. Therefore, farmers could be advised to use 75 % P-critical from NPS fertilizer rate with recommended nitrogen for bread wheat production in the district. Demonstration and further scale up as well as verification at other district of similar soil type agro-ecology should be pre requisite.

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Determination of NPS Fertilizer Rate Based on Calibrated Phosphorus for Yield of Tef in Girar Jarso District, North Shewa Zone, Oromia, Ethiopia

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Abstract

Appropriate soil fertility management practices based on the actual limiting nutrients and crop nutrient requirement for a given crop is economic and judicious use of fertilizers for sustainable crop production. Moreover, application of balanced fertilizers and nutrient requirements of the crop is the basis to produce more crop yield from the land under cultivation. Accordingly, field experiment was conducted in 2019 & 2020 main cropping season to determine NPS fertilizer rate in relative to determined P-critical and P-requirement factor for tef and to estimate the economically feasible NPS fertilizer rate for higher yield of tef in Girar Jarso district. Accordingly the result of study indicated that, plant height, panicle length, biomass and grain yield was highly significantly ($P<0.01$) affected by NPS fertilizer rate. The highest plant height (86.32cm), panicle length (32.51cm), biomass yield (8626kg ha^{-1}) and grain yield (1622 kg ha^{-1}) of tef was recorded from the application of 100% P-critical from NPS fertilizer rate supplemented with recommended Nitrogen whereas, the lowest value was recorded from the field without fertilizer which was significantly inferior to all other treatments. Furthermore, the economic analysis depicted that, application of NPS fertilizer at the rate of 100% P-critical in NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}) for the production of tef was more economically beneficial for the district. In conclusion, farmers and other end users could be advised to use 100% PC from NPS fertilizer rate with recommended nitrogen for tef production in the district and other area having similar soil type and agro- ecology.

Keywords: NPS fertilizer rate, recommended Nitrogen, Phosphorus critical, yield

Introduction

Tef (Eragrostistef), a cereal crop that belongs to the grass family Poaceae, is endemic to Ethiopia and has been widely cultivated in the country for centuries (Tekluand Tefera 2005). Tef is adaptable to a wide range of ecological conditions in altitudes ranging from near sea level to 3000 msl and even it can be grown in an environment unfavorable for most cereal, while the best performance occurs between 1100 and 2950 m a.s.l in Ethiopia (Hailu and Seyfu, 2000). Almost two thirds of the Ethiopian population use teff as their daily staple food. It is estimated that per capita consumption grew by 4 percent over the last 5 years (ATA, 2013c).Tef is considered an economically superior good, relatively more consumed by urban and richer consumers (Berhane *et al.* 2011; Minten *et al*. 2013).

Growth in average incomes and faster urbanization in Ethiopia are likely to increase the demand for teff over time (Berhane *et al.* 2011). Even though, Ethiopia is a center of origin and diversity of tef and has the above-mentioned importance and coverage of large area, its productivity is very low to feed the demand of its people and market. These is due to low soil fertility and suboptimal use of mineral fertilizers in addition to weeds, lack of high yielding cultivars, erratic rainfall distribution in lower altitudes, lodging, water logging, low moisture, and low soil fertility conditions (Fufa, 1998). On the other hand, under conditions where most growth requirements are available and in organic matter rich soils, application of fertilizers without knowing its fertility status causes yield and fertilizer losses (Tekalign *et al.*,2001). There are different blanket fertilizer recommendations for various soil types of Ethiopia for tef cultivation. This is due to its cultivation in different agro ecological zones and soil types, having different fertility status and nutrient content. Accordingly, N/P recommendation rates by the Ministry of Agriculture were set at 55/30, 30/40, and 40/35 N/P kg ha^{-1} for tef crop on Vertisols, Nitosols, and Cambisols, respectively across the country (Seyfu, 1993). However, 100 kg DAP ha^{-1} and 100 kg urea ha^{-1} were set by the Ministry of Agriculture and Rural Development later (Kenea *et al.*, 2001).

Those blanket recommendations brought generally, an increase in yield of improved cultivars ranging from 1700 to 2200 kg/ha (Seyfu, 1997). Accordingly, the average national yield in the year 2010 reached 1200 kg/ha (CSA, 2010). However, the recommendations do not work for all Production aspects of various soil types of different regions. Tef responds to fertilizers especially to N highly in all its yield components. N is essential for carbohydrate use within plants and stimulates root growth and development as well as uptake of other nutrients (Tisdale *et al*., 1993; Brady and Weil, 2002).

Soil test based application of plant nutrient helps to realize higher response ratio and benefit: cost ratio as the nutrients are applied in proportion to the magnitude of the deficiency of a particular nutrient and correction of the nutrients imbalance in soil helps to harness the synergistic effects of balanced fertilization. Location specific fertilizer recommendations are possible for soils of varying fertility, resource conditions of farmers and level of target yield conditions of similar soil classes and environment (Ahmed *et al*., 2002). Since, Ethiopia is moving from blanket recommendations to soil test based fertilizer recommendations, Fitche Agricultural Research Center was conduct a research to determine critical phosphorus concentration and phosphorus requirement factors for tef in Girar Jarso District, North Shewa Zone. However, the effect of NPS fertilizer rate was not determined for tef in the study area. Thus, based on the determined Pc (18 ppm) and Pf (3.03), optimum NPS fertilizer rate determination was carried out in the study area with the objectives; to determine NPS fertilizer rate in relative to determined P-critical and P-requirement factor for tef and to estimate the economically feasible NPS fertilizer rate for higher yield of tef in Girar Jarso District.

Material and Methods

Description of the Study Area

The study was conducted in Girar Jarso District North Shewa Zone Oromia, Ethiopia. The district is located at 112 km from the capital Addis Ababa. Geographically the district is located between 09038’52.8’’N to 10000’10.8’’N latitude and $38^0$34'22.8"E to $38^0$50'20.4"E longitude. The elevation ranged from 1300 and 3419 meters above sea level. The mean annual rain fall is 1200mm According to Fitche Station Meteorological data (Haile Mariam, 2014). The maximum and minimum mean temperature of the area is 35^0C and 11.5^0c respectively.

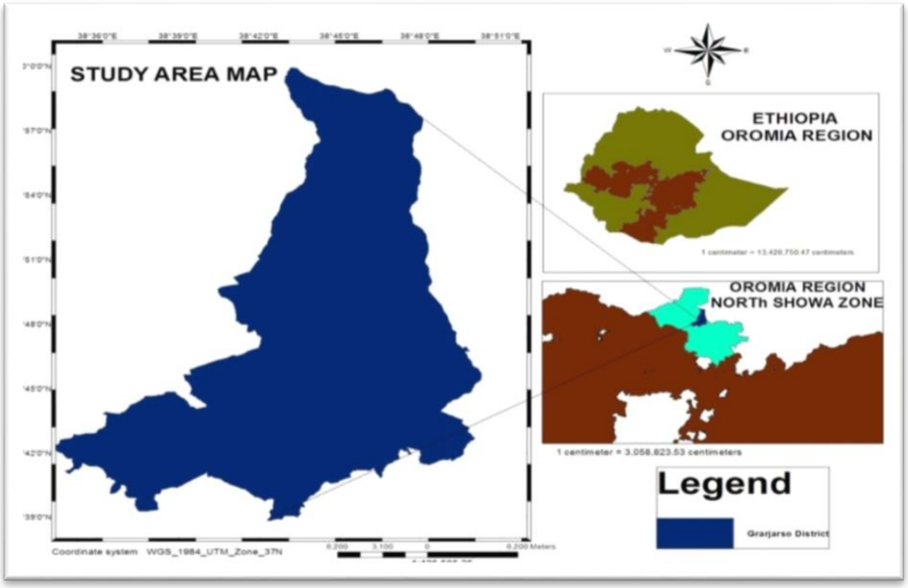

Figure 1: Location map of Girar Jarso district.

Site Selection, Soil Sampling and Analysis Methods

Tef production potential kebeles (small administrative unit) were selected from the district. Accordingly, the 11 farmer's fields were selected based on their willingness to handle the experimental fields. Before planting, 45 surface composite soil samples were collected in duration of two years from 45 farmer's fields for analysis at a depth of 0-20 cm in a zig zag methods. Soil samples were collected using auger. The collected surface soil samples from the experimental field were air dried, grinded and allowed to pass through 2 mm sieve for further analysis in the laboratory (FAO, 2008). The collected soil samples were analyzed for the pH (H_2O) in the suspension of a 1: 2.5 soil to water ratio using a pH meter (Rhoades, 1982) and available P was determined by the Olsen's method using a spectrophotometer (Olsen *et al.*, 1954). Then the farmer's field was selected based on the analyzed soil sample results in which the soil pH above 5.5 and available soil phosphorus below critical phosphorus (Pc) was selected for the experiments.

Experimental Design and Treatments

The experimental field study was arranged with a total of 6 treatments in a randomized complete block design (RCBD) in three replications. The recommended Nitrogen (92 kg ha^{-1}) for the district was used. The gross plot size was 3m * 4m and the space between block and plot was 70cm and 30cm respectively. The net plot size was 2 * 2m. The required amount of seeds was weighed per plot by considering the recommended rate of tef seed per hectare. Urea, NPS, and DAP (Di ammonium Phosphate) was used as source of Nitrogen and Phosphorus containing fertilizers. Uniform field management practices for all plots were conducted. A tef variety (kora) was used as test crop.

The treatments were;

T1 = Control (without fertilizers).
T2 = 25% P-critical from NPS fertilizer +Recommended Nitrogen
T3 = 50% P-critical from NPS fertilizer + Recommended Nitrogen

T4 = 75% P-critical from NPS fertilizer + Recommended Nitrogen
T5 = 100% P-critical from NPS fertilizer + Recommended Nitrogen
T6 = 100% P-critical from DAP fertilizer + Recommended Nitrogen

The determined P-critical value (18 ppm) and phosphorous requirement factor (3.03) was used to calculate the rate of phosphorus fertilizer to be applied. Thus, Phosphorus fertilizer rate was calculated by using the formula given below;

$$\text{Rate of P-applied} = (\text{Pc-Pi}) * \text{pf}$$

Where

Pc: Critical phosphorus concentration; P: Initial available P; Pf: Phosphorus requirement factor which was derived from the calibration study

Data Collection

Tef grain yield was harvested at the ground level from the net plot area and weighed for biomass data. Then plant height and panicle length was measured at harvest. After threshing, grain yield were cleaned and weighed. The biomass yield was determined by addition of the grain yield and the straw yield for each respective treatment. Economic data such as production cost (input cost), gross income and net income based on the current market price of the yield and input was recorded.

Data Analysis

All data recorded and collected were subjected to the analysis of variance (ANOVA) using GenStat 18th edition software program. The comparisons among treatment means were employed by using of Least Significance Difference (LSD) at 5% significant level.

Economic Analysis

Partial budget analysis was done to identify economical feasibility among the treatments. The average open market price (Birr kg^{-1}) of tef, price of fertilizers was used for analysis. For a treatment to be considered a worthwhile option to farmer, the minimum acceptable rate of return (MRR) should be 100 % (CIMMT, 1988), which is suggested to be realistic. This enables to make recommendations from marginal analysis. Marginal rate of return (MRR) were calculated by using the formula given blow;

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

Result and Discussions

Soil Reaction (pH) and Available Phosphorus of Experimental Field

The soil was moderately to slightly acidic in reaction with the pH (H_2O) value of 6.6, which is value ranged from 5.56 to 5.9 according to the ratings suggested by Tekalign, 1991. Thus, the pH of the experimental soil was within the range for productive soils. The available phosphorus content of soils before planting was 7.37pmm, which is low to medium according to the rating given by Cottenie, 1980. Therefore, the soil of the study areas needs application of phosphorus containing fertilizers for crop production.

Table 1. Soil pH and Available Phosphorus of the experimental fields

Site	Soil pH	Available phosphorus (ppm)
1	6.33	8.2
2	6.77	7.1
3	6.21	3.17
4	6.86	9.23
5	6.03	8.65
6	7.16	5.86
7	6.4	8.13
8	6.84	5.92
9	6.79	5.28
10	6.44	14.77
11	6.73	4.74
Mean	6.60	7.37
SD	0.34	3.07

Where: SD = Standard Deviation

Response of yield and yield component of tef to NPS Fertilizer Rate

Plant Height and Panicle Length

Plant height and Panicle length revealed significantly ($P<0.05$) influenced by NPS fertilizer rate. The highest plant height (86.32cm) and Panicle length (32.51cm) of tef was recorded from the application of 100% P-critical from NPS fertilizer rate supplemented with recommended nitrogen. The lowest plant height (55.6 cm) and panicle length (20.61 cm) was recorded from the field without fertilizer which was significantly inferior to all other treatments (Table 2). The increase in plant height with increasing NPS fertilizer could be attributed due to sufficient supply of nutrient which in turn contributed to increased vegetative growth since nitrogen plays crucial role in the structure of chlorophyll and P involved in the energy transfer for cellular metabolism. This result was in agreement with the findings of (Giday *et al.*, 2014; Feyera *et al.*, 2014 and Wakjira, 2018) reported that, application of blended fertilizers was on par with blanket recommendation of fertilizers and gave significantly higher plant height and panicle length on tef. Furthermore, according to Feyera *et a*l., 2014 balanced fertilization application and efficient utilization of nutrient leads to high photosynthetic productivity and accretion of dry matter, eventually increases spike length.

Biomass Yield

The analysis of variance indicated that the biomass yield was significantly affected by NPS fertilizer rate (Table 2). The highest biomass yield (8626 kg ha^{-1}) was obtained from the application of 100% P-critical from NPS fertilizer rate supplemented with recommended Nitrogen and the lowest biomass yield (3593 kg ha^{-1}) obtained from unfertilized plot (Table 2). The significant increase in biomass yield could be attributed due to the availability of macronutrients and some secondary nutrients formulated with the NPS fertilizer, which could increase the vegetative consequently the biomass yield. Similar significant increase in biomass yield was also observed for different application rate of NPS fertilizers which states that the increased in straw yield attributed due to the proportional vegetative growth especially plant height (Giday *et al.,* 2014; Feyera *et al*., 2014 and Wakjira, 2018).

Grain Yield

The statistical analysis showed that, the grain yield of tef was highly significantly ($P<0.05$) influenced by NPS fertilizer rate. The highest (1622 kg ha^{-1}) and the lowest (617 kg ha^{-1}) grain yield was obtained from the application of 100% P-critical from NPS fertilizer rate supplemented with recommended Nitrogen and unfertilized plot respectively (Table 2). Grain yield increased consistently and significantly in response to increasing the rate of NPS fertilizer from nil up to the highest. The increased in grain yield from NPS fertilizer might be facilitated the uptake of other essential nutrients which helps to boost plant growth and yield.

Table 2. Effects of NPS Fertilizer rate and recommended Nitrogen on yield and yield components of tef

Treatment	Ph (cm)	Pl (cm)	Biomass Kg ha^{-1}	Grain yield kg ha^{-1}
Control(without fertilizer)	55.6^{e}	20.61^{f}	3503^{f}	617^{d}
25% p-critical from nps fertilizer +recommended nitrogen	69.37^{d}	25.4^{e}	5642^{e}	1076^{c}
50% p-critical from nps fertilizer +recommended nitrogen	74.67^{c}	27.17^{d}	6342^{d}	1225^{c}
75% p-critical from nps fertilizer +recommended nitrogen	81.68^{b}	30.4^{b}	7978^{b}	1498^{ab}
100% p-critical from nps fertilizer +recommended nitrogen	86.32^{a}	32.51^{a}	86264^{a}	1622^{a}
100% p-critical from dap fertilizer +recommended nitrogen	78.23^{bc}	29.08^{c}	7283^{c}	1322^{bc}
$LSD_{0.05}$	3.937	1.313	551.31	186.3
CV (%)	7.3	6.6	11.2	29.8

Means with the same letter in columns are not significantly different at 5% level of significance's, PH=plant height, SL= Panicle length, CV=Coefficient of variation, LSD=Least Significance Difference

Partial Budget Analysis

Partial budget analysis showed that the highest net benefit (64722.06 ETB ha^{-1}) and the highest marginal rate of return (MRR) (760.18 %) was obtained from the fertilizer application of 100% P-critical from NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}). The lowest net benefit (26531.00 ETB ha^{-1}) was obtained from unfertilized plots (Table 3). The MRR was indicated that tef producers can get an extra of 7.61 ETB for 1.00 ETB investments in the NPS and N fertilizers application on the rates of 100% P-critical in NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}).Therefore, application of NPS fertilizer at the rate of 100% P-critical in NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}) for the production of tef was more economically beneficial and recommended for Girar Jarso District.

Table 3. Marginal Analysis of Bread Wheat Yield as influenced by NPS Fertilizer Supplemented by Nitrogen Rate

Reatment	**Variable input (kg ha^{-1})**		**Unit price(etb)**		**Tvc**	**Output (kg ha^{-1})**	**Unit price (etb)**	**Gross income (etb ha^{-1})**	**Net income (etb ha^{-1})**	**Mrr (%)**
	Dap/ nps	Urea	Dap/ nps	Urea						
Control(without fertilizer)	0	0	0	0	0	617	43	26531	26531.00	
25% p-critical from nps fertilizer +recommended nitrogen	51.36	178.78	16.04	15.01	3506.78	1076	43	46268	42761.22	462.82
50% p-critical from nps fertilizer +recommended nitrogen	102.73	157.57	16.04	15.01	4012.66	1225	43	52675	48662.34	551.54
75% p-critical from nps fertilizer +recommended nitrogen	154.09	136.35	16.04	15.01	4518.22	1498	43	64414	59895.78	738.45
100% p-critical from nps fertilizer +recommended nitrogen	205.45	115.14	16.04	15.01	5023.94	1622	43	69746	**64722.06**	760.18
100% p-critical from dap fertilizer +recommended nitrogen	169.72	133.59	16.35	15.01	4188.74	1322	43	56846	52657.26	623.73

Where: ETB = Ethiopian Birr, TVC = Total Variable Cost, MRR = Marginal Rate of Return, PC = Critical phosphorus, Rec. N = Recommended Nitrogen

Conclusion and Recommendations

Appropriate soil fertility management practices based on the actual limiting nutrients and crop nutrient requirement for a given crop is economic and judicious use of fertilizers for sustainable crop production. According to this study NPS fertilizer rate based on calibrated phosphorus significantly influences yield and yield component of tef which is at promising level to sustain soil fertility and to tackle the problems. Therefore, the study was conducted to determine the effect of NPS fertilizer rate in relative to determined critical phosphorus for tef in Girar Jarso District. The analysis of variance depicted that, plant height, spike length, straw and grain yield was significantly ($P<0.05$) affected by NPS fertilizer rate. The highest plant height (86.32cm), panicle length (32.51cm), biomass yield (8626 kg ha^{-1}) and grain yield (1622 kg ha^{-1}) of tef was recorded from the application of 100% P-critical from NPS fertilizer rate supplemented with recommended Nitrogen whereas, the lowest value was recorded from the field without fertilizer which was significantly inferior to all other treatments. Furthermore, the economic analysis depicted that, application of NPS fertilizer at the rate of 100% P-critical in NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}) for the production of tef was more economically beneficial for the district.

Therefore, farmers could be advised to use 100% PC from NPS fertilizer rate with recommended nitrogen for tef production in the district. Demonstration and further scale up as well as verification at other district of similar soil type agro-ecology should be pre requisite.

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Determination of NPS Fertilizer Rate Based on Calibrated Phosphorus for Yield of Bread Wheat in Degem District, North Shewa Zone, Oromia, Ethiopia

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Abstract

Ethiopian agriculture depended solely on fertilizer urea and diammonium phosphate (DAP) which is a source of N and P. The field experiment was conducted to determine NPS fertilizer rate in relative to determined P-critical and P-requirement factor for bread wheat production and to estimate the economically feasible NPS fertilizer rate for higher yield of bread wheat in Degem District. The experiment was laid out in randomized complete block design with three replication. The analysis of variances revealed that, the yield and yield components of bread wheat was very highly influenced ($P<0.01$) by different rates of NPS fertilizers. The result showed that the highest mean values of plant height (96.81 cm), spike length (7.5 cm), number of total tiller per plant (5.16), number of productive tillers per plant (4.16), biomass yield (14071 kg ha^{-1}) and grain yield (4173 kg ha^{-1}) of bread wheat was recorded from the application of 75 % P-critical from NPS fertilizer rate supplemented with recommended Nitrogen whereas, the lowest value was recorded from the field without fertilizer. Hence, farmers could be use 75 % critical phosphorus from NPS fertilizer rate with recommended nitrogen for bread wheat production in the district

Keywords: NPS fertilizer rate, yield, recommended nitrogen

Introduction

Wheat is an important crop that is grown on more acres globally than any other and provides a major share of the nutritional requirements for the growing world population (Shapiro, 2009). It is cultivated in Ethiopia on about 1.51 million hectares and delivers about 3.3 million tons of grain, which makes Ethiopia the largest wheat producer in sub Saharan Africa (CSA, 2013). However, Soil chemical degradation such as (soil acidity, salinity and sodicity, low levels of fertilizers), pesticides and improved seeds, moisture stress, are some of the major crop production constraints in Ethiopia (Taffesse *et al*., 2011). For the last three decades, Ethiopian agriculture depended solely on imported fertilizer products, only urea and diammonium phosphate (DAP), sources of N and P. However, recently it is perceived that the production of such high protein cereals like wheat and legumes can be limited by the deficiency of S and other nutrients. In Ethiopia, major prone areas of S deficiency are the central highlands, because of their high crop production, which is driven by high market access in the big towns/cities in the center of the country. Reasons that lead to S deficiency in soils of central high lands include improved use of high analysis fertilizers that contain no S, intensive agriculture that leaves behind little organic matter (OM), and/or complete removal of OM for alternative uses, including farm yard manure (FYM), increased crop yields due to high yielding varieties, resulting in more S removal, and intensive cropping systems that include legumes and oil crops that mine more S etc.

is a nutrient most overlooked in Ethiopian agriculture. In Ethiopia, incidental addition of S from low analysis sources is nil due to a shift to high analysis fertilizers. It is true that farmers and extensions can aim at increasing crop yields only in quantity by applying significantly higher amounts of NP from urea and DAP. But, in such conditions, failure to supplement S in balanced fertilizer programmers' can rapidly deplete available soil reserve leading to hidden S deficiency. Regardless of its importance, very little research is done on the status in soils and crops, and the available information/data are quite scanty. Furthermore, nitrogen and phosphorus are considered as the most deficient nutrients in soils of Ethiopia (Asnakew *et al*., 1991. This indicates that nitrogen and phosphorus are the most yield limiting factors of cereals including wheat production in Ethiopia. Soil fertility status also varies with in adjacent farms or plots mainly due to preceding individual farmer's soil management practices. Therefore, developing site specific fertilizer recommendations that consider existing soil nutrient supply and recommend fertilizer based on crop nutrient demand to achieve target yield is required. Site and crop specific fertilizer recommendation is very useful for easy adoption of technologies as it better increases productivity as compared to the blanket recommendation. Site and crop specific recommendation is resulted from solving the real production constraints in the specific area.

Since, Ethiopia is moving from blanket recommendations to soil test based fertilizer recommendations, Fitche Agricultural Research Center was conduct a research to determine critical phosphorus concentration and phosphorus requirement factors for bread wheat in Degem District, North Shewa Zone. However, the effect of NPS fertilizer rate was not determined for bread wheat in the study area. Thus, based on the determined Pc (22 ppm) and Pf (5.85), optimum NPS fertilizer rate determination was carried out in the study area with the objectives; to determine NPS fertilizer rate in relative to determined P-critical for bread wheat and to estimate the economically feasible NPS fertilizer rate for higher yield of bread wheat in Degem District.

Materials and Methods

Description of the Study Area

The experiment was conducted in Degem district of North Shewa Zone, Oromia, central high lands of Ethiopia. The district is located at 124 km of the capital Addis Ababa in the Northwest direction. The district is located between 9°34'0" to 10°03'0" North and 38°29'0" to 38°44'0" East and at an average elevation of 2878 m.a.s.l. The mean annual rainfall of the area is about 1150 mm that ranges from 900 to 1400 mm. The maximum and minimum annual temperature is 15^0C and 22^0C, respectively.

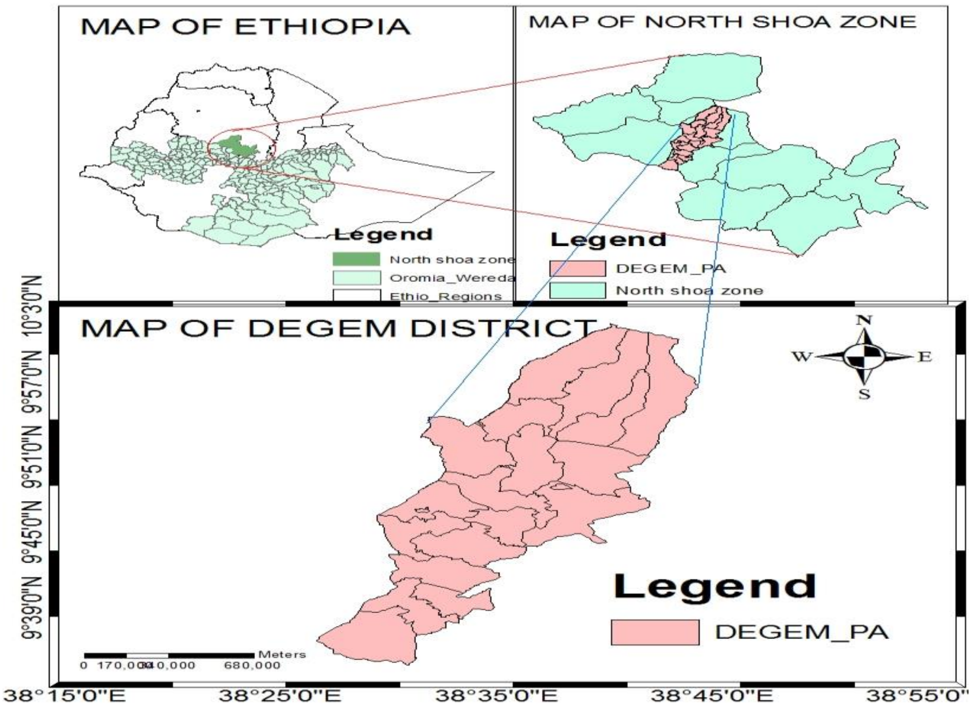

Figure 1: Location map of Degem district

Site Selection, Soil Sampling and Analysis Methods

Wheat production potential kebeles were selected with the office of Agriculture and Natural Resource Office of Degem District. Accordingly, the 9 farmer's fields were selected based on their willingness to handle the experimental fields. Before planting, 28 surface composite soil samples were collected from the farmers' field for analysis at a depth of 0-20 cm in a zig zag methods. Soil samples were collected using auger. The collected surface soil samples from the experimental field were air dried, grinded and allowed to pass through 2 mm sieve for further analysis in the laboratory (FAO, 2008). The collected soil samples were analyzed for the parameters of pH (H_2O) in the suspension of a 1: 2.5 soil to water ratio using a pH meter (Rhoades,1982) and available P was determined by the Olsen's method using a spectrophotometer (Olsen *et al*., 1954). Then the farmer's field was selected based on the analyzed soil sample results in which the soil pH above 5.5 and available soil phosphorus below critical phosphorus (Pc) was selected for the experiments.

Experimental Design and Treatments

The experimental field study was arranged with a total of 6 treatments in a randomized complete block design (RCBD) in three replications. The recommended nitrogen (92 kg ha^{-1}) for the district was used. The gross plot size was 3 * 4 and the space between block and plot was 70cm and 30cm respectively. The net plot size was 1.5 * 1.5 m. The required amount of seeds was weighed per plot by considering the recommended rate (150 kg ha^{-1}) of wheat seed per hectare. Urea, NPS, and DAP (Di ammonium Phosphate) was used as source of nitrogen and phosphorus containing fertilizers. Uniform field management practices for all plots were conducted. A bread wheat variety (Sanate) was used as test crop.

The treatments were;

T1 = Control (without fertilizers).

T2 = 25% P-critical from NPS fertilizer +Recommended Nitrogen

T3 = 50% P-critical from NPS fertilizer + Recommended Nitrogen

T4 = 75% P-critical from NPS fertilizer + Recommended Nitrogen

T5 = 100% P-critical from NPS fertilizer + Recommended Nitrogen

T6 = 100% P-critical from DAP fertilizer + Recommended Nitrogen

The determined P-critical value (22 ppm) and phosphorous requirement factor (5.85) was used to calculate the rate of phosphorus fertilizer to be applied. Thus, Phosphorus fertilizer rate was calculated by using the formula given below;

$$\text{Rate of P-applied} = (Pc - Pi) * pf$$

Where

Pc: Critical phosphorus concentration; P: Initial available P; Pf: Phosphorus requirement factor which was derived from the calibration study

Data Collection

Ten plants were randomly selected from the net plots area of each experimental unit for plant height and spike length measurements. Then the heights were measured from the selected plant from the ground to the tips of spike. Effective tillers were selected randomly from each plot at the time of harvesting and the spike was measured from the bottom of spike to the tip of the spike excluding of the awns. Number of total tillers per plant was measured from ten plant samples taken randomly from each plot at full tillering stage of crops by counting the total number of tillers and then the mean value was determined. Number of productive tillers was determined from those ten plant samples of spikes which can bear kernels at full tillering of the crop. The plants were harvested from the plot close to the ground level by hand; air dried in an open dry environment. The biomass and grain was determined by weighing using sensitive balance. Grain yield per plot was determined after carefully separating the grain from the biomass and finally concerted and expressed in kg per ha. Economic data such as production cost (input cost), gross income and net income based on the current market price of the yield and input was recorded.

Data Analysis

All data recorded and collected were subjected to analysis of variance (ANOVA) using GenStat 18th edition software program. The comparisons among treatment means were employed by using of Least Significance Difference (LSD) at 5% significant level

Economic Analysis

Partial budget analysis was done to identify economical feasibility among the treatments. The average open market price (Birr kg^{-1}) of bread wheat, price of fertilizers was used for analysis. For a treatment to be considered a worthwhile option to farmer, the minimum acceptable rate of return (MRR) should be 100 % (CIMMT, 1988), which is suggested to be realistic. This enables to make recommendations from marginal analysis. Marginal rate of return (MRR) were calculated by using the formula given blow;

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

Result and Discussions

Soil Reaction (pH) and Available Phosphorus of Experimental Field

The soil pH (H_2O) of the study area was moderately acidic with the value ranged from 5.56 to 5.72 according to the ratings suggested by Tekalign, 1991 (Table 1). Thus, the pH of the experimental soil was within the range for productive soils. The available phosphorus content of soils was very low to medium with the value ranged from 4.68 to 11.28 ppm according to the rating given by Cottenie, 1980. Therefore, the soil of the study areas needs application of phosphorus containing fertilizers for crop production.

Table 1. Soil pH and Available Phosphorus of Experimental field

Site	Soil pH	Available Phosphorus
1	5.59	10.21
2	5.72	5.73
3	5.66	4.68
4	5.72	6.89
5	5.71	6.57
6	5.63	4.73
7	5.59	4.78
8	5.60	11.21
9	5.56	4.78
Mean	5.64	6.62
SD	0.06	2.47

Where: SD = Standard Deviation, CV = Coefficient of variation

Response of Yield and Yield Components of Bread Wheat to NPS Fertilizer Rate

Plant Height

The result of analysis of variance showed that plant height was very highly significantly ($P < 0.01$) affected by the NPS fertilizer rate. Mean of the tallest plants height of 96.81 cm was recorded from the application of 75% PC from NPS supplemented with optimum N fertilizers while the shortest plants 65.25 cm were recorded from the plots without fertilizer application (Table 2). The result indicated that plant height increased with an increased up to optimum NPS fertilizer rate based on calibrated phosphorus supplemented by nitrogen fertilizer (Urea). The increment in plant height might be due to increase in cell elongation and vegetative growth attributed to different nutrient content of NPS fertilizer and the increasing of sulfur content caused a significant increase in wheat root and shoot growth as well as nutrient uptake. In conformity with this result, Melesse, 2017, Abebaw and Hirpa, 2018, Tilahun and Tamado, 2019, Abera *et al.,* 2021 and Tigist *et al.,* 2021 reported that increased application of balanced fertilizer significantly increased plant height of wheat.

Spike Length

The effect of NPS fertilizer was highly significantly ($P < 0.01$) influences spike length. The tallest (7.50 cm) and the shortest (4.95 cm) spike length was recorded from the application of 75% PC from NPS supplemented with optimum N fertilizers and unfertilized fields respectively (Table 2). The fertilizer application up to 75% PC from NPS showed increasing tendency of spike length with optimum nitrogen fertilizer. This might be due to an adequate and balanced nutrient supply especially nitrogen, phosphorus and sulfur available in the formulation of applied NPS fertilizer as in fact that it have a great role in cell division and grain filling there by it attributes to increased spike length. These results are in agreement with Diriba Shiferaw *et al.,* 2019, Abebe and Hirpa, 2018, reported that spike length was significantly affected by NPS fertilizer rate and the longest spike length was observed at the highest application of fertilizers.

Table 2. Effects of NPS Fertilizer rate and recommended Nitrogen on yield components of bread wheat

Treatment	PH (cm)	SL (cm)	NTTPP	NPTPP
100% P-critical from DAP fertilizer +Recommended Nitrogen	90.36^{bc}	6.53^{c}	3.62^{d}	2.88^{d}
100% P-critical from NPS fertilizer +Recommended Nitrogen	93.55^{b}	6.94^{b}	4.62^{b}	3.71^{b}
75% P-critical from NPS fertilizer +Recommended Nitrogen	96.81^{a}	7.50^{a}	5.16^{a}	4.16^{a}
50% P-critical from NPS fertilizer +Recommended Nitrogen	89.72^{c}	6.36^{c}	4.01^{c}	3.19^{c}
25% P-critical from NPS fertilizer +Recommended Nitrogen	84.75^{d}	5.94^{d}	3.03^{e}	2.43^{e}
without fertilizer	65.25^{e}	4.95^{e}	2.23^{f}	1.63^{f}
$LSD_{0.05}$	3.21	0.21	0.25	0.20
CV (%)	6.9	6.20	12.20	12.40

Means with the same letter in columns are not significantly different at 5% level of significance's, PH=plant height, SL= Spike length, CV=Coefficient of variation, LSD=Least Significance Difference, NTTPP = Number of total tillers per plant, NPT= Number of productive tillers per plant.

Total Number of Tillers per plant

The analysis of variance showed that the number of total tillers per plant was very highly significantly ($P< 0.01$) affected by NPS fertilizer rates. Application of fertilizers at an application of 75% PC from NPS supplemented with optimum N fertilizers resulted in the highest (5.16) number of total tillers per plant and the minimum (2.23) number of total tillers per plant was recorded from unfertilized plots (Table 2). The increase in the numbers of tillers in response to increasing rate of balanced fertilizer indicated the importance of availability of balanced nutrients for better growth and development of wheat. The number of tillers per plant has a vital position in controlling yield of wheat. It is clear that the more the number of tillers is, the better will be the stand of the crop, which ultimately increases the yield. This result agrees with Bizuwork, 2018, Dinkinesh, 2018, Tigist *et al.,* 2021 reported that the highest number of total tillers was produced by plants treated with the highest rate of balanced fertilizers and the lowest was recorded from unfertilized plots.

Number of Productive Tillers per Plant

The analyzed result indicated that there was very highly significant ($P < 0.01$) variation among the NPS fertilizer rates. Application of fertilizers at an application of 75% PC from NPS supplemented with optimum N fertilizers resulted in the highest number of productive tillers per plant (4.16), and the minimum number of productive tillers per plant (1.63) was recorded from unfertilized plots (Table 2). The result in this study was in conformity with Diriba Shiferaw *et al.,* 2019, Tilahun and Tamado, 2019, Dinkinash *et al.,* 2020, who reported that the highest number of productive tillers, was obtained from the application of the highest rate of NPS fertilizers.

Biomass Yield

The analysis of variance revealed that the effect of NPS fertilizer was very highly significant ($P < 0.01$) affect the biomass yield. The highest biomass yield 14071 kg ha^{-1} was obtained at an application of 75% P-critical from NPS fertilizer with recommended Nitrogen and the lowest biomass yield of 3860 ton ha^{-1} was registered from the control plot (Table 3). The result is consistent with that of Bizuwork, 2018, Usman Kedir *et al.,* 2020, 2018, Diriba Shiferaw *et al.,* 2019 who reported increased in biomass yield of bread wheat with increased application of balanced fertilizers with nitrogen.

Grain Yield

The result showed that grain yield was very highly significantly ($P < 0.001$) influenced due to NPS fertilizer rate application. The highest grain yield (4173 kg ha^{-1}) was obtained from the application of 75% P-critical from NPS fertilizer rate supplemented with optimum recommended nitrogen while the lowest (1422 kg ha^{-1}) grain yield was recorded from the fields without fertilizers. The highest grain yield at the highest rates of NPS and nitrogen might be connected with provision of adequate plant nutrient requirement which results the induction of more productive tillers that directly correlated with the production of better yields. This result is in agreement with Usman Kedir et al., 2020, Tigist *et al.,* 2021, Abera *et al.,* 2021 who reported that, the maximum grain yield of bread wheat was recorded at the highest application of blended fertilizer rate.

Table 3. Effects of NPS Fertilizer rate and recommended Nitrogen on Biomass and grain yield of bread wheat

TREATMENT	BIOMASS YIELD (KG HA^{-1})	GRAIN YIELD (KG HA^{-1})
Control(without fertilizer)	5282^{e}	1422 ^{c}
25% p-critical from nps fertilizer +recommended nitrogen	9056^{d}	2930 ^{b}
50% p-critical from nps fertilizer +recommended nitrogen	11402^{c}	3338 ^{b}
75% p-critical from nps fertilizer +recommended nitrogen	14071^{a}	4173 ^{a}
100% p-critical from nps fertilizer +recommended nitrogen	12943^{b}	3959 ^{a}
100% p-critical from dap fertilizer +recommended nitrogen	10736^{c}	3299 ^{b}
$LSD_{0.05}$	919.14	419
CV (%)	16.2	24.5

Means with the same letter in columns are not significantly different at 5% level of significance's, CV=Coefficient of variation, LSD=Least Significance Difference.

Partial Budget Analysis

The economic analysis showed that the highest net benefit (101570.65 ETB ha^{-1}) was obtained from the application of 75% Pc from NPS with recommended nitrogen, whereas the least net benefit (36972 ETB ha^{-1}) was obtained from the unfertilized treatment (Table 4). The highest marginal rate of return (MRR) (932.52 %) was obtained from the fertilizer application of 75 % P-critical from NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}). The MRR was indicated that bread wheat producers can get an extra of 9.33 ETB for 1.00 ETB investments in the NPS and N fertilizers application on the rates of 75 % P-critical in NPS fertilizer with recommended nitrogen fertilizer (92 kg N ha^{-1}). Therefore, application of NPS fertilizer at the rate of 75 % P-critical in NPS fertilizer with recommended nitrogen fertilizer (92 kg N ha^{-1}) for the production of bread wheat was more economically profitable.

Table 4. Marginal Analysis of Bread Wheat Yield as influenced by NPS Fertilizer Supplemented by Nitrogen Rate

Treatment	Variable input ($kg\ ha^{-1}$)		Unit price(etb)		Tvc	Output ($kg\ ha^{-1}$)	Unit price (etb)	Gross income ($etb\ ha^{-1}$)	Net income ($etb\ ha^{-1}$)	Mrr (%)
	Dap/nps	Urea	Dap/nps	Urea						
Control(without fertilizer)	0	0	0	0	0	1422	26	36972	36972.00	
25% p-critical from nps fertilizer +recommended nitrogen	439.24	28.12	16.35	15.01	7603.15	3299	26	85774	78170.85	541.87
50% p-critical from nps fertilizer +recommended nitrogen	445.53	14.65	16.04	15.01	7367.70	3959	26	102934	95566.30	795.29
75% p-critical from nps fertilizer +recommended nitrogen	398.78	35.29	16.04	15.01	6927.35	4173	26	108498	101570.65	932.52
100% p-critical from nps fertilizer +recommended nitrogen	265.85	90.19	16.04	15.01	5618.64	3338	26	86788	81169.36	786.62
100% p-critical from dap fertilizer +recommended nitrogen	132.93	159.51	16.04	15.01	4526.27	2930	26	76180	71653.73	766.23

Where: ETB = Ethiopian Birr, TVC = Total Variable Cost, MRR = Marginal Rate of Return, PC = Critical phosphorus, Rec. N = Recommended Nitrogen

Conclusions and Recommendations

Ethiopian agriculture depended solely on fertilizer urea and diammonium phosphate (DAP) which is a source of N and P. However, recently it is perceived that the production has been limited by the deficiency of Sulfur and other nutrients. Based the needs to supply limited nutrients at optimum rate, this study was initiated with the objectives to determine NPS fertilizer rate in relative to determined P-critical for bread wheat production and to estimate the economically feasible NPS fertilizer rate for higher yield of bread wheat in Degem district. The analysis of variances revealed that, the yield and yield components of bread wheat was very highly influenced ($P<0.01$) by different rates of NPS fertilizers based on calibrated phosphorus supplemented with optimum nitrogen in Degem district.

The analyzed result showed than the highest mean values of plant height (96.81 cm), spike length (7.5 cm), number of total tiller per plant (5.16), number of productive tillers per plant (4.16), biomass yield (14071 kg ha^{-1}) and grain yield (4173 kg ha^{-1}) of bread wheat was recorded from the application of 75 % P-critical from NPS fertilizer rate supplemented with recommended nitrogen whereas, the lowest value was recorded from the field without fertilizer.

The economic analysis showed that, the application of NPS fertilizer at the rate of 75 % P-critical from NPS fertilizer with recommended nitrogen fertilizer (92 kg N ha^{-1}) gave the highest the net income (101570.65 ETB ha^{-1}) with the highest marginal rate of return (932.52 %) are economically feasible. Therefore, farmers could be advised to use 75 % P-critical from NPS fertilizer rate with recommended nitrogen for bread wheat production in the district. Demonstration and further scale up as well as verification at other district of similar soil type agro-ecology should be pre requisite.

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Evaluation of pigeon pea varieties and cultivars for soil nutrient addition and fertility level in case of Fadis district of Eastern Hararghe zone

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Abstract

*The study was conducted at Fadis research station of Fadis district in the eastern hararghe zone during 2019, 2020 and 2021. Pigeon pea is a deep-rooted and drought tolerant grain legume that adds substantial amount of organic matter to the soil and has the ability to fix up to 235 kg N/ha and produces more N per unit area from plant biomass than many other legumes. Nine pigeon pea cultivars and two variety were used as treatment materials. The objective of study was to quantify amount of soil nutrient (N) obtained/fixed because of the pigeon pea cultivars or varieties. Treatments of the experiments were pigeon pea cultivars and variety, ELR16555, ILRI16526, ELR16524, ILRI 11575, Tsegas variety, Local, Danda'a variety, ELR 11566, ELR 16520, ELR 16537 and ELR 11563 respectively. The experiment was laid out in randomized complete block design with three replications of each. Data like Plant height, Total biomass, canopy area, soil sample before and after were collected and analyzed using SAS version 9.1 (SAS, 2002). Different Pigeon pea cultivars shows highly significant difference among the treatment in terms of plant height at 5% significance level. Different Pigeon pea cultivars and variety shows highly significant difference among the treatment in terms of plant height at 5% significance level (table.2). The highest plant height (331.5cm) was recorded from Belabas variety followed by Tsegas (308.6 cm) and Danda'a variety (294.4cm***)***. On the other hand, ELRI 16555 cultivars showed the shortest plant height (213.0cm) followed by local chek (221.7cm). The highest biomass (125000 kg/ha) was recorded from Tsegas variety and the lowest biomass (45000 kg/ha) was recorded from ELRI 16537 cultivars. The highest %OC2.46%), %TN (0.36%) and available phosphorus (2.86 ppm) and CEC (50.92 %) were recorded from the soil under the Tsegas pigeon pea variety followed by Belabas pigeon pea variety. On the contrary the lowest were recorded from ELR11575 and local check. Generally, from the result it is possible to conclude that the highest biomass yield and almost all of the highest desired soil parameters were recorded by Tsegas variety and it is possible to recommend for the farmers of Fadis District and similar agro- ecologies.*

Keywords: Soil Nutrient, Pigeon Pea, Variety, Fixation, cultivars

Introduction

Globally pigeon pea (Cajuns *Cajun* (L.) Millsp) is the fifth most important pulse crop mainly grown in the developing countries by resource-poor farmers in drought prone areas and on degraded soils. It is a multipurpose leguminous crop that can provide food, forage, fuel wood and fodder for the small-scale farmer in subsistence agriculture (Egbe, 2005).Pigeon pea is a deep-rooted and drought tolerant grain legume that adds substantial amount of organic matter to the soil (Egbe, 2005) and can fix up to 235 kg N/ha (Peoples *et al*., 1995) and produces more N per unit area from plant biomass than many other legumes.

In a situation in which the farmer uses little or no fertilizer and the soil is very low in organic matter, the issue of transfer of N from legume to cereal assumes great importance. Nitrogen is an essential plant nutrient. It is the nutrient that is most commonly deficient in Ethiopian soils, contributing to reduced yields of crops in the country. Pigeon pea is a drought-tolerant leguminous crop with vast potentials for cultivation for food, feed, and fuel wood and as soil-ameliorant (Egbe, 2007). Moreover (Odeny, 2007). (*Robe Elema et al., 2022)* reported that pigeon pea fixe approximately between 37.52 – 164.82 kg/ha under intercropping with sorghum. It has also been reported that long duration pigeon pea is one legume that has considerable potential to improve soil fertility when grown as an intercrop (*Robe Elema et al., 2022)*. Biological nitrogen fixation has become very important not only because of reduced energy costs but also in seeking more sustainable way of crop production (Montanez, 2000).Also, the benefits of improving legume N fixation include reduced reliance on soil N, leading to more sustainable agricultural systems and reduced requirements for fertilizer N, enhanced residual benefits to subsequent crops, and increased legume crop yields (Herridge et al., 2004). The main goal of this study is to enhance soil nutrients sustainably, improve soil fertility and the productivity of the intercropping systems with consequent enhancement of food security of the region. Not only for nitrogen fixing but also pigeon pea can be used as forage in eastern Hararghe zone. This is why, this system/ practice can compensate/ solve the problem of low availability of forage for livestock in this low land area. For this sake, this activity was designed with the following objectives. to quantify amount of soil nutrient (N) obtained/fixed because of the pigeon pea cultivar or variety, to identify the best nitrogen fixing cultivar or variety and to recommend the best nitrogen fixer pigeon pea accessions.

Objectives

- ✓ To quantify amount of soil nutrient (N) obtained/fixed because of the pigeon pea cultivar or variety.
- ✓ To identify and recommend the best nitrogen fixing cultivars or variety

Materials and Methods

Description of the Study Area

The study was conducted at Fadis research station of Fadis District in the eastern Hararghe zone, Oromia regional state. It is located in the eastern part of the country at 550 km from Addis Ababa the capital city of Ethiopia and 24 km from Harar city. The geographical location of the research station is 9^0 07’ 56.2” N and 42^0 04’ 26.2” E. The altitude of the research station is 1698m above sea level. The district mean annual maximum and minimum rainfall, mean annual maximum and minimum temperature in the area were 850 to 650mm, 30.4°C, and 10.0°C, respectively. The soil textural classes of the study area was dominantly sandy clay.

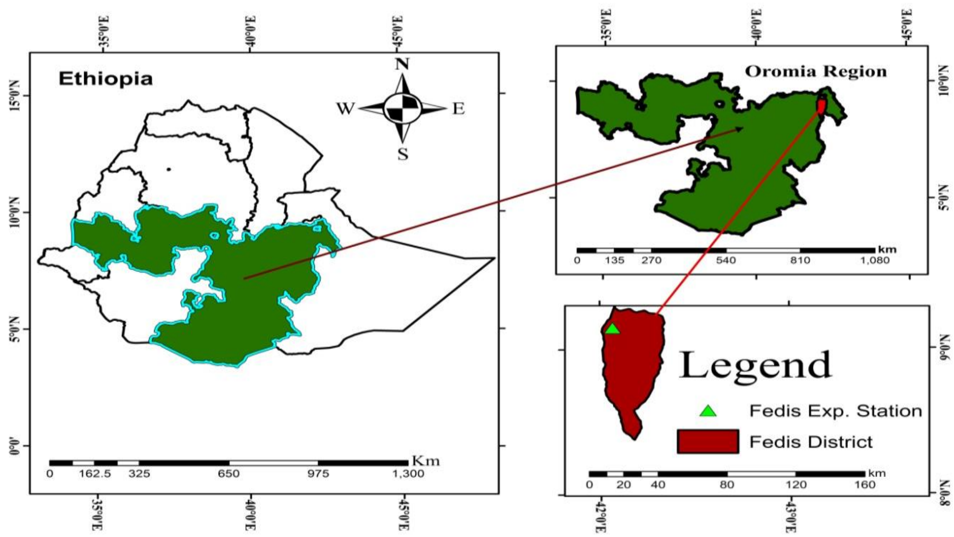

Figure 1. Map of the study area

Materials Used for Treatments

Pigeon pea cultivars and varieties like ELR6526, ELR16526, ELR 11575, Tsegas Variety, local variety, Belabas, ELR 11566, Danda'a, and ELR1537 and ELR115663 were used as the treatments. And also materials like, strings, meters, rags and hoe were used for land preparation 3.2.1. Experimental design and Treatments

Parameters and Testing Methods

The pH and Electrical Conductivity (EC) was analyzed using the - potentiometer (1:2.5) methods. And organic carbon was analyzed by using - Walkley and Black methods

Total nitrogen - Kjeldahal method. Available phosphorus by - Olsen method. Cation Exchange Capacity (CEC) and Exchangeable cations K was analyzed by - neutral 1M ammonium acetate, neutral 1M ammonium acetate (by flame photometer) respectively. And Available K by - Morgan methods.

Experimental Design and Treatments

Design: RCBD with three replication of each

The experiment was laid out in randomized complete block design with three replications of each. And 4 m long and 3m wide plots (12 m^2), was used. Land preparation was done manually using traditional implements. Egbe (2007): formula was used for Estimation of N fixation and to determine the N-difference. The estimation of the apparent net amount of atmospheric N2 fixed by legumes in short- and long-term cropping systems and used by Egbe (2007): N2 = (L-M) + (fi – fm).

Where N2 = amount of nitrogen fixed by systems; L = N harvested in a N2-fixing legume; M = the amount of N in a non-fixing crop grown under the same condition as the legume; fi = soil N after the legume; fm = soil N under the non-N2-fixing crop.

Seven cultivars and four variety of pigeon pea were raised and the Space between plant and between rows were 0.5m and 1m respectively. And space between block was 1.5m. With three seeds per hole and later thinned to one plant/stand (26,667 plants /ha).

Treatments

Table1.Tretements of experiments

No	*Treatments*
1	**Elr16555**
2	**Elr16526**
3	Elr16524
4	**Elr 11575**
5	Tsegas variety
6	Local
7	Belabas
8	Elr 11566
9	Danda'a
10	Elr 16537
11	Elr 11563

Data Collection and Soil Sampling

Plant height, above ground biomass and canopy area was collected to determine treatment effect. The composite soil sample was collected from each experimental plot at depth of 0-20 cm in zigzag movement before planting and after harvest and analyzed for pH, TN, OC, Ec, Available P, Exchangeable K, Na, CEC and Soil texture. The samples were air dried, grinded and sieved at particle size of less than 2mm.

Data Analysis

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

Result and Discussion

Pigeon pea Component

Table 2. Combined mean of Plant height, Biomass and Canopy of three years as affected by different Pigeon pea verities and Cultivars

No	Treatments/ cultivars	Plant height(cm)	Biomass in kg/ha	Canopy Area in m² per plant
1	ELRI 16555	213.0^{d}	65000^{bcd}	0.73^{cde}
2	ELRI 16526	223.5^{cd}	55000^{cd}	0.73^{cde}
3	ELRI 16524	246.5^{c}	63333^{bcd}	0.97^{bcd}
4	ELRI 11575	285.8^{b}	50000^{cd}	0.99^{bc}
5	Tsigas variety	308.6^{ab}	125000^{a}	1.8^{a}
6	Local variety	221.7^{c}	58333^{bcd}	0.45^{e}
7	Belabas variety	331.5^{a}	88333^{b}	1.4^{ab}
8	ELRI 11566	285.1^{b}	63333^{bcd}	0.47^{e}
9	Danda'a variety	**294.4^{b}**	**83333^{b}**	0.33^{e}
10	ELRI 16537	230.9^{cd}	45000^{d}	0.53^{e}
11	ELRI 11563	227.3 ^{cd}	65000^{bcd}	0.34^{e}
	LSD	15.42	344.35	0.44
	CV (%)	6.7	28.4	32.8

Plant Height

Different Pigeon pea cultivars and variety showed highly significant difference in terms of plant height at 5% significance level (table.2). The highest plant height (331.5cm) was recorded from the Belabas variety followed by Tsegas (308.6 cm) and Danda'a variety (294.4cm) at P<.001, this was in statistical parity with ELRI 11575 and 11566 cultivars. On the other hand, ELRI 16555 cultivars shows the shortest plant height (213.0cm) followed by local chek (221.7cm) and ELRI 16526 (223.5cm). Plant height, canopy cover and biomass yield have direct relationship with soil organic matter and soil fertility. The highest plant and biomass yield it is, the highest organic matter it can accumulate and influence soil fertility. This result was in line with (Teshale Jabessa ,and Ketema Bekele, 2021), states that ,The higher plant height varieties had high canopy, with the large volume of biomass, proving pigeon pea as multipurpose plant, its leaves: sources of fodder, and nutrition, pod wall/seed coat: sources of feed, seeds, and food . Purwanto (2007) study was also in line with the current study, who reported that the pigeon pea plant is a shrub with woody stems and has a height ranging from 50-500 cm.

Biomass

Different Pigeon pea cultivars showed highly significant difference among the treatment in terms of total biomass production at 5% significance level (table.2). The highest total biomass (125000 kg/ha) was recorded from Tsegas variety and followed by Belabas (**88333^{b}**kg/ha) and **Danda'a variety (83333b k**g/ha)

Pigeon pea with large volume of biomass, proving as multipurpose plant, its leaves: sources of fodder, and nutrition, pod wall/seed coat: sources of feed, seeds, and food S. The lowest biomass (45000 kg/ha) was recorded from ELRI 16537 cultivars, this was statistical parity with the rest treatment except Tsegas variety. (Robe Elema wako and Ibsa Aliy Usman, 2020) reported that, the total fresh weight of pigeon pea showed an increasing trend across sites throughout three years from the constructed soil bund with integrated system as 8200kg/ha, 9620kg/ha, 13800kg/ha. Adjei-Nsiah 2012 also reported that pigeon pea yielded about 25.5 tons of shoot biomass which have high nutrient quality and is used for livestock forage within 16 months.

Canopy Area

Different Pigeon pea cultivars showed highly significant differences in terms of canopy area at 5% significance level (table.2). The highest canopy area (1.8 m^2 per plant) was recorded from Tsegas variety, this was statistical parity with ILRI Belabas variety. Pigeon pea form canopy after one year and shades out obnoxious weeds by suppressing their growth (S. Adjei-Nsiah, 2012). The lowest canopy area (0.33 m^2 per plant) was recorded from ELRI 16520 cultivar, this was statistical parity with the rest of treatments except Tsegas variety, ELRI 16524, ELRI 11575 and ELRI Belabas cultivars. Plant height, canopy cover and biomass yield have direct relationship with soil organic matter and soil fertility. The highest plant and biomass yield it is, the highest organic matter it can accumulate and influence soil fertility.

Table 3. Soil analysis result of before experimentation

Treatments	EC Ds/m	PH H2o	OC%	TN%	Available p	Available k	CEC	Exch. Na	textural class
Before Experiment	1.194’	7.95	1.35	0.078	1.2	400	19.08	0.484	clay

According to the result above (table 3), EC of the soil was fall under less alkaline range and the PH of soil was also in alkaline range. Organic carbon, TN% available p and k, and CEC of the soil before the experiment were falls under the low range.

Soil Component

Table 4. Effects of pigeon pea cultivars/ variety on soil pysico chemical properties of soil after three years experimentation

Treatments	**EC Ds/m**	**PH H2o**	**OC%**	**TN %**	**Availab le p**	**Available k**	**CEC**	**Exch. Na**	**textural class**
ELRI1655	0.267	7.8	1.51	0.15	2.33	1250	47.05	0.26	Clay
ELRI16526	0.269	7.9	1.52	0.15	1.84	1200	48.32	0.2	Clay
ELR16524	0.268	7.8	1.56	0.22	2.01	900	47.61	0.22	Clay
ELR11575	0.25	8	1.5	0.12	1.84	1500	47.38	0.2	Clay
Tsegas variety	0.26	7.8	2.46	0.36	2.86	1500	50.92	0.15	Clay
Local	0.283	8	1.53	0.12	2.61	1350	45.79	0.17	Clay
Belabas variety	0.268	8	1.73	0.25	2.82	1700	48.89	0.2	Clay
ELR11566	0.255	8	1.5	0.14	2.61	1500	48.64	0.22	Clay
Danda’a variety	0.28	8	1.71	0.14	2.23	1800	48.12	0.2	Clay
ELR16537	0.331	7.9	1.61	0.12	1.9	950	48.84	0.17	Clay
ELR1163	0.276	8	1.51	0.12	2.06	1300	47.55	0.15	Clay

Total Nitrogen

According to the laboratory result (table 2), the highest (0.36TN %) was obtained from Tsegas variety of pigeon pea, followed Belabas variety (0.25 TN %). Pigeon pea can fix and add about to 235kg/ha N the soil , When compared to that of control (plot without pigeon pea) plot, pigeon can increase the total nitrogen of the soil by 0.282 TN% than control. And also, the soil under the treatments of tsegas variety showed good results in terms of EC, %OC, Available P, and Available and K, CEC by Belabas cultivars.

Soil Reaction

The soil pH is an important indicator of the level of plant nutrient availability in the soil. The initial pH of the study site before experimentation fall in moderately alkaline range. It's significantly improved from moderately alkaline to slightly alkaline due to regardless of Tsegas variety. The soil pH is an important indicator of the status of plant nutrient availability in the soil because of its positive and significant correlations with many of the plant nutrients. It had a strong and positive relationship of soil pH with exchangeable Ca, K and CEC (Nega, 2006) and with extractable Mn, Cu and Zn (Houlong *et al*., 2014).

Soil Organic Carbon (OC %)

According to the result (table3), the highest soil organic carbon (2.46 % OC) was recorded from the Tsegas pigeon pea variety followed by ELRI16528 (1.73 %OC) and ELR11563 cultivars. On the other hands the lowest 1.35 %OC was recorded from the absolute control (with no pigeon pea treatments, followed by ELR11575 (1.5 % OC) and ELR11566 (1.5% OC) respectively. Based these result, pigeon pea can add about 1.11 %OC and play a crucial role in soil organic matter restoration. The current study was in line with the findings of, Eegbe (2005) states that, pigeon pea can add substantial amount of organic matter to soil. And also as *Johnson et al. (2007)*, organic carbon build up is favored by conservation agriculture, standing biomass, long term harvested products and living biomass in the soil.

Cation Exchange Capacity (CEC)

The highest cation exchange capacity (50.92**)** of soil was recorded from the soil with tsegas pigeon pea variety treatments followed by ELRI16528 (48.89) cultivar. On the other hand, the lowest CEC was obtained from absolute control without no pigeon pea cultivars. As showed in the result above (table3), the CEC of soil was increased by 62.5 % because of pigeon pea variety, since pigeon could be decomposed easily.

Soil Available Phosphorus

The highest available phosphorus was recorded from the soil under the treatments with Tsegas variety and ELRI16528 cultivar respectively. This was because of the up taken phosphorus by pigeon pea could return back to the soil through faster decomposition of pigeon pea's leaf, root, stems and branches. On the other hand, the lowest available P was obtained from the plot without pigeon pea (before experimentation). The variation of P across the pigeon pea cultivars might be attributed to the biomass and ability to extract insoluble p. this study was in agreement with the findings of Shiferaw Tadesse and Zerihun Abebe (2019) and Hector smith (2007), states that, the highest available P was found when all lower branches were removed leaving upper 4 followed by leaving upper 6 branches on the main stem.

Conclusion and Recommendation

Generally, the highest plant height and total biomass was recorded from ELRI 16520 and Tsesgas pigeon pea variety respectively. The highest amount of TN% from Tsegas pigeon pea variety and ELRI16528 cultivar. Pigeon pea can increase, TN%, soil organic carbon, CEC, available P and improve soil fertility. The highest available phosphorus was recorded from the soil under the treatments with Tsegas variety and ELRI16528 cultivar respectively. This was because of the up taken phosphorus by pigeon pea could return back to the soil through faster decomposition of pigeon pea's leaf, root, stems and branches. The highest cation exchange capacity (50.92**)** of soil was recorded from the soil with tsegas pigeon pea variety treatments followed by ELRI16528 (48.89) cultivar. On the other hand, the lowest CEC was obtained from absolute control without no pigeon pea cultivars. The initial pH of the study site before experimentation fall in moderately alkaline range. It's significantly improved from moderately alkaline to slightly alkaline due to regardless of Tsegas variety. This study recommend that, Farmers , NGOs , research centers and universities ,should use , tsegas pigeon pea variety , for soil fertility management ,for degraded land rehabilitation and as additional source of fertilizers(organic).Research extantion should popularize tsegas pigeon pea variety as both, soil nutrient fixer and animal feed, through demonstration and scaling up.

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Introducing and Evaluation of Conservation Agriculture in Dry Land of Borana, Oromia, Southern Ethiopia

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Abstract

Conservation agricultural practice is purposes to conserve, improve and make more efficient use of natural resources. The experiment was objected to improve production and productivity of maize by different moisture conservation practices and to determine and recommend best moisture conservation practice for agro-pastoralists of Borana. The field experiment was conducted at kadale, cholksa and kobo PA's of Yabello districts for two consecutive years from 2019 to 2020 main cropping seasons. The experiments had four treatments (runoff diversion, Furrow, Runoff diversion plus furrow and control) laid in randomized complete block design (RCBD) of three replications. The analysis of variance showed that there was significant difference among treatments in cob diameter, hundred seed weight and grain yield in all cropping seasons and locations. The highest grain yield was obtained from furrow with diversion structure treatment (5.83, 5.59, 4.2 ton/ha) followed by Diversion structure (5.51, 4.84, 3.9 ton/ha) at kadale cholkasa and kobo PA'S respectively. The lowest grain yield was recorded for control (Farmers practice) treatment (3.56, 3.05, 3.36 ton/ha) at Kadale, Cholkasa and Kobo Kebeles respectively. In all sites moisture conservation treatments (furrow plus diversion, diversion and furrow) have yield advantage 2. 27 ton/ha (40.68%), 2.54 ton/ha (45.44%), 0.84 ton/ha (20%), 1.95 ton/ha (35.39%), 1.79 ton/ha (36.98%), 0.54 ton/ha (13.84%) and 1.88 ton/ha (34.55%), 2.02 ton/ha (39.84%), 0.36 ton/ha (9.43%) more than farmer's practices respectively. Therefore, moisture conservation practice is recommended for optimum production of maize in moisture stress areas of Borana Zone.

Key words: Conservation agriculture, Evaluation, Furrow, Run off diversion, Diversion

Introduction

In the semi-arid and dry sub humid tropics of rain fed agricultural systems water scarcity is a series problem, however in situ moisture conservation has able to solve this important bottleneck of agricultural productivity (Opolot et, al., 2013). In situ moisture harvesting focuses on the principle of properly using the harvested rainfall or runoff when the rainfall is scarce. This is especially true in arid and semi-arid areas where water is a limiting factor for agricultural activities or where the rainfall is erratic in its occurrence. The most common technology for this purpose is conservation tillage, which aims at maximizing the amount of soil moisture within the root zone

A number of agronomic practices such as mulching, ridging, manuring, and other small farm structures such as field ridges/bunds, contour bunds, bench terraces within cropped area and others, could fall under in situ moisture conservation category (Desta et al., 2005). Soil and water conservation practices are important to improve crop yields by enhancing soil moisture, conserving rain water and controlling erosion (Mekuria et. al., 2016). Addressing the problem of moisture stress requires means of supplying additional water for crops to meet their Evapo-transpiration demand with the help of either irrigation or on-farm water harvesting techniques.

Slope of the land less than 5%, impermeable soils and low topographic relief are the main requirements for its better performance (UNEP, 1997). In situ soil water conservation technologies are suitable for increasing soil moisture for increased land productivity in Arid and Semi-Arid Lands (ASALs) of eastern Kenya. In field, water harvesting technology is a solution to the problems of arid area that can enhance soil water storage, and this will enable crops to survive during mid-season droughts (Kathuli et. al., 2015). To improve dry land agricultural production adopting in situ rainwater harvesting has greater potential to effectively conserve adequate soil moisture (Manyatsi et al., 2011). In situ moisture conservation is an important strategy to increase infiltration and storage of water in soil and reduce the effects of drought stress on maize grain yield (Mudatenguha et. al., 2014).

Unpredictable flood and recurrent droughts are the other factors limiting dry lands to become productive environment and lead to very subsequent fragile environment. Lack of appropriate technologies, biotic pressures and limitation of resources contribute further in conversion of dry lands into deserts. Change in seasonal rainfall is one of the feature of climate change which affect significantly the agro-ecosystem. Rainfall is predicted to be highly erratic with fewer rainy days but with greater intensity. Borana pastoral and Agro-pastoral community are dependent of rainfall for water resource both in domestic and livestock watering. To protect its livelihoods enhancing resilience of agriculture to climate risk is paramount important.

In the arid, regions where access to irrigation and insufficient rainfall is prevailing to meet the water demands of crops, water can be harvested in order to increase the available water for crops. Water harvesting and soil moisture retention are cheap and simple options for increasing soil moisture. According to Milkias et. al., (2018) in-situ water harvesting techniques such as furrow ridges, tied ridges and contour ridges improve soil moisture stored within the root zone, improve the agronomic components and produce higher grain yields .Therefore, Climate smart agriculture such as adoption of conservation agriculture incorporating in rangeland management which includes different innovative technologies may able to contribute towards the improvement of food security, improve the productivity of dry land ecosystem of Borana rangeland and maintain the stability of environment. Therefore, the objectives the study were to improve production and productivity of maize under different soil moisture conservation structures; to determine and recommend best moisture conservation practice for agro-pastoralists of Borana.

Materials and Methods

Description of the Study Areas

The study was conducted at moisture stress areas of Borana zone of yabello district during a main cropping season for testing adoption and introduction to conservation agriculture on grain yield of maize (Mekasa-1 maize variety). Three peasant associations (Kobo, Kadale and Cholkasa) were selected from Yaballo district where moisture stress is the primary problem. Yabello is located at 570km from south of Addis Ababa, Ethiopia. Yabello is located at 04° 52' 49" and 038 ° 08' 55" latitude and longitude, respectively, at an altitude of 1656 m.a.s.l.

Experimental Design and Management

The experiment was designed in RCBD and planted on two farmer's field with three replications. The furrow structure was constructed with 1m spacing and 30cm deep ripping and the Diversion was constructed trapezoidal channel width 0.5m, depth of 1m and at 1% slope of bottom width of runoff structures on standard maize plot was design for the treatment. Each entry was planted in a plot having 6 rows of 5.5 meter length. Four rows were harvested and two border rows were left to exclude border effect. The row and plant spacing was kept at 40 cm and 10 cm, respectively. Individual plot size was 5.5 m x 5m=27.5 m2 and 1.5m and 2m between plot and block, respectively. 60kg NPS/ha Fertilizer was applied at the time of planting. All other agronomic managements were applied uniformly in all experimental plots as per national recommendation for the crop.

Data Collection

The data on yield attributes, biological yield, was collected from all treatments equally. Plot base collected data were Days to physiological maturity and grain yield. Plant base collected data were hundred seed weight, plant height, Ear height, Ear length, and Ear diameter**.**

Cob diameter (cm): The length of five randomly selected cobs from each of the five randomly selected plants was measured at harvesting and the average was used.

Number of cobs per plant: this was recorded as average total number of cobs of five randomly selected plants from each experimental plot at harvest.

Days to physiological maturity: The number of days from emergency to the date when 90% of the plant in each plot are physiologically matured determined by the formation of black layer at the base of each kernel.

Grain yield per plot (g/plot): Grain yield in grams obtained from the central four harvestable rows of each plot was harvested, threshed and weighted using sensitive balance. Grain yield obtained from each plots were used to estimate grain yield (tons) per hectare.

Hundred seed weight (HSW): Hundred seeds randomly taken from each plot and weighted using sensitive balance.

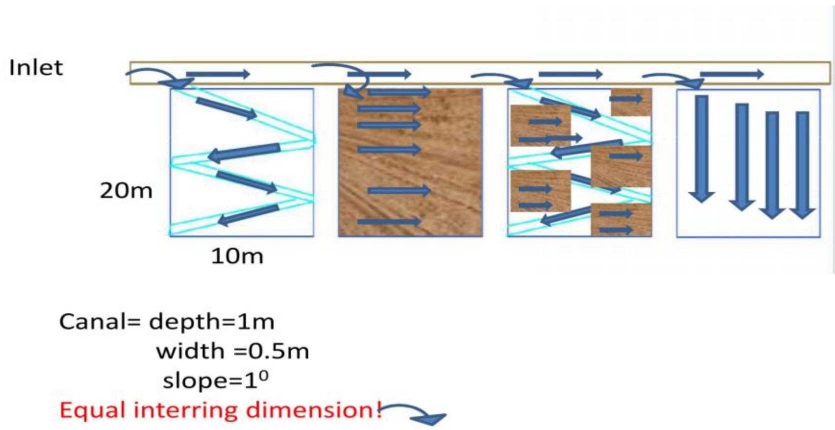

Figure 1. Site design of the experiment

Data Analysis

Analysis of Variance

Analysis of variance (ANOVA) was computed for grain yield and other traits as per the methods described by Gomez and Gomez (Gomez et al, 1984) using SAS computer software (Version 9) for Randomized Complete Block Design. Comparison of treatment means was made using Duncan Multiple Range test (DMRT) at 5% level of significance. Location wise analyses were performed and error variances were subjected to F-test for homogeneity test of variances. Variables with homogeneous error variances were directly used for combined analyses, while those with heterogeneous error variances were analyzed in individual locations.

Individual locations ANOVA model

$X_{ij} = \mu + T_i + B_j + E_{ij}$ --- equation 1

Where, Xij = Observed value, μ = general mean, Ti = effect of treatments, Bj = effect of replication (block),

Eij = residual effects or experimental error

Results and Discussions

The first year (2019) result indicated that furrowing + diversion of water treatment was best in terms of yield and yield components. The maize yield was lowest under the control treatment. This may indicate that conservation agriculture have promising contribution for improving maize yield under moisture stress areas like Yaballo.

Table 1: Mean performance value of Maize under different moisture conservation structures during main cropping season of 2019 at Kobo site

Treatments	MD (day)	HSW(gm)	Gyd (tone/ha)
Diversion	113.3[ab]	27.5[a]	3.90[ab]
Furrowing	112[ab]	28.17[a]	3.71[ab]
Furrowing +diversion	114[a]	28.8[a]	4.21[a]
Control	110[b]	26.8[a]	3.36[b]
CV	1.98	9.16	7.81
LSD	1.38	2.59	0.28

MD-maturity date, HSW-hundred seed weight and Gyd- grain yield

Means with the same letter are not significantly different but means with different letter are significantly different, at $P < 0.05$ at Kobo site data of yield and yield components were evaluated and significance differences were observed among the treatments.

Hundred seed weight (gm); analysis of variance showed significance difference among different soil moisture structures ($p < 0.05$). Furrow plus diversion soil moisture conservation structures showed highest hundred seed weight than all other structures (28.8gm) while control (farmer practice) showed lowest hundred seed weight (26.8 gm)

Grain yield (ton/ha); analysis of variance showed significance difference among different soil moisture structures ($p<0.05$). Furrow + diversion soil moisture conservation structures showed highest grain yield than all other structures (4.21 ton/ha) while control (farmer practice) showed lowest grain yield (3.36 ton/ha. The result indicated that diversion and furrowing + diversion of water treatment was best in terms of yield and yield components. This may indicate that conservation agriculture have promising contribution for improving maize yield under moisture stress areas like Yaballo.

Table 2: Mean performance value of Maize during main cropping season of 2020 at Kedale site

Treatments	CD	CL	HSW(gm)	Gyd (tone/ha)
Diversion	4.49[a]	15.87[a]	31.53[a]	5.51[a]
Furrowing	4.34[b]	14.87[ab]	31.93[a]	5.44[a]
Furrowing +diversion	4.49[a]	15.27[ab]	33.50[a]	5.83[a]
Control	4.13[c]	14.20[b]	27.13[b]	3.56[b]
P value	0.0009	0.0839	0.0112	0.0012
LSD	0.137	1.28	3.2977	0.87
CV	1.66	4.51	5.65	9.12

HSW-hundred seed weight and Gyd- grain yield; Means with the same letter are not significantly different but means with different letter are significantly different, at P<0.05

Cob diameter (cm), Analysis of variance showed significance difference among different soil moisture structures ($p<0.05$). Furrow plus diversion soil moisture conservation structures showed highest cob diameter than all other structures (4.490cm). While control (farmer practice) showed lowest cob diameter (4.13 cm) this results was in line with (Natol Bakala, 2019).

Cob length (cm); analysis of variance showed significance difference among different soil moisture structures ($p<0.05$) diversion soil moisture conservation structures showed highest cob length than all other structures (15.87cm) while control (farmer practice) showed lowest hundred seed weight (14.20cm).

Hundred seed weight (gm); analysis of variance showed significance difference among different soil moisture structures ($p<0.05$). Furrow plus diversion soil moisture conservation structures showed highest hundred seed weight than all other structures (33.50gm) while control (farmer practice) showed lowest hundred seed weight (27.13 gm.)

Grain yield (ton/ha); analysis of variance showed significance difference among different soil moisture structures ($p<0.05$). Furrow plus diversion soil moisture conservation structures showed highest grain yield than all other structures (5.83 ton/ha) while control (farmer practice) showed lowest grain yield (3.56 ton/ha).

Table 3: Mean performance value of Maize during main cropping season of 2020 at Cholkasa site

Treatments	CD	CL	HSW(gm)	Gyd (tone/ha)
Diversion	4.39^{a}	15.33^{a}	26.00^{a}	4.84a
Furrowing	4.35^{a}	15.67^{a}	28.0^{ab}	5.07^{a}
Furrowing +diversion	4.30^{a}	15.73^{a}	29.0^{ab}	5.59^{a}
Control	4.07^{b}	13.47^{b}	25.66^{b}	3.05^{b}
P value	0.0082	0.0021	0.1157	0.0209
LSD	0.165	0.9844	3.17	1.49
CV	2.05	3.47	6.196	17.12

HSW-hundred seed weight and Gyd- grain yield

Means with the same letter are not significantly different but means with different letter are significantly different, at $P<0.05$

Cob diameter (cm); analysis of variance showed significance difference among different soil moisture structures ($p<0.05$) diversion soil moisture conservation structures showed highest cob diameter than all other structures (4.39cm) while control (farmer practice) showed lowest cob diameter (4.07 cm).

Cob length (cm); analysis of variance showed significance difference among different soil moisture structures($p<0.05$) furrow +diversion soil moisture conservation structures showed highest cob length than all other structures (15.73cm)while control (farmer practice)showed lowest hundred seed weight(13.47cm).

Hundred seed weight (gm.); analysis of variance showed significance difference among different soil moisture structures ($p<0.05$). Furrow plus diversion soil moisture conservation structures showed highest hundred seed weight than all other structures (29.0gm) while control (farmer practice) showed lowest hundred seed weight (25.66 gm).

Grain yield (ton/ha); analysis of variance showed significance difference among different soil moisture structures ($p<0.05$). Furrow plus diversion soil moisture conservation structures showed highest grain yield than all other structures (5.59 ton/ha) while control (farmer practice) showed lowest grain yield (3.05 ton/ha). In generally the analysis of variance showed that there was significant difference among treatments in cob diameter, hundred seed weight and grain yield in all cropping seasons and locations. The highest grain yield was obtained from furrow with diversion structure treatment (5.83, 5.59, 4.2 ton/ha) followed by Diversion structure (5.51, 4.84, 3.9 ton/ha) at kadale cholkasa and kobo PA'S respectively. The lowest grain yield was recorded from control (Farmers practice) treatment (3.56, 3.05, 3.36 ton/ha) at Kadale Cholkasa and Kobo Kebeles respectively. Moisture conservation treatments had 2. 27 ton/ha (40.68%), 2.54 ton/ha (45.44%), 0.84 ton/ha (20%), 1.95 ton/ha (35.39%), 1.79 ton/ha (36.98%), 0.54 ton/ha (13.84%) and 1.88 ton/ha (34.55%), 2.02 ton/ha (39.84%), 0.36 ton/ha (9.43%) yield advantage over farmers practice for furrow plus diversion, diversion and furrow, respectively .This result in line with Lia and Gong (J.D.Gong,2002) which indicated 21-92% yield increments under soil moisture structures and also in line with (Wolde et. al., 2020).

Conclusions and Recommendation

Conservation agriculture in moisture stress Area improves the soil moisture rooting zone due to improved soil infiltration catches run off at the time .rainfall which increased the grain yield of early maturing maize in the study Area. The maximum mean grain yield were recorded from combination of furrow and Run off diversion than they alone. This is due soil moisture retention aims at preventing runoff and keeping rainwater as much as possible. Therefore farmers of Yaballo and similar agro ecology area those have their farm land with steep slopes should use Furrow plus run off diversion soil moisture conservation structures. Therefore, moisture conservation practice is recommended for optimum production of maize in moisture stress areas of Borana Zone. The study had limitation that it was not supported by soil moisture and soil parameter analysis. Hence, it is also batter recommended the study by including other suitable soil moisture conservation structures and soil parameters is important.

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Determination of NPS Fertilizer Rates Based on Calibrated Phosphorus for Bread Wheat (Triticum Aestivum L.) Production in Horo District, Western Oromia Region

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Abstract

The aim of this research was to determine the optimum NPS rate based on calibrated phosphors for bread wheat production in Horo District. NPS fertilizer based on the critical levels of P and optimum N fertilizer determined for the district to determine the economically optimum levels of NPS. The treatments consist of 100% Pc from DAP and recommended N fertilizer and 100%, 75%, 50%, 25% Pc from NPS fertilizer with recommended N fertilizer and control (no fertilizer application) on a bread wheat, with seed rate of 150 kg ha^{-1} The two years (2020-2021) analysis of variance showed that biomass yield of bread wheat was highly significantly affected by the rate of NPS. The highest grain yield (5028.30 kg ha^{-1}) and biomass yield (11455.4 kg ha^{-1}) were obtained in response to the application of 100% of Pc from NPS + Rec. N, whereas the lowest grain yield (2882.2 kg ha^{-1}) and biomass yield (8144.3 kg ha^{-1}) were obtained from control treatment, respectively. The highest net benefit of 56941.3 Birr ha^{-1} was obtained from 100% of Pc from NPS with optimum N fertilizer application. Based on the results of this study, both agronomic data and partial budget analysis 100% of Pc from NPS plus recommended nitrogen fertilizer was chosen as the best and led to the maximum yields of bread wheat production in Horo district. Therefore, verifying and demonstration of the technology for popularization should be followed up.

Key Words: NPS, Bread wheat, Horo district

Introduction

Wheat is an important staple food crop all over the world (Mathpal, *et al.*, 2015). Ethiopia is one of the largest wheat producers in Sub-Saharan Africa and approximately 80% of the wheat area is planted to bread wheat (Assefa *et al*., 2013). Even though, the current wheat production is inadequate to fill Ethiopia's needs (Minot *et al*., 2015) due to low soil fertility and soil management practices. According to the report of Food and Agricultural organization, global wheat production in 2018 was estimated at 734 million tons from a total of 214 million hectares area harvested; with average yield of 3425 kg ha^{-1}. Enhancing agricultural productivity is one of the central challenges to achieving food security and poverty reduction in Ethiopia. Applying agricultural inputs based on site-specific requirements of soils and crops entails the quantification of the spatial variability of soil properties across the field (Fraisse *et al.*, 1999; Hatfield, 2000; Wang *et al.*, 2009). Considering the fact that soil fertility is one of the biggest challenges, an obvious strategy is to increase fertilizer application and promote good agronomic practices to enhance productivity.

In Ethiopia, century-long, low-input agricultural production systems and poor agronomic management practices, limited awareness of communities and absence of proper land-use policies have aggravated soil fertility degradation (Agegnehu and Bekele, 2005). Phosphorous is the most yield limiting of soil-supplied elements, and soil P tends to decline when soils are used for agriculture (David and David, 2012). Soil analyses and site-specific studies indicated that elements such as K, S, Ca, Mg, and micronutrients (e.g. Cu, Mn, B, Mo, and Zn) were becoming depleted and deficiency symptoms were observed in major crops in different parts of the country(Asgelil *et al.*, 2007; Ayalew *et al.*, 2010).

As a result, Ethiopia has begun to use NPS fertilizer as a compound fertilizer to overcome plant nutrient deficiencies for crop production and to boost agricultural production. Moreover, a practice on the use and application of the newly introduced fertilizer in the form of NPS instead of DAP has been already started. However, the rate and response of NPS fertilizer trial is not carried out in accordance to crop and soil types. Therefore, this study was conducted to determine optimum NPS fertilizer rate for bread wheat production in Horo District

Materials and Methods

Description of the Study Area

Horo is situated at latitude: 1,042,726N to 1,091,814N; Longitude 270,000E to 316,199E and an altitude ranging from 1449-3147 m above sea level; in Horo-Guduru Wollega Zone of the Oromia regional state, Ethiopia (Figure 1.). The terrain is generally undulating to rolling plains. The area is characterized by a mono-modal rainfall pattern. The mean monthly rainfall ranges from 12.8 to 343.8 mm, and mean monthly temperature is 17.23 to 22.9°C. The major soil types are generally described as Nitisols (FAO. 1990).

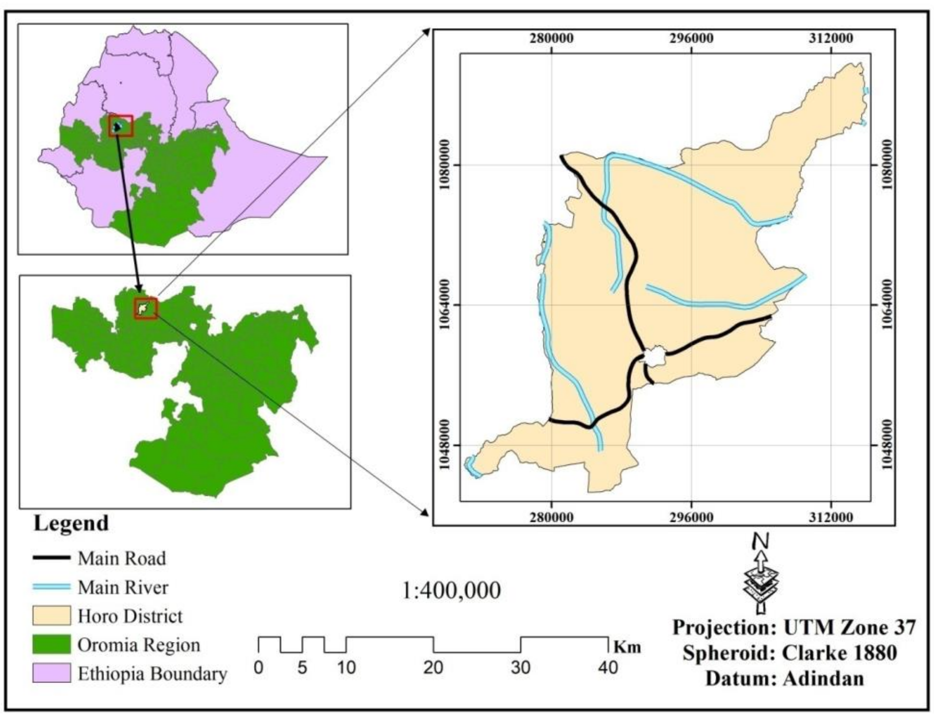

Figure 1: Location map of Horo District, Oromia, Ethiopia

Treatments, Experimental Design and Procedures

The study was conducted on farmers' fields across Horo District of Horo Guduru Wollega Zone during the main cropping seasons of 2019/20-2020/21. Twelve farmers were selected purposively based on their willing, wealthy and initial soil P-value. Improved bread wheat variety Liban was used at 150 kg/ha seeds rate with 20 cm inter row spacing. Phosphorus fertilizer rate was given according to the formula developed, P (kg/ha) = (P critical-P initial)* Prf. Urea and DAP were used as the source of N and P, respectively. For verification purpose the experiment was laid out in randomized complete block design that was replicated. It is aimed to determine the NPS rate based on phosphorus critical level for hybrid bread wheat variety. Before planting date, composite soil samples were collected and analyzed to determine initial soil P for phosphorus fertilizer to be applied. Phosphorus fertilizer recommendation rate were calculated according to the formula

$$P\ (kg/ha) = (P_{critical} - P_{initial})*Prf.$$

This recommendation was compared with *farmers practice (blanket recommendation) and control*.

Treatments

Six treatments within the experiment were arranged in randomized complete block design with three replications.

T1=100% of P critical from DAP + recommended nitrogen
T2=100% of P critical from NPS + recommended nitrogen
T3=75% of P critical from NPS + recommended nitrogen
T4=50% of P critical from NPS + recommended nitrogen
T5=25% of P critical from NPS + recommended nitrogen
T6= Control (without fertilizers)

Recommended N (46 kg N/ha) determined in the area for bread wheat production was used. The gross plot size (3m x4m) received DAP and an NPS fertilizer at planting time. Nitrogen was applied at 30 days after planting in the form of urea.

Data Collection

Agronomic data: Date of planting, number of tiller, plant height, number of seeds per spike, spike length, biomass, grain yield and thousand kernel weight.

Soil Sample Collection:

Composite soil samples were collected randomly from each field following a zigzag fashion from 0 to 20 cm depth before planting/application of fertilizer using an auger. The composite soil sample was air dried, crushed with wooden pestle and mortar to pass through a 2mm sieve size for the analysis chemical properties.

Data Analysis

Data were handled and documented appropriately using Excel Microsoft. A frequent monitoring and evaluation technique was employed to control reliability of the data. The data obtained from the experiment was analyzed using one way analysis of variance (ANOVA) with SAS software version 9.1 Windows. Least significance difference test (LSD) was employed to test the significant difference between treatment means.

Economic Analysis

The average yield was adjusted downwards by 10 percent to reflect the difference between the experimental plot yield and the yield farmers was expected from the same treatment. The average open market price (Birr kg^{-1}) for different crops and the official prices of N and P fertilizers were used for analysis. For a treatment to be considered a worthwhile option to farmers, the minimum acceptable rate of return (MARR) should be 100% (CIMMT, 1988), which is suggested to be realistic. To use the marginal rate of return (MRR) as basis for fertilizer recommendation, the minimum acceptable rate of return (MARR) should be 100%. This will enable to make farmer recommendations from marginal analysis.

$$\boldsymbol{MRR} = \frac{Net\ Income\ from\ fertilized\ field - Net\ income\ from\ unfertilized\ field}{Total\ variable\ cost\ from\ fertilizer\ application}$$

Marginal rate of return (MRR) was calculated both farmer practice and soil test Total variable cost, was a cost incurred due to application of P fertilizer (both but in separate of Soil test based P calibration result and farmers' fertilizer rate) with the assumption that the rest of the costs incurred are the same for all treatments. Gross income is obtained by multiplying mean grain yield (kg/ha) of each treatment by the price of one kg of the grain. *Net income* is calculated by subtracting the total variable cost from the gross income.

Result and Discussion

Soil pH and Available Phosphorus

The soil reaction of the experimental sites before planting ranged from 4.56-5.26 (Table 1). Accordingly, the soils were strongly to extremely acidic in reaction. FAO (2000) reported that the preferable pH ranges for most crops and productive soils are 4 to 8. Mengel and Kirkby (1996) reported optimum pH range of 4.1 to 7.4 for wheat production. The soils of all sites were strongly acidic based on Bruce and Rayment (1982) soil pH classification system. A similar finding was reported for the site. Moreover, all the sites contained very low available P (1.56–9.96ppm) on the basis of Karltun *et al.* (2013) ratings. This might be attributed to fixation of P in acid soils. Besides, the availability of P in most soils of Ethiopia continuously decline by the impacts of abundant crop harvest, land management practices and soil erosion (Temesgen and Chalsissa, 2020; Dawit *et al.,* 2002; Birhanu *et al.*, 2016; Bereket *et al.,* 2018). Variation in available P content of the sites could be due to differences in strength of acidity, organic matter content, rocks, and amount of residual p-fertilizers found in the soils. The exchangeable acidity (Al + H), on the other hand, varied between 0.42 and 3.50 $cmol_c\ kg^{-1}$ for soils with pH values 5.5 and its mean value was 1.55 $cmol_c\ kg^{-1}$ soil.

Table 1. Selected chemical properties of the soil of the experimental sites before sowing.

SITES	PH(H_2O)	AV. P (PPM)	EX. ACIDITY (CMOLC(+)/KG)
1	4.92	3.49	2.71
2	5.02	6.04	2.18
3	5.17	5.61	0.83
4	4.92	3.49	1.66
5	5.18	4.24	0.88
6	5.26	4.20	0.42
7	4.97	9.96	0.98
8	4.70	2.22	3.50
9	4.84	9.18	0.56
10	4.56	3.56	2.91
11	5.06	2.28	0.51
12	4.77	1.56	1.45

Plant Height

Plant height was highly significantly (P <0.01) affected by the application of NPS fertilizer (Table 2). The highest plant height (83.5cm) was recorded from application of 100% of Pc from NPS + Rec. N. While, the lowest plant height (65.7cm) was recorded from the Control (without fertilizers). The increased plant height at the highest level of NPS fertilizer supplemented with supplemental nitrogen rates could be attributed to the increasingly adequate supply of nitrogen, phosphorus and sulphur nutrients, which attributed to better vegetative development that resulted in increased mutual shading and inter-nodal extension. Nitrogen is considered as one of the major limiting nutrients in plant growth and adequate supply of it promotes the formation of chlorophyll which in turn resulted in higher photosynthetic activity, vigorous vegetative growth and taller plants. P is required for shoot and root development where metabolism is high and cell division is rapid. Similarly, sulfur in NPS fertilizer promotes formation of chlorophyll, higher photosynthetic activity, vigorous vegetative growth and taller plants (Rao *et al.*, 2001).

Spike Length and Seed per Spike

The result revealed that fertilizer showed spike length and seed per spike not significantly (p<0.05) affected by the application of different rates of NPS fertilizers and optimum N. The effect of fertilizer showed that the highest number of seed per spike (44.15) was recorded from 50% of Pc from NPS plus recommended N fertilizer rate (Table 2). The highest number of spike length was recorded from 100% of Pc from NPS plus recommended N fertilizer application. The lowest spike length and seed per spike was obtained from the control (without application of fertilizer) (Table 2).

Grain yield and above ground biomass

The mean grain yield of wheat was significantly (P<0.05) affected by the NPS fertilizer application and optimum nitrogen fertilizer application (Table 2). The highest grain yield (5028.30 kg ha^{-1}) was obtained by the application of 100% of Pc from NPS + Rec. N, which was not statistically different from application of 100% of Pc from DAP + Rec. N, whereas the lowest (2882.2 kg ha^{-1}) grain yield was obtained from control treatment (Table 2). Similarly, Temesgen and Chalsissa (2020) found that soil test crop response based P application had a significant effect on bread wheat grain yield at the same District than blanket fertilizer application. The mean biomass yield of bread wheat was highly significantly affected by the effect of NPS and optimum N fertilizer rates (Table 2). Biomass yield increased as the rate of NPS increased from zero to the highest rate of application. Maximum (11455.4 kg ha^{-1}) biomass yield was obtained at application of 100% of Pc from NPS with optimum recommended N fertilizer, whereas the lowest (8144.3 kg ha^{-1}) biomass yield was recorded by control plot (Table 2). The result is consistent with that of Tagesse *et al.* (2018) who found that maximum application of NPS (200 kg ha^{-1}) and 92 kg ha^{-1} N application increased biomass yield of bread wheat.

Table 2: Effect of NPS fertilizer and optimum N fertilizer on yield and yield components of bread wheat in Horo district during 2021-2022 main cropping seasons

Treatments	Parameters				
	Grain yield (kg/ha)	Above ground dry biomass(kg/ha)	Plant Height (cm)	Spike Length(cm)	Seeds per Spike (No)
Control (without fertilizers)	2882.2[c]	8144.3[e]	65.7[d]	6.32	36.30
25% of Pc from NPS + Rec. N	3637.4[bc]	9109.7[d]	76.3[c]	7.71	42.60
50% of Pc from NPS + Rec. N	3950.10[ac]	9590.2[cd]	76.9[bc]	7.69	44.15
75% of Pc from NPS + Rec. N	4226.70[ab]	10055.1[bc]	80.5[ab]	7.83	42.85
100% of Pc from NPS + Rec. N	5028.30[a]	11455.4[a]	83.3[a]	7.98	43.30
100% of Pc from DAP + Rec. N	4547.10[a]	10447.9[b]	80.6[ab]	7.96	42.00
Significance	**	***	***	NS	NS
$LSD_{(5\%)}$	1131.60	740.68	4.0047	1.86	8.50
CV (%)	11.43	3.09	2.92	10.05	8.30

Partial Budget Analysis

The highest net benefit of (*56941.3*) Birr ha^{-1} was obtained from 100% of Pc from NPS with optimum N fertilizer application. However, the lowest net benefits of (38909.7) Birr ha^{-1} were obtained from the recorded from the treatment without fertilizers (Table 3).

Table 3. Partial budget analysis for NPS fertilizer rate determination trial for bread wheat production at Horo District during 2019/20 and 2020/21 cropping season.

Treatments	GY (qt/h)	AGY (qt/h)	GFB (ETB/h)	FC (birr/h)	TVC (birr/ha)	NB (birr/ha)	MRR (%)
Control (without P fertilizers)	28.8	25.9	51879.6	0.0	12969.9	38909.7	
25% of Pc from NPS + Rec. N	36.4	32.7	65473.2	5206.7	21575.0	43898.2	58.0
50% of Pc from NPS + Rec. N	39.5	35.6	71101.8	7118.0	24893.5	46208.3	69.6
75% of Pc from NPS + Rec. N	42.3	38.0	76080.6	9029.4	28049.6	48031.0	57.8
100% of Pc from NPS + Rec. N	50.3	45.3	90509.4	10940.8	33568.1	56941.3	161.5
100% of Pc from DAP + Rec. N	45.5	40.9	81847.8	9631.3	30093.3	51754.6	149.3

Where GY = Grain Yield; AGY= Adjusted grain Yield; GFB = Gross field benefit; FC = Fertilizer cost; TVC = Total variable cost; NB = Net Benefit and MRR = marginal rate of return

Conclusion and Recommendation

In Ethiopia, the blanket recommendations that are presently in use were issued several years ago, which may not be suitable for the current production. Since the spatial and temporal fertility variations in soils were not considered, farmers have been applying the same P fertilizer rate to their fields regardless of soil fertility differences. The treatment consisted of 100% of P critical from DAP, 100% of P critical from NPS, 75% of P critical from NPS, 50% of P critical from NPS, 25% of P critical from NPS, control and recommended N fertilizer. Based on the results of this study, both agronomic data and partial budget analysis 100% of Pc from NPS plus recommended nitrogen fertilizer was chosen as the best and led to the maximum yield and yield components of bread wheat production in Horo district. Therefore, verifying and demonstrating of the technology for popularization should be followed up.

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Soil Test Crop Response Based Phosphorous Calibration Study on Maize at Abay Choman District, Horo Guduru Wollega Zone, Oromia Region, Ethiopia

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Abstract

*Soil test crop response based P calibration study can give farmers more economic use of fertilizers and better soil management practices. In a view of this, the trial was done in Abay Choman district on ten experimental farmers' field in the first year of the experiment (2018/19 cropping season) to determine the economic rate of N and on twenty farmers field in the second and third years of the experiment (2019/20 and 2020/21 cropping season respectively) to determine phosphorus critical level and requirement factor. In the first year of the experiment the treatments were combined in factorial with four level of phosphorus (0, 10, 20, 40 kg/ha) and four level of nitrogen (0, 46, 92 and 138 kg/ ha). While experiments in the second and third years of the experiment were six levels of Phosphorus 0, 10, 20, 30, 40 and 50 kg/ha. The treatments were laid out as a randomized complete blocked design (RCBD) with three replications. Representative soil samples were taken before planting and analyzed. Experimental sites that have a pH of < 5.5 were amended using lime application before the setup of the experiment. Soil test results of the study sites before planting indicated that pH values of most soils were strongly acidic (<5.5) and available phosphorus of experimental soil ranged from 3.22 to 13.62 pp**.** The main effects of both N and P were significantly influenced the mean grain yield of maize, but their interaction was not significant with grand mean of 76.53 qt/ha during N determination trial. Economic analysis using partial budget analysis showed 92 kg/ha of N was economically optimal for production of maize in Abay Choman District. The study also showed that P- critical value (12 ppm) and P- requirement factor (10.55 Kg P/ha) were determined for the phosphorus fertilizer recommendation in the study area. Thus, the farmers in the area might be advised to use soil test crop response-based fertilizer recommendation to increase productivity of maize in and around the study District.*

Key words: Abay Choman Calibration, Maize and Phosphorus

Introduction

Land is intensively used in Ethiopia (Bacha, *et al.*, 2001). However, P and N deficiency is a major constraint to crop production. Land productivity could improve only if, the soil fertility problems were improved. Soil degradation is occurring at an alarming rate and threatens soil productivity and maize production in Western Oromia due to continuous cropping over the last three decades. To overcome the soil fertility problem, farmers in western Oromia use mainly chemical fertilizers and manures for crop production.

For instance, in the mid-altitude areas like Bako, more than 80% of the farmers use chemical fertilizers (Abdissa *et al.*, 1999). The major sources of these chemical fertilizers were DAP (Di-Ammonium Phosphate) and Urea, which are becoming the most expensive input (personal observation). Therefore, it is understandable that soil test crop response-based fertilizer recommendations that can give farmers a service leading to better and more economic use of fertilizers and better soil management practices for increasing agricultural production are necessary. Bekele *et al.* (2002) has observed encouraging result from the model calibration trial undertaken at Hetosa district of Arsi Zone, and forwarded the importance of undertaking similar trial across the country, Ethiopia. The use of fertilizers without first testing the soil is like taking medicine without consulting a physician.

So, sound soil test calibration is essential for successful fertilizer program and crop production. It is essential that the results of soil tests could be calibrated or correlated against crop responses from applications of plant nutrients. An accurate soil test interpretation requires knowledge of the relationship between the amount of a nutrient extracted by a given soil test and the amount of plant nutrients that should be added to achieve optimum yield for each crop (Sonon and Zhang, 2014). Fertilizer recommendations on soil test basis for economic crop production should be both location and crop type.

Objectives

- To determine the economic rate of N;
- To determine critical P concentration and
- P requirement factors so as to establish soil test-based fertilizer recommendation for Maize production in Abay Choman district.

Materials and Methods

Description of the Study Area

Abay Choman District is found in Oromia regional state of Ethiopia, containing 19 kebeles, located at 9° 31' 42" to 9° 59' 48" N latitude and 37° 10' 03" to 37° 28' 44" E longitude and the capital of the district Fincha town is 289 kms northwest of Finfinnee. The area receives high rainfall in one season of the year. The total area of the District is estimated to be 801.7 km2; approximately 45, 37, 4, 3 and 11% of the total area are cultivated land, non-cultivated, water bodies, settlements, and woodlands and forests, respectively (Tegbaru Belette, 2014).

The Ethiopian population projection by CSA for 2017, based on 2007 national census reported a total population for this district to be 64,672, of whom 33,263 (51.43%) were male and 31,409 (48.57%) were female; 15,232 or 23.55% of its population were urban dwellers (CSA, 2013). The altitude of the study area ranges from 1,061 to 2,492 meters above sea level (m.a.s.l) with two agro ecological zones, mid-highland and low land. The northern part of the district (low land), which is mainly situated at altitude ranging from 1,138 to 1,687 masl in the Nile River Basin, is owned by Fincha Sugar Factory and is entirely being used for irrigated sugarcane (*Saccharum officinarum L.*) production. At altitudes ranging from 2,213 to 2,492 masl (mid high land), smallholder farmers practice mixed farming systems that integrate both crops and livestock (animals used for traction, meat and milk).

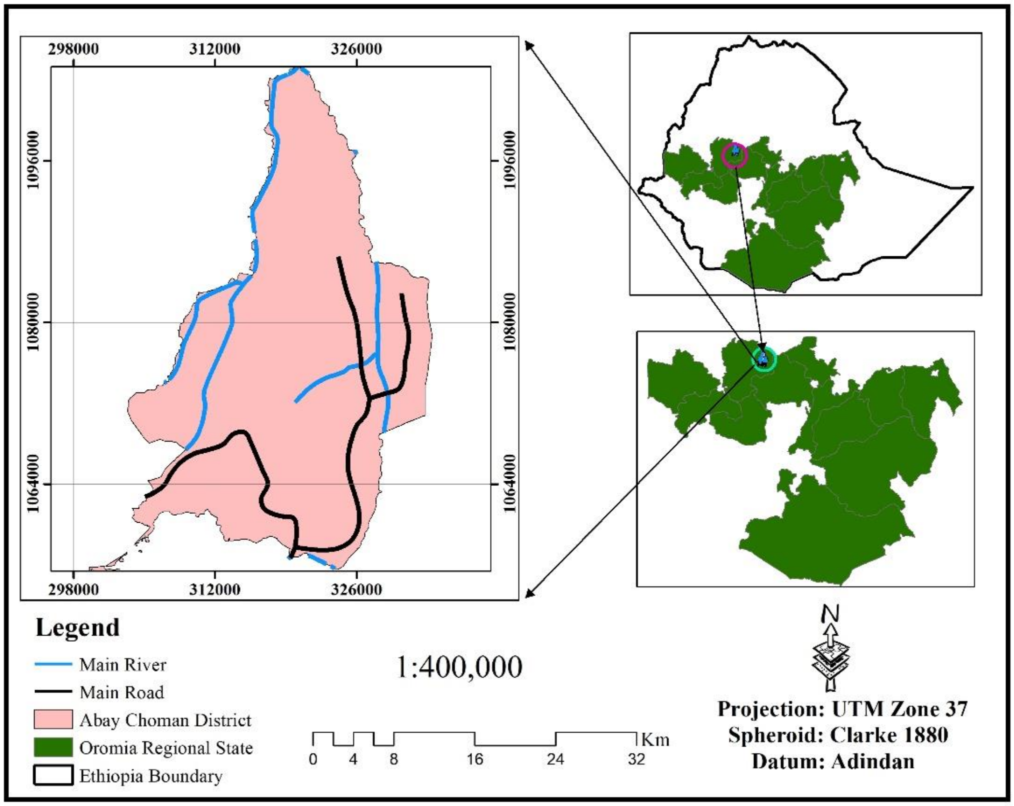

Figure 1. Location Map of the Study Area

The recent years meteorological data of the nearby representative stations, Fincha Sugar Factory and Shambu Meteorological Stations showed that the mean annual minimum and maximum temperatures of the district are 13.4 and 27.2°C, respectively, and the mean annual rainfall is 1,399 mm (Tegbaru Belette, 2014). The area has a uni-modal rainfall pattern and the highest intensity of rainfall is recorded in the month of July. The area is characterized as hot to warm moist lowland and tepid to cool moist mid-highlands (Alemayehu Mengistu, 2006).

Experimental Design and Procedures

The study was done for three consecutive years (2018/19- 2020/21). In the first year of the experiment (2018/19 cropping season); economic rate of N determination trial was done on ten (10) farmers' sites and in the second and third year of experiments (2019/20 and 2020/21 cropping season) Pc and Pf determination trials were done on twenty (20) farmers' sites. The specific Experimental sites in the districts were selected based on: - Ranges of phosphorus contents (Very low, Low and medium were selected); willingness of farmers to provide land and initiative to implement the activity; accessibility for supervision and vicinity to the road. Maize variety of *BH 661* was used. Composite soil samples were taken from all experimental fields before planting to analyze selected chemical properties of the experimental soil. During optimum N determination trial, the treatments were factorially combined four levels of both P and N which are,

0, 10, 20, 40 kg P/ha and

0, 46, 92 and 138 kg N/ha

While six levels of P (0, 10, 20, 30, 40 and 50 kg/ha) were used during Pc and Pf determination trials. The treatments were replicated three times. N was split-applied (1/3 at planting and the remaining about three weeks after planting). The entire P rate was applied at sowing. Just three weeks after sowing, intensive soil samples were collected to determine Pc and Pf. Available P was determined using Olsen's method.

Critical phosphorus level was determined using Cate-Nelson diagram method, where soil phosphorus values put on the X-axis and the relative grain yield on the Y-axis. While Phosphorus requirement factor was determined/calculated using available phosphorus values in the samples collected from unfertilized and fertilized plots.

Data Analysis

The agronomic data were statistically computed using SAS software version 9.0. Mean separation was done by LSD at 5% level. Economic analysis was performed following procedures described in CIMMYT (1998).

Result and Discussion

Initial Soil pH and Phosphorus of the Experimental Sites

Soil test results of the study sites before planting indicated that pH values of most soils were strongly acidic according to Chude *et al*. (2005) rating. Available phosphorus of experimental soil in both districts ranged from 1.3 to 15.41 ppm (see Table 1 below). This low available phosphorus could be due to fixation in such acidic soils. Tekalign and Haque (1987) and Dawit *et al.* (2002) reported that availability of P in most soils of Ethiopia decline by the impacts of fixation as a result of low pH. In order to increase bioavailability of P in such soil, increase in soil pH is the best management option to minimize fixation.

Yield Responses of maize to N and P Fertilizers during Optimum N Determination Trial

The maize grain yield responses to the main and interaction effects of Nitrogen and phosphorus fertilizer were presented in the following Table 2. The main effects of N and P were significantly influenced the mean grain yield of maize but their interaction was not significant with grand mean of 76. 53qt/ha in Abay Choman district. The results clearly indicated that N and P were limiting nutrients factors. It is in general in accordance with the results of several studies, which showed the positive response of maize grain yields and yield related parameters (Khan *et al*., 2014).

Table 1. Selected experimental soil properties of experimental sites before planting in Abay Choman District for 2019/20 and 2020/21 cropping season

Sites	PH (H_2O)	Av. P (ppm)	Ex. Acidity (cmol(+)/kg)
1	5.01	5.25	0.15
2	4.69	3.22	0.12
3	4.85	8.19	0.16
4	4.75	11.45	0.18
5	4.86	7.74	0.16
6	5.21	10.1	0.19
7	5.54	12.85	0.23
8	4.52	4.44	0.14

9	4.54	11.38	0.20
10	4.55	9.13	0.20
11	4.56	13.22	0.18
12	5.21	11.62	0.18
13	4.74	9.42	0.27
14	4.79	12.62	0.24
15	4.71	13.62	0.18
16	4.65	12.02	0.15
17	4.68	11.42	0.19
18	4.7	11.22	0.20
19	4.58	13.62	0.22
20	4.52	11.22	0.13

Table 2. Main and interaction effects N and P on grain yield of Maize in Abay district as the whole during N determination trial

Factors	**Districts**
	Abay Choman
Nitrogen (N)	***
Phosphorus (P)	**
N*P	NS
Mean(Kg/ha)	7653.45
CV (%)	17.87

Optimum N Fertilizer Rate Determination for Maize Production

Economic analysis using partial budget showed that fertilizer rates of 92 kg N/ha was economically optimal for production of maize in Abay Choman district (Table 3).

Table 3. Summary of partial budget analysis for optimum N fertilizer recommendation for maize production at Abay Choman district

N (kg/ha)	**P (kg/ha)**	**AGY (Qt/ha)**	**GFB (ETB/ha)**	**FC (birr/ha)**	**TSC (birr/ha)**	**HBC (birr/ha)**	**TVC (birr/ha)**	**NB (birr/ha)**	**MRR (%)**
0	0	39.93	25953.57	0.00	1197.86	798.57	1996.4	23957.14	
0	10	45.02	29265.41	645.50	1350.71	900.47	2896.7	26368.72	267.88
0	20	50.71	32964.30	1291.00	1521.43	1014.29	3826.7	29137.58	297.72
0	40	58.69	38148.81	2582.00	1760.71	1173.81	5516.5	32632.28	206.81
46	20	70.90	46088.09	2639.00	2127.14	1418.10	6184.2	39903.85	56.12
46	40	75.76	49245.24	3930.00	2272.86	1515.24	7718.1	41127.14	105.83
92	0	66.86	43457.14	2696.00	2005.71	1337.14	6038.9	37418.29	244.69
92	10	68.62	44602.38	3341.50	2058.57	1372.38	6772.5	37829.93	56.11
92	20	75.36	48986.75	3987.00	2260.93	1507.28	7755.2	**41231.54**	346.13
138	0	64.52	41940.47	4044.00	1935.71	1290.48	7270.2	34670.28	228.15
138	10	69.64	45267.86	4689.50	2089.29	1392.86	8171.6	37096.21	269.11
138	20	73.29	47635.71	5335.00	2198.57	1465.71	8999.3	38636.43	186.10
138	40	78.95	51319.04	6626.00	2368.57	1579.05	10573.6	40745.42	133.96

Where **A**GY= Adjusted grain Yield; GFB = Gross field benefit; FC = Fertilizer cost; TSC = Total service cost; HBC = Harvesting and bagging cost; TVC = Total variable cost; NB = Net Benefit and MRR = marginal rate of return

Remark: - Dominated treatments are not included in the table.

Critical Phosphorus Level Determination

The scattered plots using Cate-Nelson diagram method showed that 12ppm was critical phosphorus level for maize production in Abay Choman. Soil phosphorus values taken from each plot taken three weeks after planting put on the X-axis and the respective relative grain yield on the Y-axis.

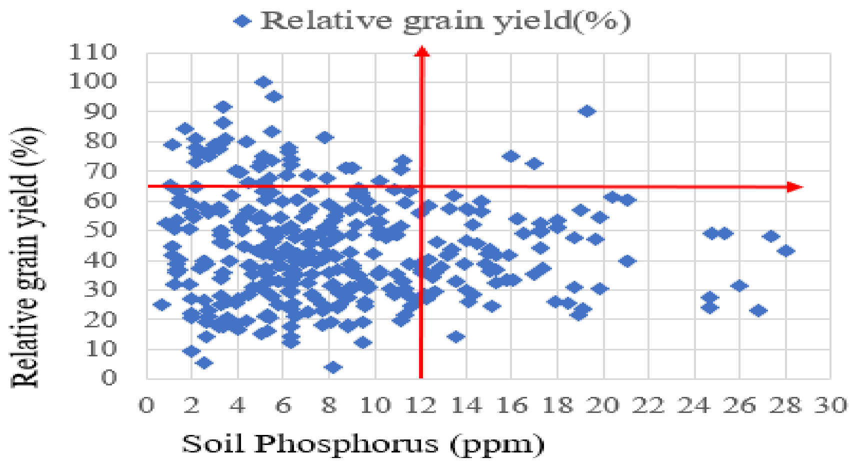

Figure 2. Scattered plot of relative grain yield (%) of maize and soil test phosphorus (Olsen) in Abay Choman District.

Phosphorus requirement factor Determination

Phosphorus requirement factor (Pf), for maize production at A/Choman district was found to be 10.55 Kg P/ha (table 4 below). It is computed from the difference between available soil test P values from plots that received 0-50 kg P/ ha using the second formula mentioned above. These Phosphorus requirement factor enables to determine the quantity of P required per hectare to raise the soil test by 1 ppm, and to determine the amount of fertilizer required per hectare to bring the level of available P above the critical level.

Table 4. Pf Calculation for maize production in Abay Choman Distri

P rate (Kg/ha)	Av. P (ppm) in soil	P increased over Control	Pf(Kg/ha)
0	6.14		
10	7.40	1.26	7.92
20	8.44	2. 30	8.71
30	8.84	2.70	11.11
40	9.28	3.13	12.77
50	10.22	4.07	12.27
	Mean		**10.55**

Conclusion and Recommendation

The study also showed that; P- critical value (12 ppm) and P- requirement factor (10.55 Kg/ha) were determined for the phosphorus fertilizer recommendation for maize production in Abay Choman District. Thus, the farmers might be advised to use soil test crop response-based fertilizer recommendation to increase productivity of Maize in the Abay Choman District.

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Verification of Soil Test Crop Response based phosphorous Calibration Study for Bread Wheat at Jimma Arjo District, East Wollega Zone of Western Oromia

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Abstract

*This study was conducted to verify the recommended soil test-based Pc and Pf for one year (2020/21 cropping season) on nine (9) farmer's fields. The treatments were three fertilizer rates. Control/ (*0 N/ P_2O_5*), blanket recommendation(*23, 46 kg N/P_2O_5) *and soil test-based Pc and Pf. Composite soil samples before planting were collected and analyzed for its selected properties. Grain yield, biomass yield, plant height, spike length and number of seeds per spike were collected and analyzed. Economic feasibility of the treatments was determined using partial budget analysis. Available P of most samples fall under low category and below Pc. This shows the need for external application of phosphorus fertilizer sources for good crop growth and yield. The highest mean grain yield (3963.8 kg/ha), biomass yield (13923.5 kg /ha) and the highest net benefit (70155.6 ETB) were obtained from soil test based Pc and Pf . Soil test crop response-based fertilizer recommendation (Pc, Pf and optimum N) at Jima Arjo district was verified as it can give consistently high grain yield and economically feasible for bread wheat production. It was paramount to increase the crop production with improving the income of small-scale farmers of study area. Therefore, it should be wider popularized.*

Keywords: - Bread wheat, Jima Arjo, Phosphorus fertilizer, Recommendation and Soil test

Introduction

Wheat is one of the most important cereals in Ethiopia and Ethiopia is one of the largest producers of wheat in sub-Saharan Africa. The area coverage and production of the crop in Ethiopia is estimated to be 1.7 million hectares and 4.8 million tons of grain yields, respectively. There are two types of wheat grown in Ethiopia: durum and bread wheat accounting 40 and 60% of production, respectively. Wheat production in Ethiopia is characterized by subsistence farming and mostly dominated by small holder farmers. The national average productivity of wheat is 2.7 tone/ha (CSA, 2019; Minot *et al.*, 2015) which was still lower than the world's average (3.4 tone ha) (FAOSTAT, 2014). There are several factors that hampered wheat production in our country. Among others, inappropriate soil fertility management is the most important factors that limit wheat production potential of Ethiopia (Rahman , 2018; Xu *et al.,* 2014). To solve this soil fertility problem, farmers have been using fertilizers; however, the high costs of fertilizers and farmers' limited financial resources resulted in reduced fertilizer application (Wairegi and van Asten, 2010). Moreover, the fertilizer recommendation did not consider existing soil nutrient supply and resulted in low crop yield response (Masvaya *et al.*, 2010). Ethiopia used different strategies and policies to solve the soil fertility management problems and in order to enhance agricultural production (Belete *et al.,* 2018). Blanket recommendations that are presently in use all over the country were issued several years ago, which may not be suitable for the current production systems (Hurni *et al.,* 2010). Since the spatial and temporal fertility variations in soils were not considered, farmers have been applying the same Phosphorus fertilizer rate to their fields regardless of soil fertility differences.

Soil tests are designed to help farmers predict the available nutrient status of their soils. Once the existing nutrient levels are established, producers can use the data to best manage what nutrients are applied, decide the application rate and make decisions concerning the profitability of their operations (Agegnehu and Lakew, 2013). local assessments for the soil P critical levels and soil P requirement factors even for the major crops of the country are negligible. Currently, soil fertility research improvement is agreed with respect to site specific fertilizer recommendation in Ethiopia (Mesfin *et al.*, 2021). Previously, soil test crop response-based phosphorus calibration for bread wheat study was carried out in Jima Arjo district and the critical phosphorus and phosphorus requirement factor have to be verified to approve the acceptance of the technology at farmers' level.

Objectives

- ❖ To verify economic profitability of the technology,
- ❖ To verify critical levels and requirement factor of phosphorus calibrated previously in Jima Arjo district.

Materials and Methods

Description of the Study Area

Jima Arjo district is situated between 8°32´39" to 8°55´10" N latitude and 36°22´17" to 36°43´53" E longitude in East Wollega Zone of the Oromia Region, Ethiopia. Arjo town is a capital of the district that far about 378 km from Finfinnee in western direction. The elevation of the study area ranges from 1280.67 m to 2563.77 m above sea level.

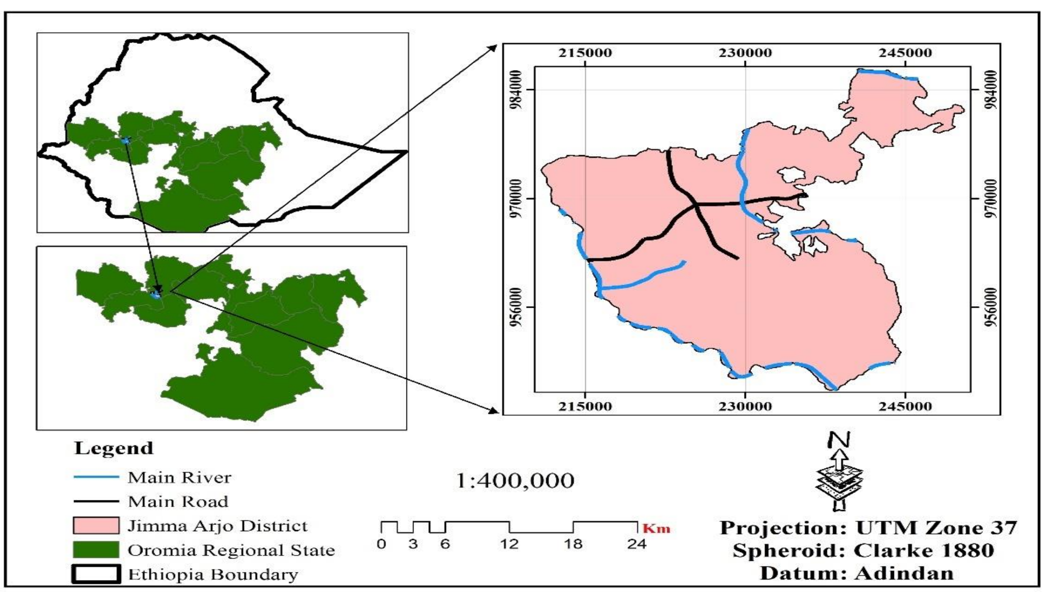

Figure 1: Location map of Jima Arjo district

The recent ten years meteorological data of the nearby station at Jimma Arjo shows that the mean annual minimum and maximum temperatures of the district are 11.72 and 22.09 °C respectively, and the mean annual rainfall is 2417 mm (Fig. 2). The area has a unimodal rainfall pattern and the highest rainfall is recorded in the month of July. The district falls in between the traditional wet Kolla and wet Dega agro-climatic zones. From the total area of the district, 4.5% falls in Wet Kolla which is hot to warm moist lowland (Tropical), 80.7% is Wet Weyna Dega which is tepid to cool moist mid highlands (subtropical) and 15% falls in Wet Dega (temperate) climates (Mulata, 2009).

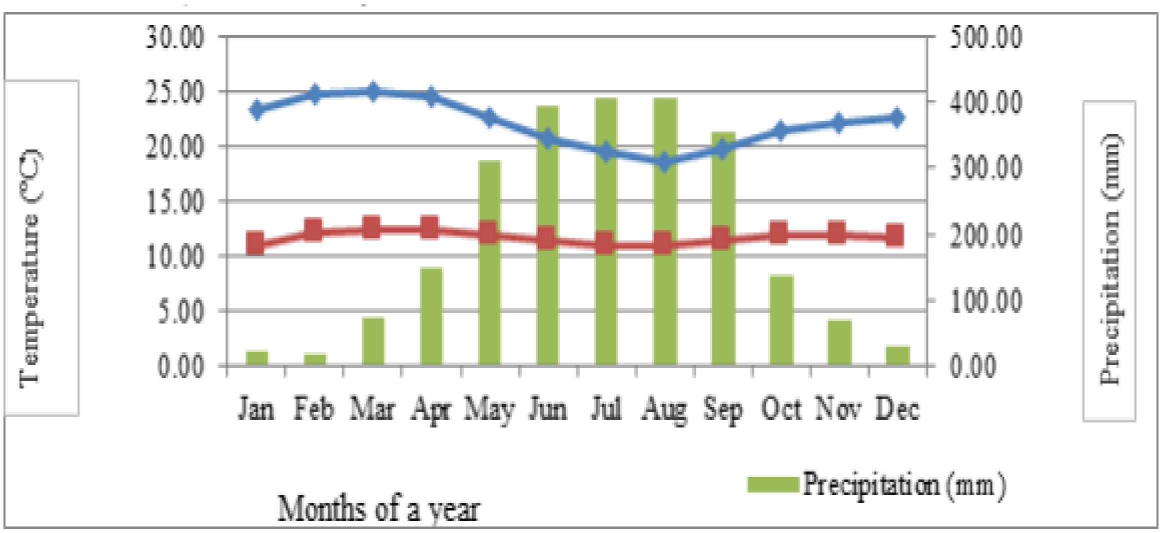

Figure 2. The ten years meteorological data.

The total area of the district was estimated to be 76,574 ha with a total population of 86,329. Some area of the southern part of the district is owned by Arjo Didessa Sugar Factory and is entirely being used for irrigated sugarcane (*Saccharum officinarum L.*) production. South Western part of the area is occupied by investors and is entirely used for rain-fed agriculture mainly for maize (*Zea mays*) production. The remaining agricultural land is occupied by local small holder farmers who practice mixed agriculture. During the field study the district, especially the highland is under intensive cultivation and teff (*Eragrostis tef Zucc.*), maize (*Zea mays*), bread wheat (*Triticum aestivum L.*), sorghum (*Sorghum bicolor*), barley (*Hordeum vulgare L.*), niger seed (*Guizotia abyssinica*), sesame, beans, and peas were the major crops grown. According to the extracted digital soil data obtained from MoA (2005), the area has 4 major soil orders based on FAO/UNESCO soil classification system. They are Dystric Nitisols, Pellic Vertisols, Dystric Gleysols and Orthic Acrisols.

Experimental Design and Procedures

The study was done on nine (9) farmers' fields that were selected from several farmers' fields purposively based on their willing nd initial soil P-value. Improved wheat variety *Dendea* was used at 150 kg/ha seeds rate with 20 cm inter row spacing were sown. Phosphorus f was applied according to the formula developed, P (kg/ha) = (P critical-P initial) * Pf (ranged from 189 to 242 kg P_2O_5/ha with optimum N 92 kg/ha). This recommendation was compared with blanket recommendation (23, 46 N/P_2O_5 per hectare) and control (0 N/P_2O_5). For verification purpose the experiment was laid out in randomized complete block design that was replicated over farmers. The treatment considered were calculated P (Rate of P fertilizer to be applied = (Critical P conc.-initial P values) *P requirement factor whereas Pc= 13 ppm, and Pf= 9.1) with determined optimum N (92 kg/ha), Farmer practice /blanket recommendation (46 kg P_2O_5 and 23 kg N) and control (0 NP). Plot size was 10 m x 10 m and there was 1 m between blocks and 0.5m between plots. Composite soil samples were collected from each selected farmers' field to determine important properties. The grain data and biomass yield of the crops were collected. Grain yield, biomass yield, plant height, spike length and number of seeds per spike were collected on the plot bases and analyzed.

Data were analyzed using descriptive statistics as well as analysis of variance. One way analysis of variance (ANOVA) was performed to assess the significance differences in the yield and yield related components of wheat among the treatments. SAS statistical software was used for the analysis of the collected data. Means separation was done using least significant difference (LSD). Partial budget analysis was following procedures described as (CIMMYT, 1998). Total cost of labor, fertilizer price, and fertilizer transportation also considered for economic analysis.

Result and Discussion

Initial Soil Phosphorus and pH of the Experimental Sites

The initial soil P value ranged from 1.38 ppm to 3.92 ppm, indicating that the soil phosphorus level fall under low category according to the critical level set by EthioSIS (Karltun *et al.*, 2013). The results of the soil analysis also indicated the available phosphorus statuses of the soils in the study area are below the critical level. This shows the need for external application of phosphorus fertilizer sources for good crop growth and yield. The results of the soil analysis in this study showed that the pH of the soil varied from very strongly acidic to moderately medium acidic (4.86 to 5.57). Therefore, the soil pH values recorded for the study area of the present study showed the need for soil acidity management/or amendment.

Table 1. Initial soil pH and available soil phosphorus in Jima Arajo District during verification trial of 2020/21 cropping season

Sites	pH(H_2O)	Av. P(ppm)
1	5.21	1.38
2	5.55	3.1
3	4.93	3.02
4	5.53	2.54
5	5.34	3.92
6	5.57	3.1
7	5.09	3.7
8	4.86	3.72
9	5.2	3.88

Response of Bread Wheat to the Treatments

The highest mean grain yield (3963.8 kg/ha) and biomass yield (13923.5 kg/ha) were recorded from soil test crop response-based fertilizer recommendation plot.(Pc and Pf) This level was resulted in the mean grain yield advantage of about 9 and 4.5 qt/ ha as compared to control and blanket recommendation respectively. The average dry biomass yield obtained from the plot of soil test-based fertilizer recommendation has a yield advantage of about 39.86 and 22.9 qt/ha over the control and farmer practice respectively. That is due to the soil test-based fertilizer application is suitable in such a way that it receives an optimal fertilizer required by the crop . This result is in line with the findings of Gebremeskel *et al.*, (2015). These results also agreed with Mesfin *et al.* (2021) who suggested increased and balanced N, P and K level enhanced yield.

The maximum plant height also obtained in soil test-based fertilizer recommendation and the minimum is gained in control (Table 2). Slaton *et al.*, 2004 and Kasdtens *et al.*, 2000 reported that soil test-based phosphorus fertilization for wheat predicts accurately the need of phosphorus fertilization.

Partial Budget Analysis

Farmers want to evaluate all the changes that are involved in adopting a new practice (CIMMYT, 1988). During the course of this study, we were registering the costs payable for different purposes and the benefits produced due to the straw and grain yields. Net return were calculated from the total revenue and total costs incurred from each treatment. These costs and benefits calculated were based on the prices valued for each item in the 2020 cropping season. As a result, the soil test-based fertilizer recommendation returns highest net income (70155.6 ETB/ha) with acceptable MRR (Table 3).

Table 2. Response of bread wheat to the treatments in Jima Arjo District during 2020/21 cropping season.

	Parameters				
Treatments	**Grain yield(kg/h)**	**Biomass (kg/ha)**	**Plant Height(cm)**	**Spike Length (cm)**	**seeds per spike No)**
Control (0 NP)	3060.2^{b}	9937.5^{c}	86.31^{c}	8.23	34.78
BR (23, 46 N/P_2O_5 per ha)	3508.1^{ab}	11630.9^{b}	89.85^{b}	7.75	34.60
STCRBFR (Soil test based)	3963.8^{a}	13923.5^{a}	94.04^{a}	7.84	33.57
Significance	**	***	***	NS	NS
LSD (5%)	890.25	1582.3	2.72	0.99	5.77
CV (%)	12.69	6.69	1.51	6.26	8.42

*Where *** = Significant at $P \leq 0.01$; ** Significant at $P \leq 0.05$= LSD: Least significant difference ; CV: Coefficient of variation. NS, Non significant at $P \leq 0.05$; BR = Blanket Recommendation;* STCRBFR = *Soil test crop response based fertilizer recommendation*

Table 3. Partial budget analysis for verification of soil test crop response based fertilizer recommendation on bread wheat at Jima Arjo district in 2020/20 cropping season.

Treatments	GY (qt/ha)	AGY (qt/ha)	GFB (ETB/ha)	FC (birr/ha)	TSC (birr/ha)	HBC (birr/ha)	TVC (birr/ha)	NB (birr/ha)	MRR (%)
Control (0 NP)	30.6	27.5	60592.0	6974.7	2754.2	1377.1	11106.0	49486.0	
Blanket recommendation (23, 46 N/P_2O_5 per ha)	35.1	31.6	69460.4	2952.3	3157.3	1578.6	7688.2	61772.2	D
STCRBFR (Soil test based recommendation)	39.7	35.7	78483.2	2976.5	3567.4	1783.7	8327.6	**70155.6**	**1311.0**

Where STCRBFR = Soil test crop response based fertilizer recommendation; GY = Grain Yield; **A**GY= Adjusted grain Yield; GFB = Gross field benefit; FC = Fertilizer cost; TSC = Total service cost; HBC = Harvesting and bagging cost; TVC = Total variable cost; NB = Net Benefit and MRR = marginal rate of return.

Conclusion and Recommendation

Soil test crop response-based fertilizer application gave consistently higher yield and other yield related parameters of bread wheat in Jima Arjo District. Result of economic analysis also showed that recommended rate of fertilizer with site specific recommendation is economically optimum and feasible for bread wheat production in the study district. Soil test-based fertilizer recommendation was paramount to increase the crop production with improving the income of small-scale farmers and therefore, it should be wider popularized.

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Determination of NPS Fertilizer Rates Based on Calibrated P for Teff, production in Guduru District, Western Oromia, Ethiopia

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Abstract

Teff is a major staple cereal crop and the major crops grown at Guduru, in Oromia regional state, Ethiopia. However, its productivity is limited due to the lack of appropriate and site-specific application of nutrient fertilizer rates. The study was conducted for two years on farmers' fields in (2019/20-2020/21) at Guduru district to evaluate the effect of rates of NPS fertilizer on growth, yield, and yield components of teff and to determine the economically appropriate rate of NPS fertilizer rate for teff production in the study area. The experiment design was a randomized complete block design (RCBD) with three replications. The treatments consist of 100% Pc from DAP and recommended N fertilizer and 100%, 75%, 50%, 25% Pc from NPS fertilizer with recommended N fertilizer and control (no fertilizer application) on a teff variety, Guduru with seed rate of 15 kg ha^{-1}. Soil pH value ranges from 4.77 to 5.59 with a mean value of 5.05 before planting in the study area indicated that it was strong acidic to moderate acidic. Soil available P values ranged from 1.74 to 4.78 mg kg^{-1} with a mean value of 3.05 mg kg^{-1} soil in the study area. The highest grain yield (1670.1kg ha^{-1}) and (1653.8 kg ha^{-1}) was obtained in response to the application of 100% Pc from DAP and 75% Pc of NPS with recommended 46 kg N ha^{-1} fertilizers, respectively, while the lowest grains yield (1183.6 kg ha^{-1}) was obtained in response to control treatment. This study showed the use of appropriate balanced NPS fertilizer rate with P critical and P requirement factors and optimum N rates is the realistic approach to address the problem of low productivity of teff in the Guduru district. According to the partial budget analysis, 75% of Pc from NPS + 46 kg N fertilizer rates per hectare provided the highest benefit (ETB 39088.6). The marginal rate of return showed that it could get yield 4.416 ETB for every birr invested. The net positive benefit obtained with the application of 75% Pc NPS ha^{-1} + 46 kg N ha^{-1} to teff are economically profitable application rates and can be recommended for farmers of the study area. The result of this research work needs validation and demonstration around the study area and awareness should be created for farmers through demonstration and agricultural experts. Further, integrating this finding with other organic and biological fertilizers is also essential to improve yield, maintenance, and sustainability of soil health in the study area.

Keywords: Critical P, P requirement factor, Guduru District, Teff, MRR

Introduction

Teff is a staple cereal crop food for about 50 million Ethiopian people. It is versatile to adverse climatic conditions and is high in nutritional value makes suitable for both farmers and consumers (Assefa *et al.*, 2013). It is originated and has been cultivated in Ethiopia for centuries (Teklu and Tefera, 2005). Ecologically, teff is adapted to diverse agro-ecological regions of Ethiopia and grows well under stress environments better than wheat, barley, and other cereals are known worldwide (Refissa, 2012).

Because of this, it is said to be a “low-risk" crop for farmers. Even though teff can grow under different agro-ecology but it is most suited at altitudes of 1800 to 2100 m. a. s. l.

Accordingly, most of the fertilizer studies on cereals in the past also focused on N and P fertilizers. However, crop production demands more nutrients. Any technology that will improve teff yields will greatly benefit teff farmers and the country at large (ATA, 2014). Fertilizer usage plays a major role in the universal need to increase food production to meet the demands of the growing world population (Mitiku, 2008). Recently completed research and soil tests through the Ethiopian Soil Information System Project revealed that Ethiopian soils are deficient in various other nutrients that are not provided by DAP and Urea (ATA 2013). It was reported that crops have been suffering from deficiencies of several nutrients throughout the country. Phosphorus, Nitrogen, and Sulfur deficiency are major constraints to crop production in Sub-Saharan Africa. To assess the extent of soil-P deficiency, to estimate the P requirement of major crops.

Blended fertilizers are a combination of macro and micronutrients. The first major production constraint of teff in Ethiopia is low yielding due to poor soil fertility management (CSA, 2013). The second main problem in the study area is the lack of information on the agronomic and economic role of blended fertilizer. Soil test-based fertilizer recommendations that can give farmers a service leading to better and more economic use of fertilizers and better soil management practices for increasing agricultural production are necessary. Assess the extent of soil-P deficiency, estimate P requirement for teff in the study area, and soil test-based phosphorus calibration study on teff (*Eragrostis tef* (Zucc.) Trotter) production in Guduru district was conducted in 2000/2001 cropping season. The Applied kg P ha^{-1} = (Critical P - Po) * Pf, Whereas Pc = 6ppm; Pf = 17.3 kg ha^{-1} for teff in the Guduru district was established. Phosphorus, Nitrogen, and Sulfur deficiency are major constraints to crop production in the study area.

Although there is a general opinion that the new fertilizer blends better than the traditional fertilizer recommendation (Urea and DAP), their comparative advantages are not explicitly examined and understood under various production environment. Based on the phosphorous critical and phosphorous requirement factor the need for site-specific fertilizer prescriptions is increasingly apparent, however, fertilizer trials involving multi-nutrient blends of NPS fertilizer is recommended in the study area. Therefore, it needs calibration of NPS fertilizer rate based on soil test in the study area for increasing teff production and productivity in the study area. This study was aimed to determining the economic rate of NPS fertilizers; and to establish soil test-based fertilizer recommendation for teff (*Eragrostis teff* (Zucc.) Trotter) production in Guduru district of Oromia regional state, Ethiopia.

Material and Method

Description of the study area

The experiment was conducted on farmer’s field in Guduru district in Horro Guduru Wollega zone of Oromia Regional State, Ethiopia. Guduru is situated at an altitude ranging from 878 – 2448 m above sea level; latitude: $9^0$16’55” N to $10^0$02’31” N; Longitude: $37^0$12’42” E to $37^0$42’45”E in Horro Guduru Wollega zone of the Oromia regional state, Ethiopia and the study area map (Figure 1). The terrain is generally undulating to rolling plains. The mean monthly rainfall ranges from 10.43 mm to 344.7 mm, and mean monthly temperature is 16.11^0C to 19.11^oC. The major soil types are generally described as Nitisols (FAO, 2014).

Site Selection for the Experiment

The study was conducted in 2019/20 and 2020/21 consecutive years during the main cropping seasons at Guduru district, Horro Guduru Zone, Oromia region. Guduru district was selected for the implementation of the trial due to its potentiality for teff production and to have confidential on the technology of soil test-based phosphorus calibration study done previously in the district. The study was conducted on farmers' fields in the district. Thirteen experimental sites were selected based on farmer willingness and initial phosphorous soil test value and best performing farmers in teff production and willingness to provide land for the experimental purpose. For this experiment, Guduru teff variety was used as a test crop. Accordingly, composite soil samples were collected from different farmers' fields of the district by using the zigzag method. Soil chemical analysis was done for available phosphorus using Olsen method.

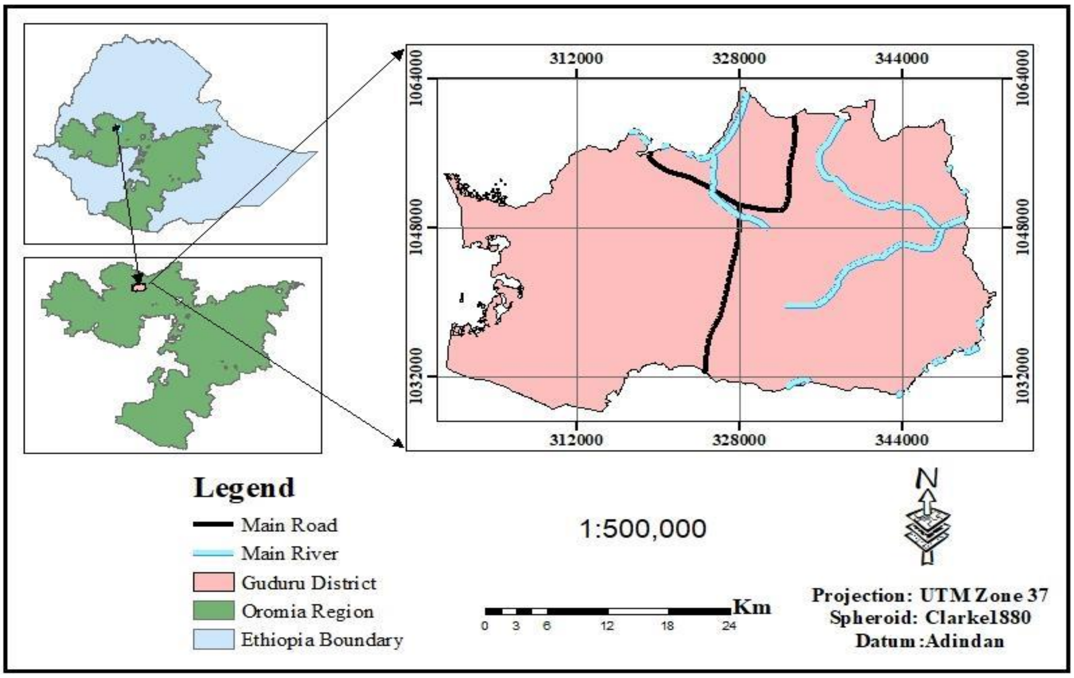

Figure 1: Location of the study area map

Experimental Materials, Treatments and Design: The experiment design was randomized complete block design (RCBD) with three replications. The plot size was 4m by 3m with 20cm inter row spacing. The spacing between blocks and plots of the experiments is 1m and 0.5m, respectively. The treatments consist of 100% Pc from DAP and recommended N fertilizer and 100%, 75%, 50%, 25% Pc from NPS fertilizer with recommended N fertilizer and control (no fertilizer application) on a teff variety Guduru with seed rate of 15 kg ha^{-1}.

Treatments	**Rates**
T1	Control (without fertilizers)
T2	25% of Pc from NPS + 46 kg N ha^{-1}
T3	50% of Pc from NPS + 46 kg N ha^{-1}
T4	75% of Pc from NPS + 46 kg N ha^{-1}
T5	100% of Pc from NPS + 46 kg N ha^{-1}
T6	100% of Pc from DAP + 46 kg N ha^{-1}

Applied P (kg ha^{-1}) = (Pc - Po) * Pf. Whereas Pc = 6 ppm; Pf = 17.3 kg ha^{-1} for teff in the Guduru district. Nitrogen fertilizers in the form of urea were used according to the recommended optimum rate of 46 kg N ha^{-1} during determined phosphorous critical in the district. Soil data before sowing samples was taken from the thirteen experiments sites to analyze the major chemical properties of the soil and sent to Nekemte Soil Research Center for laboratory analysis. Thirteen soil samples of soil pH and available phosphorous were analyzed the in Nekemte soil research center. According to Olsen *et al.* (1954) methods soil available phosphorus was determined by extraction with 0.5 M $NaHCO_3$.

Recommended seed rate was used 15kg ha^{-1} for row planting and seeds were drilled at 20 cm spacing (Berhe *et al.,* 2011). DAP and blended fertilizers were applied in full dose during planting while nitrogen was applied in split where 50% was added at 25days after planting to avoid losses through leaching and volatilization. Habtegebriel and Singh (2006) reported that nitrogen should be applied in split for optimum nutrient use efficiency of teff for all the treatments except the control. Furthermore, during the different growth stages of the crop, all the necessary agronomic practices and other management practices were carried out as per the recommendation.

Data Collection

Agronomic data were collected such as plant height, biomass and grains yield and panicle length. A total biomass and grain yields recorded on plot basis were collected and converted to kg ha^{-1} for statistical analysis.

Economic Analysis: Partial budget, domina, and marginal analyses were calculated based on the technique described by CIMMYT (1988). The presence significant difference of the mean grain yields of two years among the effect of the treatments the economic analysis was performed. According to CIMMYT (1988) justifying the Partial budget, dominance and marginal analyses were performed. The average grain yield data obtained from each treatment was adjusted downwards by 10%, to narrow the yield gap that occurs due to differences in the management of the crop by research and farmers.

Dominance analysis was conducted by listing the treatments according to increasing order of costs that vary and comparing the net benefit of the treatments. Treatments were found with decreasing net benefit while; total cost the variety increases were eliminated (Dominated). Marginal rate of return was computed for those which were none dominated. Marginal rate of return (MRR) was calculated as the change in net benefit (NB) divided by the change in total variable cost (TVC) of the successive net benefit and total variable cost levels (CIMMYT, 1988). Marginal rate of return (MRR %) $=\frac{marginal\ increasing\ in\ benefit}{marginal\ increasing\ in\ cost}*100$

Result and Discussion

Soil Chemical Properties of the Experimental site

Selected soil characteristics of the experimental soil are presented (Table 1). Soil pH value ranges from 4.77 to 5.59 with a mean value of 5.05 before planting (Table 1) in the study area indicated that it was Strong acidic to moderate acidic which was conducive for teff production as established by EthioSIS (2014). The soil available P values range between 1.74 to 4.78 mg kg^{-1} soils with a mean value of 3.05 mg kg^{-1} soil in the study area. Available P content of the soil was low (<5mg kg^{-1}) according to Olsen (1954).

Table 1. Soil chemical characteristics of the experimental field before sowing

Experimental Sites	Ɨ (H_2O) 1: 2.5	Soil available. P(ppm) Olsen method
1	4.82	3.40
2	5.26	3.33
3	4.64	4.77
4	5.02	4.54
5	5.26	1.55
6	5.07	4.78
7	4.97	1.82
8	4.79	1.74
9	5.59	3.16
10	5.34	3.12
11	4.77	2.54
12	5.13	2.78
13	4.96	2.1
Mean	5.05	3.05

Effect of NPS Fertilizer Rate on Yield and Yeld Components of Teff

The effects of NPS fertilizer rates based on phosphorus critical and requirement factors for teff production was highly significant ($p<0.05$) on plant height, panicle length and grain yield. The biomass yield was not significantly ($p<0.05$) influenced by the NPS fertilizers rates application (Table 2). However, the minimum aboveground dry biomass yield of teff obtained from control treatment was (7207.8kg/ha) and there is a biomass variation between treatments, which might be due to low variation nutrients in the soil. This showed that fertilizer consists of the balanced nutrients fertilizer rate to enhance the aboveground biomass yield of teff than recommended NPS.

The highest grain yield was obtained due to the application of 100% Pc from DAP with recommended 46 kg N ha^{-1}, 75% of Pc from NPS with recommended 46 kg N ha^{-1}, and flowed by the rate of 100% Pc from NPS with recommended 46 kg N ha^{-1} (Table 3). The highest grain yield (1670.1kg ha^{-1}) and (1653.8kg ha^{-1}) was obtained in response to the application of 100% Pc from DAP and 75% Pc of NPS with recommended 46 kg N ha^{-1}fertilizers, respectively, while the lowest grains yield (1183.6kg ha^{-1}) was obtained in response to control treatment (Table 3). This study showed the use of appropriate balanced blended NPS fertilizer rate with P critical and P requirement factors and supplemental N rates is the realistic approach to address the problem of low productivity of teff in the Guduru district. Achieving the goal of yield increment depends not only on the kind and amount of fertilizer but also on the cost of the fertilizer and the price of the yields (Black, 1992). Therefore, combining application 75% Pc of NPS with recommended supplemented 46 kg N ha^{-1}fertilizers rate is economically benefited in the study area. The responses of the crops under investigation to the NPS fertilizer rates were evaluated by researchers and key stakeholders. The feedback from the evaluation at this stage revealed that there was a significant difference between and among treatments.

Table 2. Effect of NPS fertilizer rates on plant height, Panicle length, biomass and grain yield of teff in Guduru District

ıts and rates		s(kg/ha)	)
ol (without fertilizers)			
ɔf Pc from NPS + 46 kg N ha^{-1}	b		
ɔf Pc from NPS + 46 kg N ha^{-1}	b		
ɔf Pc from NPS + 46 kg N ha^{-1}			
of Pc from NPS + 46 kg N ha^{-1}			
of Pc from DAP + 46 kg N ha^{-1}			
:ance			
%)			

GY= Grain Yield, PH= Plant height, Pl= panicle length, CV= coefficient of variation, LSD= least Significance difference

Partial budget analysis: The estimating economic parameters, products were valued based on the marketed price collected during February 2020-2021. The recommended treatment of the total price of fertilizer was 4519.6birr per hectare of the study area.

The minimum acceptable rate of return (MARR) was set at 100% based on CIMMYT (1988). The marginal rate of return showed the rate of return per unit cost of production at the highest MRR (441.6%) (Table 3). This result showed that it could get yield 4.416 ETB for every birr invested. The highest benefit was higher over 26.6% as compared to the control treatment. The partial budget analysis showed that the maximum net benefit with an acceptable MRR was obtained from 75% of Pc from NPS, and 50% of Pc from NPS fertilizer rates and supplemented with 46 kg N ha^{-1} application (Table 3). The net benefit obtained by the use of improved teff with rates of 75% of Pc from NPS with 46 kg N ha^{-1} application fertilizer was found to be greater than the benefit of applying fertilizer rates.

The highest net income (39088.6 EB) was obtained from 75% of Pc from NPS + 46 kg N ha^{-1} treatments with greater than the acceptable minimum rate of return (>100%) than the control treatment (Table 3). According to the partial budget analysis, 75% of Pc from NPS + 46 kg N per hectare provided the highest benefit (ETB 39088.6). Therefore, the net positive benefit obtained with application of 75% Pc from kg NPS ha^{-1} + 46 kg N ha^{-1} to teff production economically profitable application rates and can be recommended for farmers of the study area.

Table 3. Partial budget analysis of fertilizer uses in tef production for yields, variable costs, gross benefit, and net benefit under different treatments.

Treatments	GY ;/ha)	GFB :TB/ha)	FC ΓB/ha)	ΓVC ΓB/ha)	NB TB/ha)	IRR %)
(without P fertilizers)	20	2669.6	'41.0	53.4	)866.9	
Pc from NPS + 46 kg N/ha^{-1}	40	7536.5	)37.6	'50.7	3278.9	8.3
Pc from NPS + 46 kg N/ha^{-1}	)10	0203.0	778.6	04.1	5117.8	22.2
Pc from NPS + 46 kg N/ha^{-1}	130	5073.1	519.6	01.5	)088.6	41.6
f Pc from NPS + 46 kg N/ha^{-1}	100	4077.7	555.7	81.6	1089.5	56.8
f Pc from DAP + 46 kg N/ha^{-1}	190	7671.6	491.0	53.4	1631.2	7.8

AGY = Actual Grain yield, N= Nitrogen, TCV = Total cost for variable costs, GB = Gross benefit, NB = Net benefit, MRR= Marginal Rate of Return, FC= Fertilize Cost

Conclusion and Recommendation

This study revealed that, 75% of Pc from NPS + 46 kg N per hectare produced high yield of teff, in Guduru district. Therefore, the application of 75% of Pc from NPS + 46 kg N fertilizer rate per hectare is recommended for teff production in the Guduru district. The result of this research work needs validation and demonstration around the study area and awareness should be created for farmers through demonstration. Furthermore, integrating this finding with other organic and biological fertilizers is also essential to improve yield, maintenance, and sustainability of soil health.

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Soil Test Crop Response Based Phosphorous Calibration Study for maize in Sibu Sire District, Western Oromia, Ethiopia

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Abstract

Calibration of soil test P could be a stage in determining P fertilizer rates to meet plant P requirement and soil nutrient availability of phosphorous. The objective of this study was to determine the critical phosphorous (Pc) and phosphorous requirement factor (Pf) for maize production in the district. Field experiments which were laid out in randomized complete block design (RCBD) with three replications were conducted from 2018 to 2021. Maize response to different levels of Phosphorus was conducted at 17 sites in the Sibu Sire District East Wollega Zone, Oromia Regional State during the 2019/20 and 2021 cropping seasons. Partial budget analysis showed 138 kg/ha of N was economically optimal for the production of maize in the Sibu Sire district. Phosphorus calibration study included the application of 0, 10,20,30,40, and 50 kg P ha^{-1} with recommended 138 N kg ha^{-1} The critical concentration and requirement factor of Phosphorus on maize in the study area were 10 mg kg^{-1} and 20.69 kg/ha, respectively. Using the developed calibrated phosphorus would enhance the profitability of maize production across the Sibu Sire district. This phosphorus requirement factor and critical phosphorus level can help to give recommendations based on soil test phosphorus level for maize production in the Sibu Sire district. Thus, in soils with available P status below 10 mg kg^{-1}, the yield of maize could show a significant response to applications of P *fertilizers. Whereas in areas with available P status greater than 10 mg kg^{-1}, the P concentration in the soil exceeds crop needs so further addition of P fertilizer may not result in a profitable yield increase in the study area. In addition, coordination of this finding with other us of biofertilizer, compost, vermicompost, and organic fertilizers is additionally basic to move forward yie ld, maintenance, and sustainability of soil health. Further studies should be done on phosphorous use efficiency and other related plant nutrition parameters.*

Keyword: Sibu Sire, phosphorous Critical, maize, BH-661

Introduction

Phosphorus is one of the second essential plant nutrients. Phosphorus is one of the seventeen essential nutrients required for plant growth (Ragothama, 1999). Phosphorus is a non-renewable resource found naturally at high concentrations in some minerals as well as in manures, the latter being the most economically exploitable sources of P. Due to its many uses, P is in high demand globally and the fact that the many functions which it performs cannot be substituted by any other element; makes its purported declining availability so serious. As a result, there is substantial global interest in minimizing P losses from land application and the overuse of P fertilizers, i.e., applications above crop requirements that do not increase crop productivity (Dodd and Mallarino, 2005).

Fertilizer P recommendations depend on (i) the existing level of available soil P, (ii) the optimum level of soil P for the crop to grow, and (iii) the level of fertilizer that must be added to raise available soil P to the optimum level. Therefore, soil testing for P is used to determine the amount of P required for crop production. Soil test P is also used for determining environmental risks associated with elevated levels of soil P (Dahnke and Olson, 1990).

The basic construct of soil fertility guidelines and recommendations should include nutrient studies concerning soil and plant tissue analyses. These guidelines and nutrient management recommendations should be established through soil test and plant tissue correlation and calibration procedures. Soil test correlation can be described as the process of determining whether there is a relationship between plant uptake of a nutrient and/or yield with the amount of that nutrient extracted by a particular soil test. Different methods may be used to examine such a relationship. One example of a simple graphical method is the Cate Nelson method (Cate and Nelson, 1965). This method plots percent relative yield against soil test values which can effectively provide a visual indication of the reliability of a specified soil test and its correlation to plant response or the uptake of a specific nutrient.

In addition, this method also allows for the identification of a soil test critical level by dividing soil test values into soils that are likely or unlikely to respond to an added fertilization. Once this analysis has been conducted and a good correlation exists between the soil test and plant response, calibration analysis should be performed. Soil test calibration is the process of relating the soil test measurement in terms of crop response and it should describe soil test results in easily understood terminology and simplify the process of making fertilizer recommendations by placing soils in response categories (Dahnke and Olson, 1990). These response categories cannot be used to predict yield but can offer the probability that a response to fertilization will occur. Thus, the method for determining critical concentrations of soil test phosphorus for maize provides insight into P nutrition and can serve as a guide to improved agricultural practice in acidic soils of West Oromia as an indicator of P deficiency in crop production (Smyth and Cravo, 1990). Running soil tests could therefore help farmers to know the nutrient status of the soils which could serve as a prior to estimating site-specific fertilizer investments by the already resource-constrained farmers.

As inherent soil fertility varies for different soils, site-specific fertilization recommendation has long been proposed as more efficient than blanket soil nutrient management. Across Ethiopia, and particularly in the study are blanket recommended rates of N and P are used in maize cultivation. Overall, to develop a valid soil test phosphorous recommendations for wider applicability using low, medium, and high categories, several years of research is required to generate sufficient information for the most important crop- soil system (Agegnehu *et al*., 2013). In Ethiopia, the blanket recommendations that are presently in use all over the country were issued several years ago, which may not be suitable for the current production systems (Zeleke *et al.*, 2010). Since the spatial and temporal fertility variations in soils were not considered, farmers have been applying the same P fertilizer rate to their fields regardless of soil fertility differences. Availability of nutrients to crops is a function of the soil, crop, environment, and management; their interactions affect fertilizer use efficiency and the crop growth condition (Agegnehu *et al.*, 2013). These factors need to be considered when using methods to calibrate soil-test nutrient values with relative grain yields. The soil test-based calibration study provides information on how many nutrients should be applied at a particular soil test value to optimize crop growth without excessive waste and confirm the validity of current P recommendations (McKenzeie and Kryzanowski 1997).

Application of fertilizer concerning initial soil fertility status and crop requirement leads to economic and judicious use of fertilizers. Experiments conducted by different researchers to decide the rate of fertilizer under different research stations and their surrounding on-farm resulted in different rates of recommendations in terms of both P and N (Kelsa *et al.*, 1992)]. Trials carried out in many localities across

Ethiopia for about nine years also recommend different rates of P and N in accordance with crop and soil types (Ho, C. T., 1992). However, the current maize grain yield has declined regardless of using improved maize varieties and NP fertilizers even in high maize growing potential areas of western Oromia. Soil tests are designed to help farmers predict the available nutrient status of their soils. Once the existing nutrient levels are established, producers can use the data to best manage what nutrients are applied, decide the application rate and make decisions concerning the profitability of their operations (Agegnehu and Lakew, 2013; Agegnehu *et al.*, 2015). However, local assessments for the soil P critical levels and soil P requirement factors even for the major crops of the country are negligible. Currently, soil fertility research improvement is agreed for site-specific fertilizer recommendation in the country. The experiment was aimed at determining the economic rate of Nitrogen and Phosphorus fertilizers, assessing and evaluating soil test-based crop response phosphorus fertilizer requirement for maize in Sibu Sire District, and giving quantitative guidelines and recommendations of phosphorus fertilizer for maize in the district. Therefore, the objectives of this study are to determine critical phosphorus concentration and phosphorus requirement factors and to establish soil test-based fertilizer recommendations for maize production in the Sibu Sire district.

Material and Method

Description of the Study Area

The study area, Sibu Sire district, is located about 270 km west of the capital city of Ethiopia, Addis Ababa. It lies between 8°56'- 9°23'N latitudes and 36°35'- 36°56' E longitudes and the study area (Figure 1). The altitude of the district varies from 1336 to 2500 meters above sea level. It has an estimated area of 1,132.51 km. About 74.2% of its surface area belongs to Midaltitude agro climate, 7.53% of the land is highland agro climate, and the remaining 18.27% is classified as low land agro climate. The mean annual temperature and mean annual rainfall is 25^{0} C and 1050 mm, respectively Ngigi (2003).

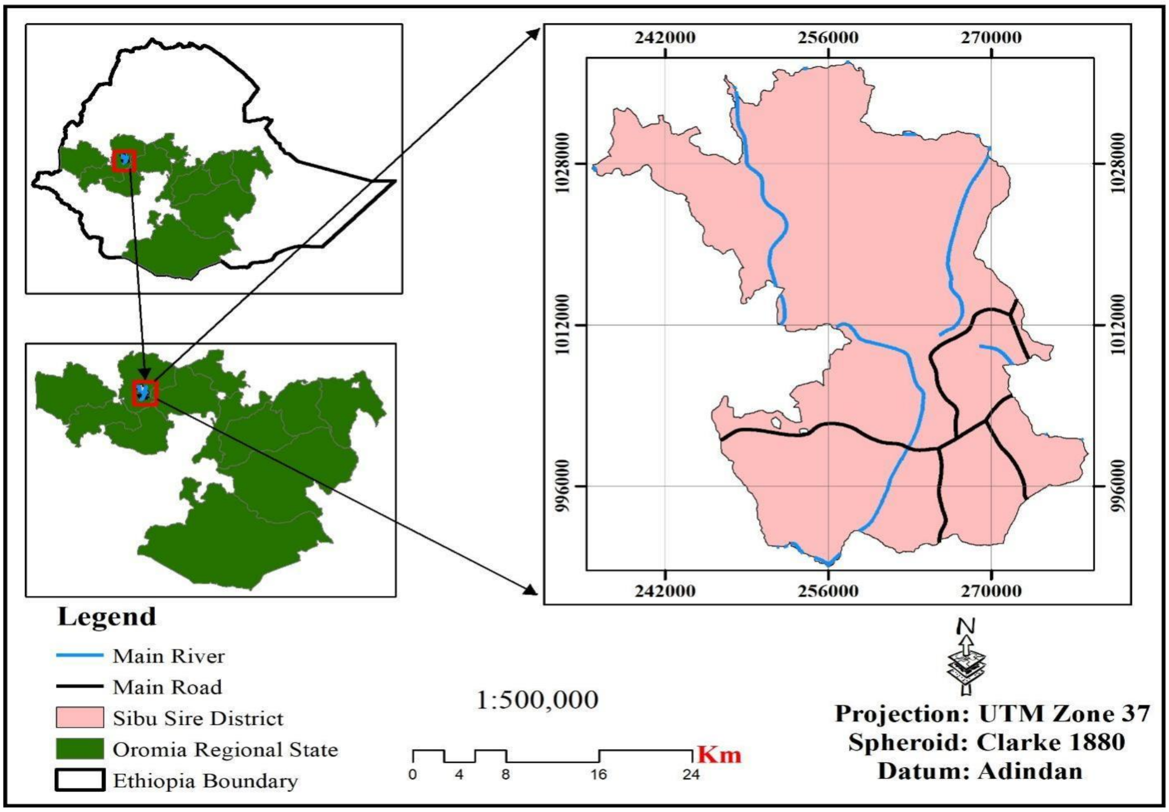

Figure 1: Location map of the study area

Agriculture provides the principal share of the source of revenue for the population of the district. Crop production took the lion's share followed by livestock production. The major crops include maize (25.6% of cultivated land), teff (20.5% of cultivated land), sorghum (16.5% of cultivated land), 'Nuog' (13% of cultivated land) followed by Finger millet (12.3% of cultivated land). The remaining percent of the cultivable land is covered by minor crops such as vegetables, roots and tubers, and some perennial crops Hoddinott (1999).

Experiment design: The study was conducted in farmers' fields. The trials were laid out in RCBD using five levels of P (0, 10, 20, 30, 40 kg P/ha) and four levels of N (0, 46, 92, 138 kg N/ha) with three replications. Source of fertilizer, phosphorous is from DAP and Nitrogen from urea as recommended rates for the district. Optimum amount of N was determined during the 1st year and applied for all plots uniformly for the 2nd and 3rd years. Lime was applied a month before planting based on the exchangeable acidity in the first year. Improved maize variety BH-661 was used. The spacing and plot size used 75*30cm and 5.m *6m values respectively.

For first-year, 10 experimental trial field representative composite soil samples were taken before planting. Soil samples were analyzed using a ratio of 2.5ml water to 1 g soil (Sahlemedhin and Taye.,2000:) available P using Olsen method (Olsen *et al.*, 1954). For the 2nd and 3rd years, 17 experimental trial field representative was selected from the study area. A total of 17 soil samples were collected for analysis of soil pH, available P and Exchangeable acidity, and determination of lime requirement amount. Soil samples at a depth of 0-20 cm were collected from all experimental plots three weeks after planting for determination of PC and Pf of maize production in the study area.

Lime recommendation and application: Soil pH was analyzed at 1:2.5 (soil: liquid mixture) using a pH meter. The amount of lime recommended for a given field was estimated by using the following formula:

$$LR, CaCO_3\ (kg/ha) = \left[\frac{cmolEA/kg\ of\ soil * 0.20m * 10^4\ m^2 * B.D.(Kg/m^3) * 1000}{2000}\right] * CCE$$

B. D=Bulk density of soil, EA= Soil exchangeable Acidity) and CCE= Calcium Carbonate Equivalent.

Data Collection: Harvesting was done at physiological maturity. Grain yields were measured based on plant samples taken from ten central rows (2m x 2m= 4m^2) at the full maturity stage. Grain yield recorded on a plot basis was converted to kg ha^{-1} for statistical analysis.

Economic Analysis: Economic analysis was performed to investigate the economic feasibility of the treatments (fertilizer rates). Partial budget analysis (CIMMTY, 1988) was used to analyze economic benefits obtained from the different rates of fertilizers applied. The mean grain yield of the selected treatment was used in the partial budget analysis (CIMMTY, 1988). A partial budget, dominance, and marginal analysis were used. The average open market price (Birr kg^{-1}) for maize and the official prices of fertilizers were used for economic analysis. The dominance analysis procedure as detailed in CIMMYT (1988) was used to select potentially profitable treatments from the range that was tested. The selected and discarded treatments using this technique are referred to as undominated and Dominated' treatments, respectively. The undominated treatments were ranked from the lowest (the farmers' practice) to the highest cost treatment. For each pair of ranked treatments, a marginal rate of return (MRR%) was calculated. The % MRR between any pair of undominated treatments denotes the return per unit of investment in fertilizer expressed as a percentage. Grain yield was adjusted down by 10% to minimize the effect of trial managed on small plots that may vary from the yield level on farmer's fields. The optimum level of Nitrogen fertilizer rate was determined for maize production in the district. All cost estimates were taken based on the 2018/2019 cropping season.

Marginal rate of return (MRR %) $=\frac{marginal\ increasing\ in\ benefit}{marginal\ increasing\ in\ cost}*100$

Determination of the Critical phosphorus level: The Cate-Nelson diagram method was used to determine the critical phosphorus level, where soil phosphorus values put on the X-axis and the relative grain yield on the Y-axis. Soil available phosphorus determined through the Olsen method from the composite soil samples that had been taken from each plot three weeks after planting was used in correlation analysis with the relative grain yields of all data taken from seventeen sites and all treatments with their replication. The Cate-Nelson graphical method (Dahnke and Olsen, 1990) was used to determine the critical P-value using relative yields and soil test P values obtained from 17 experimental sites of P fertilizer trials conducted at different P levels. Based on dividing the Y-X 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. So that a pair of intersecting lines were drawn to divide into four sectors. The point where the vertical line crosses the X-axis was defined as the optimum critical soil test level (Dahnke and Olsen, 1990). The point where the vertical line crossed the X-axis was defined as 'critical soil test level'. To assess the relationship between yield response to nutrient rates and soil test P values, relative yields in percent were calculated as follows:

Relative Yield (%) $= \frac{Yield}{maximum}*100$

Phosphorus requirement factor determination:
Phosphorus requirement factor (pf) is the amount of P in kg needed to raise the soil phosphorus by 1mg kg^{-1}. It enables to determine the quantity of P required per hectare to raise the soil test by 1mg kg^{-1}, and to determine the amount of fertilizer required per hectare to bring the level of available P above the critical level (Nelson and Anderson, 1977). It was calculated using available P values in samples collected from unfertilized and fertilized plots. phosphorous requirement factor was expressed as:

$$\text{P requirement factor} = \frac{\text{kg P applied}}{\Delta \text{ Soil P}}$$

Result and Discussion

Soil properties of the study area

Soil test results of the study experiment sites before planting indicated that pH values of most soils were strongly acidic (Table 1). The soils pH in the studied area ranged from 4.51 to 5.98 and a mean value of 5.27 which are strongly acid. Accordingly, soil pH values are classified into five classes, strongly acidic < 5.5, moderately acidic 5.6 - 6.5, neutral 6.6 - 7.3, moderately alkaline 7.3 - 8.4, and strongly alkaline > 8.4 established by (EthioSIS, 2014). The most favorable pH for the availability of most plant nutrients corresponds roughly with the optimum range of 6 to 7 (Brook, 1983). The range of soil reactions in experimental sites may limit crop production by influencing the availability of important plant nutrients. According to Landon (1991), a soil pH value below 5.5 could be an indication of the presence of an appreciable amount of exchangeable acidity and exchangeable Al^{+3}, and removal of exchangeable cations, such as calcium and magnesium. Available phosphorus of experimental soil in the district ranged from 1.3 to 15.41 ppm (Table 1). According to Landon (1991), available (Olsen extractable), soil P level of less than 5 mg kg^{-1} is rated as low, 5- 15 mg kg^{-1} as a medium, and greater than 15 mg kg^{-1} is rated as high. Thus, the available (Olsen extractable) P soils a mean value was 7.30 ppm of the studied area is at medium level. It needs additional P fertilizer to obtain the optimum yield in the study area.

Table 1. Selected experimental sites soil properties before planting in Sibu Sire District

ment sites	I (1:2.5) H_2O	osphorus in ppm	Acidity (Cmol(+)/kg)
1	5.98	14.84	0
2	4.54	6.84	1.94
3	5.48	3.42	0.32
4	5.74	5.9	0
5	4.93	3.63	1.36
6	5.08	1.3	1.11
7	5.5	3.01	0.47
8	5.07	4.94	0.39
9	5.76	9.73	0
10	5.46	5.05	0.3
11	5.63	13.45	0.17
12	4.51	15.41	1.67
13	5.31	7.78	0.26
14	4.82	5.74	0.73
15	5.05	6.15	0.47
16	4.94	4.68	0.26
17	5.82	12.28	0.14
Mean value	5.27	7.30	0.56

Critical phosphorus level and phosphorus requirement factor

Economic analysis using partial budget analysis showed that N fertilizer rate of 138 kg/ha was economically optimal for the production of maize in Sibu Sire. The N fertilizer rate of 138 kg/ha has a synergetic effect with phosphorus towards increasing grain yield. It was selected for critical P determination using the Cate – Nelson graphical method. Soil test phosphorous results were used to scatter the plot of relative grain yield versus phosphorous value. The Pc defined by the Cate- Nelson method in this study was 10 mg P Kg^{-1}, with a mean relative grain yield response of 80% (Fig 2). Hence, the scattered plots showed that 10 ppm was the critical phosphorus level for maize production in Sibu Sire District. Phosphorus requirement factor was figured out from the differences between phosphorus values in the soil samples collected from plots that received phosphorus fertilizers.

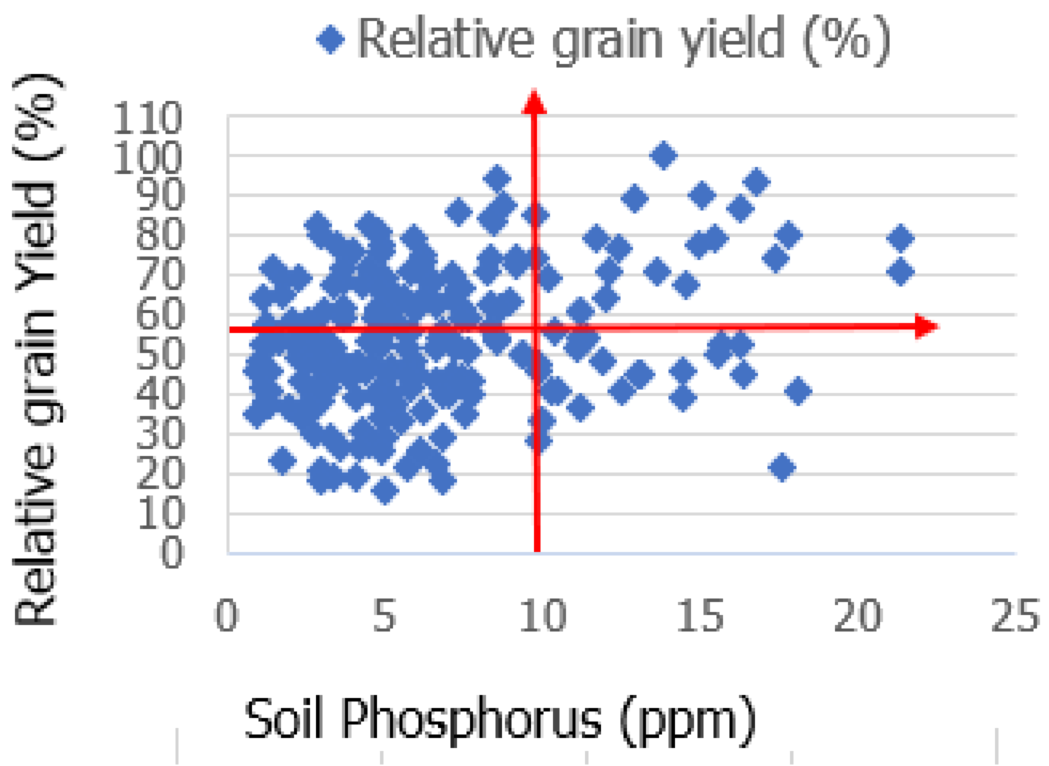

Figure:2 Scattered plot of relative grain yield (%) of maize and soil test phosphorus (Olsen) in Sibu Sire District

The phosphorus requirement factor values for the plots that received 10 kg P/ha, 20 kg P/ha, 30 kg P/ha, 40 kg P/ha and 50 kg P/ha were found to be 3.74, 9.35, 22.64, 20.14, and 47.32 values respectively recoded at the study area. The mean of these values, which represents the phosphorus requirement factor of the Sibu Sire district, was 20.63 Pkg /ha or 47.24 P_2O_5 kg /ha (Table 2). Phosphorus requirement factor and critical phosphorus value can be used as a base for phosphorus fertilizer recommendation in the district.

Table 2. Phosphorus requirement factor determination

zer applied (kg/ha)	. P (ppm)	se over the control	ement factor
0	12.10		
10	14.78	2.68	3.74
20	14.24	2.14	9.35
30	13.43	1.32	22.64
40	14.09	1.99	20.14
50	13.16	1.06	47.32
		1.84	20.63

Therefore, the rate of P fertilizer to be applied was expressed in terms of critical P concentration (Pc), initial soil P-value (Pi) and P requirement factor (Pf).

Phosphorus fertilizer rate in Kg of P/ha = $(P_c - P_0) * P_f$

Economic Analysis

First-year determination of Nitrogen fertilizer rate based on economic analysis using partial budget showed that fertilizer rates of 138 kg N/ha was economically optimal for the production of maize at Sibu Sire district (Table 3).

Table 3: Summary of partial budget analysis for economic fertilizer recommendation for maize production at Sibu Sire District.

N (kg/ha)	AGY (Qt/ha)	GFB (ETB/ha)	FC (birr/ha)	TSC (birr/ha)	HBC (birr/ha)	TVC (birr/ha)	NB (birr/ha)	MRR (%)
		2454.52	0.00	1132.78	566.39	1699.17	22844.3	
	51.50463	33478.01	645.74	1545.14	772.57	2963.44	30514.57	606.69
	52.84722	34350.69	1291.47	1585.42	792.71	3669.60	3061.10	23.58
	51.81481	33679.63	2582.94	1554.44	777.22	4914.61	28765.02	-153.90
	52.11111	33872.22	1348.25	1563.33	781.67	3693.25	30178.97	-115.77
	64.07407	41648.15	1993.99	1922.22	961.11	4877.32	36770.83	556.71
	58.77778	38205.56	2639.72	1763.33	881.67	5284.72	32920.84	-945.01
	70.66667	45933.33	3931.19	2120.00	1018.06	7111.19	38822.14	323.10
	61	39650.00	2696.50	1830.00	915.00	5441.50	34208.50	276.32
	67.87037	44115.74	3342.24	2036.11	1018.06	6396.40	37719.34	367.66
	77.74074	50531.67	3987.79	2332.22	1166.11	7486.30	40045.18	488.65
	77.83333	50591.67	5279.44	2335.00	1167.50	8781.94	41809.73	-95.35
	60.94444	39613.89	4044.75	1828.33	914.17	6787.25	32826.64	450.35
	78.24074	**50856.48**	**4690.49**	**2347.22**	**1173.61**	**8211.32**	**40645.16**	**689.47**
	77.18519	50170.37	5336.22	2315.56	1157.78	8809.55	41960.82	-214.69
	82.77778	53805.56	6627.69	2483.33	1241.67	10352.69	40345.87	135.57

N= Nitrogen, P= Phosphorous, AGY= Average Grain Yield, GFB= growth field benefit FC=Fixed Cost, TVC = Total variable cost, NB= Net Benefit MRR=Marginal Rate Return

Conclusion and Recommendation

Application of different nitrogen and phosphorus fertilizer rates had significantly increased grain yield of maize. phosphorous fertilizer application at an optimum level is necessary to improve the grain yield of maize. The results of the study revealed that the main effects of P fertilizer and its interaction with N fertilizer were significantly influenced the mean grain yield of maize in the Sibu Sire district. Partial budget analysis showed 138 kg/ha of N was economically optimal for the production of maize in the district. Therefore, one can understand that no need of applying nitrogen more than 138kg N/ha to attain optimum maize yield at Sibu Sire district. P critical 10 mg/kg and P requirement factor 20.63 mg/kg were determined for the phosphorus fertilizer recommendation in the district. These phosphorus requirement factor and critical phosphorus levels can help Nekemte Soil Research Laboratory Center to give recommendations based on soil test phosphorus levels for maize production in the Sibu Sire district.

As established by Cate- Nelson method, the critical levels of Olson method P in soil are about 10 mg kg^{-1}; at values of greater than or equal to 10 mg kg^{-1}, the crop achieved about 80% of its maximal yield in the absence of P fertilizer application (Figure 1). This implies that P fertilizer application could be recommended for a build-up of the soil P to this critical value, or maintaining the soil P at this level. Increasing P beyond this level, the cost of additional P fertilizer to produce extra yield would likely be greater than the value of additional yield. Thus, in soils with available P status below 10 mg kg^{-1}, the yield of maize could show a significant response to applications of P fertilizers. Whereas in areas with available P status greater than 10 mg kg^{-1}, the P concentration in the soil exceeds crop needs so further addition of P fertilizer may not result in a profitable yield increase. In addition, coordination of this finding with other natural and organic fertilizers is additionally basic to move forward yield, maintenance, and sust ainability of soil health. Thus, the farmers might be advised to use soil test crop response-based fertilizer recommendations to increase the productivity of maize in the Sibu Sire District.

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Pre-Extension Demonstration and Evaluation of Biofertilizer (Brhadirhizobium japonicum) TAL-379 strain on Soybean at Guto Gida and Wayu Tuka Districts, Oromia Region , Ethiopia

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Abstract

Declining of Soil fertility are the major soil chemical constraints which limit crop productivity in Ethiopia. To enhance agricultural productivity, farmers have to use fertilizers. There are many types of fertilizers in our world that enhances agricultural productivity even though many of them have drawback. The technology of using Integrated Plant Nutrient Management (IPNM) is the alternative method to increase sustainable productivity because of its zero negative impact on environment and soil. Among IPNM components, biological nitrogen fixation is the good method to fix nitrogen and improve soil fertility. This experiment was conducted for two consecutive years in 2019 and 2020 at Wayu Tuka and Guto Gida districts on 20 farmers to evaluate the effectiveness of Birhadyrhzobium japonicum biofertilizer strain (TAL-379) and the obtained result of plant height, pod number /plant, branch number/plant, yields and yield components were shown significant difference ($P \leq 0.05$) with Birhadyrhzobium japonicum biofertilizer strain-379 comparing with the treatment with no any fertilizer and chemical N fertilizer at Wayu Tuka districtS. This study present recommends using of rhizobium biofertilize TAL-379 strains in the production of soybean to increase grain yields and yield component at Wayu Tuka district, but in Guto Gida district, the experiment result shown chemical N fertilizer is significant difference at ($P \leq 0.05$) when comparing with the strain-379.

Keywords: *Soil fertility,bio fertilizer strain-379; Nutrient Management*

Introduction

Enhancing agricultural productivity is one of the central challenges to achieving food security and poverty reduction in Ethiopia. Soil fertility is one of the main constraints to agricultural intensification in Ethiopia. Like in many East African countries, nutrient depletion rates are exacerbated in Ethiopia by high erosion rates, biomass and animal manure removal from farm plots and limited application of mineral and organic fertilizers (C.L.vanBeek.,2016). Considering the fact that soil fertility is one of the biggest challenges, an obvious strategy is to increase fertilizer application and promote good agronomic practices to enhance productivity in Ethiopia particularly in the study area. (Eba and Bashargo., 2014).

Many small scale and poor farmers could not use chemical fertilizer. Therefore, it is important to understand these constraints and develop low cost techniques that focus on development of appropriate Integrated Plant Nutrient Management (IPNM) for the Ethiopian farmers. One of the alternatives method to increase the biological inputs of nutrients is here that biological fixation of atmospheric N that contribute directly in increasing of soil fertility and sustainability of yields within the minimal external inputs (Giller,2001). The increasing need for environmentally friendly agricultural practice is driving the use of fertilizers based on beneficial microorganisms (*E. Malus´a et al., 2012*).

Bacteria that colonize plant roots and promote plant growth are referred to as plant growthpromoting rhizobacteria (PGPR). They are a group of free living bacteria that colonize the rhiz osphere and benefit the root growth. Rhizobacteria are belonging to the genera Pseudomonas and Baci llus. They are well known for their antagonistic effects and their ability to trigger Induced Systematic Resistance. Resistance-inducing and antagonistic rhizobacteria might be useful in formulating new inoculants with combinations of different mechanisms of action, leading to a more efficient use for bio control strategies to improve cropping systems *(Anelise Beneduzi .,2012).* Biological nitrogen fixation contributes directly and indirectly to the maintenance or enhance ment of soil fertility and increasing productivity. Biological nitrogen fixation (BNF) by legumes is an indicator of their potential contribution to recycling nitrogen in cropping systems *(Boubi ́e Vincent Bado et al.,2018*).

Biofertilizers are definedas preparations containing living cells or latent cells of efficient strains of mi croorganisms that help crop plants' uptake of nutrients by their interactions in the rhizospher when ap plied through seed or to soil. They accelerate certain microbial process in thesoil whichaugments the e xtentofavailability of nutrients in a form easily assimilated by plants. Very often microorganisms are n ot as efficient in natural suroundings as one would expect them to be and therefore artificially multipli ed cultures of efficient selected microorganisms play a vital role in accelerating the microbial processes in soil. The uses of bio-fertilizer is one of the important component of integrated plant nutrient management, as they are cost effective and renewable source of plant nutrients supplement instead of the chemical fertilizers for su stainable agriculture (*PaulAnubrata and Dubey Rajendra,2014).*

Inoculation of biofertrilizer can be beneficial to the establishment of effective N-fixation on new seedlings of legume if done properly in areas where a legume of the cross inoculation group has not been grown previously or where N-fixing populations of soil bacteria have been severely reduced by adverse soil conditions such as drought or soil acidity. If a particular legume has not been grown in a field for several years, inoculation of seed is generally recommended as ‘insurance’ to ascertain maximum benefit from legume N-fixation (*Mothapo et al., 2011*).

Therefore by considering that there were no history with biofertilizer inoculation on soybean producti on at the study area, the study has been done by inoculating soybean seeds with biofertilizer TAL379 strain (*Birhadyrhzobium japonicum,)* during plantation to evaluate the effectiveness of the strain on t he enhancement of soybean productivity being low cost and no negative impact on the farm and demonstrate the technology.

Materials nd Methods

Description of the study area

Location

The study was conducted in 2019 and 2020 at Wayu Tuka and Guto Gida Districts. Both districts are located in East Wollega Zone of the Oromia Regional state, Ethiopia. Gute town, which is the capital town of Wayu Tuka district, is located at about 316 km distance from Finfine in western direction while Nekemt is a capital for Guto Gida district. Geographically Wayu Tuka district is located between 36°40’0’’ and 36°50’0’’ E and 8°50’0’’ and 9°10’ 0’’ N while Guto Gida district is situated at an altitude of 1500–2170 m.a.s.l and lies between 8^0 57’ 43.4” and 9^0 30’ 58.5” N latitude and 36^0 26` 25.24” E and $36^0$ 44` 419.58” E longitude according to Garmin 60 GPS reading. .

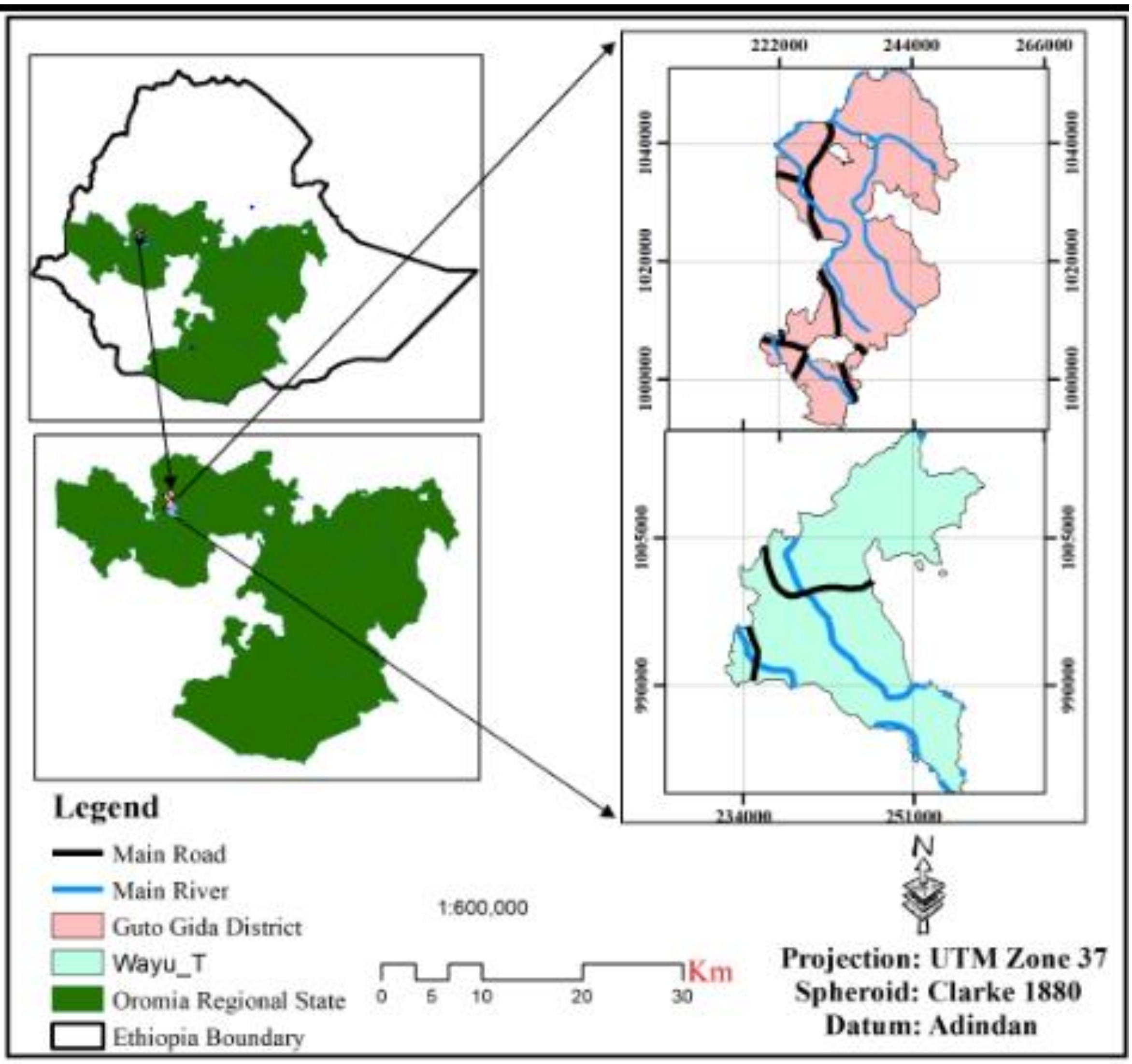

Figure 3 Location map of Guto Gida and Wayu Tuka Districts.

Agro climate, soil type and topography

The agro-climatic zone of the districts is falls in the highland (*badda*) and mid altitude (*Badda Daree*) (MOA, 1998). According to the ten years (2005 - 2014) weather data recorded at the Nekemte Meteorological Station, the average annual rainfall of the study areas is 2166.43mm and the monthly mean minimum and maximum temperatures ranges between 11.93 to 14.20 and 21.12^{o}C to 28.210^{o}C with unimodal rainfall pattern with monthly mean maximum rainfall (396.24mm) received in the month of june. While the average annual minimum and maximum temperatures of the districts are 13.05^{o}C and 26.06^{o}C, respectively. According to (Htwe, A.Z.,*et al.*,2014) classification, the dominant soil type in both districts is Nitisols.. The district is topographically characterized by mountainous and gentle sloping landscapes.

Climatic data during the study period from experimental areas

Table 4. Mean value of monthly rainfall, minimum and maximum temperature of the study area.

	ll (mm)	um temperature	um temperature
Jan	7.91	12.07	26.06
Feb	12.96	13.21	27.82
Mar	30.69	14.16	28.21
Apr	93.52	14.20	27.38
May	320.40	13.68	24.53
Jun	396.24	13.01	22.69
Jul	374.65	12.93	21.14
Aug	387.73	13.00	21.12
+sep	303.52	12.93	22.47
Oct	157.84	12.86	24.12
Nov	65.49	12.62	24.37
Dec	15.48	11.93	24.75

Total mean annual rainfall (mm) 2166.43. Source : Ethiopian National Meterology Agency, Nekemte Meterology station in 2006-2018**.**

Site Selection

Sites and farmers were selected in collaboration with key informant farmers, DAs, and the districts' agriculture and natural resource officers. The target sites were selected based on the high potential soybean production and access of road to the farm. The farmers were also selected based on their interest to accept the technology and willingness to provide their land for plantation. Total 20 farmers were selected from both districts, that means 10 farmers from each district.

Experimental *D*esign

The lands have been prepared using hand hoe (three times ploughing) before planting. The treatments were three. They are chemical N fertilizer (NPS), TAL 379 strain of (*Bradyhizobium japonicum*) biofertilizer and without any fertilizer then replicated three times. The experimental plots were $36m^2$ (6m x 6m). Treatments and treatment combinations was laid out as randomized complete block design (RCBD) and assigned randomly to the experimental units (plots) within blocks. 1Kg/ha TAL 379 strain of (*Bradyhizobium japonicum*) biofertilizer has been applied and mixed with the seed under shadow to protect the rhizobium from direct sunlight. The plots with chemical N-fertilizer were applied after the seeds have been planted. The soybean variety used was katta.

Data Collection and Analysis Method.

Qualitative data like farmers' perception towards the technology have been collected from farmers and DAs participated on field day by interviewing and discussing with them another day after they have visit the technology. While quantitative data like, Yield and yield related data such as, plant height, branch per plant, number of pods per plant, biomass and Grain yield have been collected manually. Five plants were sampled randomly at maturity time from each plot, plant height were measured in (cm) from each five plants and the average value was reported as plant height. The number of branch per plant were counted from each sampled plants and the average value was recorded and the pods were counted for all the five plants, and the average value was recorded as number of pods per plant. During the sampling, the plants were harvested by cutting with knife to the border of the ground to measure the above-ground dry biomass. The weight measurements of the five plants were done using an electronic digital balance and recorded as plant biomass. Finally the grain yields were weighted by threshing the seeds of five plants sampled from each plot and recorded as grain yield.

Statistical Analysis

The analysis of variance was carried out using the general linear model (GLM) procedure provided by SAS statistical software version 9.20 (SAS 2008). Means were separated using fisher's protected Least Significance Difference test (LSD) at 5% probability level.

Result and discussion

Field day

The field day was held in Wayu Tuka district in 2019 on which large number of stake holders, FRG members farmers, their neighbor and experts who were working on the experiments were participated on the field day to learn and share their knowledge. During the field day twenty farmers were attended. Ten farmers are those the study has been conducted on their farm and the others ten were neighbors.

Table 5 : field day participants by category

Participants	*Female*	*Male*	*Total*
Experts(DA, staffs ,and other guests)	15	50	65
Farmers	5	15	20

Yield and yield related parameters performance

The results of combined analysis of variance revealed that there are statistically significant difference between the treatments on the results of plant height, branches per plant, number of pod per plant, grain yield and biomass of soybean at Guto Gida district and Wayu Tuka districts.

Table 6: Results of Combined ANOVA for plant height branch per plant and pod per blant of soybean at Guto Gida district in 2019/20 and 2020/21 cropping seasons.

Treatments	Parameters		
	Plant height	Branch number/plant	Pod number/plant
Cont	60.38[b]	6.55[b]	53.57[b]
Biofer	64.45[a]	6.92[ab]	69.09[a]
Chem. Fer	65.32	6.92[ab]	69.78[a]
Significance	**	NS	**
CV(%)	2.25	3.45	8.16
LSD	2.8546	0.47	10.46
Mean	63.39	6.85	64.14

*Significant at $P \leq 0.05$**; LSD: Least significant difference; CV: Coefficient of variation. NS, Non significant; che fer: Chemical fertilizer; Bio fer: Biofertilizer; Cont:control: (without any fertilizer).*

Plant height, Branch number and Pod number at Guto Gida

Chemical N fertilizer significantly ($P \leq 0.05$) affects plant height where65.32cm were recorded with the treatment of chemical N fertilizer. Branch per plant were not show significant ($P \leq 0.05$) difference from each other even the treatment of *bradyrhizobium biofertilizer* (TAL379) and chemical N fertilizer show greater number (6.92)than the treatment with no fertilizer (6.55). The highest pod number/plant (69.78) were recorded at the treatment of chemical N fertilizer and significantly ($P \leq 0.05$) different from the treatment with no fertilizer and numerically greater than treatment with (TAL379) strain of*bradyrhizobium biofertilizer*(69.09) at Guto Gida district (in table 3).This results is in agreement with (Argaw, A., 2014*)*. Who reported similar findings on plant height at harvest, number of pods per plant, number of seeds per pod, that are show insignificance difference between inoculation of rhizobium biofertilizers.

Table 7: Results of Combined ANOVA for Biomass and yield of soybean at Guto Gida district in 2019/20 and 2020/21 cropping seasons.

Treatments	**Parameters**	
	Biomass (Kg/ha)	Grain yield (Kg/ha)
Cont	7936.00	4078.90[b]
Biofer	7977.40	4865.60[a]
Chem. Fer	8302.00	5067.20[a]
Significance	NS	***
CV(%)	14.26	4.62
LSD	2298.9	431.47
Mean	8071.79	4670.55

*Significant at $P \leq 0.05$**; LSD: Least significant difference; CV: Coefficient of variation. NS, Non significant; che fer:Chemical fertilizer ; Bio fer : Biofertilizer ; Cont :control: (without any fertilizer).*

Biomass and grain Yields of soybean at Guto Gida

Grain yield

Significantly higher grain yield (50.67Qt/ha) was obtained from the chemical N fertilizer than without any fertilizer which recorded (40.79Qt/ha) and numerically greater than with *br adyrhizobium biofertilizer* TAL-379 which recorded 48.66Qt/ha in table 4. Analysis of variance has shown that application of chemical N fertilizer had affected significantly ($P<0.05$) yields of soybean than the treatment with no fertilizer and *Bradirhizobi al japonicum* (TAL379) biofertilizer at Guto Gida district. The treatment with chemical N fertilizer gave additional 2.16 Qt/ha weight of Soya bean yield over *Bradyrhizobium biofertilizer* at this district. This finding agree with *(*Htwe,A.Z.,*et al.*,2019) which said the application of biofertilizer did not significantly increase the yield and yield components of soybean by on the adverse soil conditions such as drought or soil acidity.

Biomass

Analysis of variance did not show any significant ($P \leq 0.05$) difference between the treatments. Above-ground dry biomass parameter of soybean did not affected because of the difference between treatments. Even though the treatment difference couldn't cause significant ($P \leq 0.05$) difference on the yield of above-ground dry biomass of soybean, there was numerical difference between the treatments at Guto Gida district. 79.36Qt/ha, 79.77Qt/ha and 83.02 Qt/ha were recorded with no fertilizer, *Bradirhizobial japonicum* (TAL-379) biofertilizer and chemical fertilizer respectively. The treatment with chemical N fertilizer gave additional 3.25 Qt/ha weight of Soya bean biomass yield over *Bradirhizobial japonicum* (TAL-379) biofertilizer at this district. This finding again agreed with (Argaw, A., 2014). Who reported similar findings on dry biomass that are insignificant difference with inoculations of rizobium biofertilizer on the adverse soil conditions such as drought or soil acidity.

Table 8 Results of Combined ANOVA for splant height branch per plant and pod per Plant of soybean at Wayu Tuka district in 2019/20 and 2020/21 cropping seasons.

Treatments	ıeters		
	Plant height	3ranch number/plant	Pod number /plant
Cont	65.4^{b}	6.20^{b}	55.47^{b}
Bio-fer	71.61^{a}	7.25^{a}	71.00^{a}
Chem. Fer	71.33^{ab}	7.08^{a}	68.23^{a}
Significance	**	***	**
CV(%)	3.627	4.20	8.17
LSD	5.03	0.57	10.59
Mean	69.45	6.85	64.90

*Significant at $P \leq 0.05$**; LSD: Least significant difference; CV: Coefficient of variation. NS, Non significant; che fer : Chemical fertilizer; Bio fer : Biofertilizer ; Cont :control: (without any fertilizer).*

Plant height, Branch number and Pod number at Wayu Tuka

The highest plant height, branch number and pod number (71.61m, 7.25and 71.00) respectively were obtained from the application of *Bradirhizobial japonicum* (TAL-379) biofertilizer. With chemical fertilizer, (71.33m, 7.08, 68.23) of plant height, branch number and pod number respectively were recorded and with no fertilizer (65.4m, 6.2 and 55.47) of plant height, branch number and pod number were recorded respectively at Wayu Tuka district in (table5). The treatment with*Bradirhizobial japonicum* (TAL-379) biofertilizer show significant ($P \leq 0.05$) difference compared with no fertilizer on plant height, branch number and pod per plant.This results is in agreement with (Lamptey S *et al.*,2014). Who reported similar findings and concluded that the number of pods per plant, seeds per pod, branch per pod were significantly increased by application of Rhizobium inoculation.

Table 9 Results of Combined ANOVA for Effect of rhizobial inoculation and chemical fertilizer on Biomass and yield of soybean at Wayu Tuka district in 2019/20 and 2020/21 cropping seasons.

Treatments	**Parameters**	
	Biomass (Kg/ha)	Grain yield (Kg/ha)
Cont	7659.4[b]	3641.7[b]
Biofer	10709[a]	4923.0[a]
Chem. Fer	10661.7[a]	4827.5[a]
Significance	***	**
CV(%)	5.09	9.32
LSD	984.71	830.86
Mean	9676.75	4464.07

*Significant at P ≤ 0.05**; LSD: Least significant difference ; CV: Coefficient of variation. NS, Non significant; che fer: Chemical fertilizer ; Bio fer : Biofertilizer ; Cont :control: (without any fertilizer).*

Biomass and grain Yields of soybean at Wayu Tuka.

Biomass

Analysis of variance has shown that application of *Bradirhizobial japonicum* (TAL-379) biofertilizer had affected significantly (P<0.05) above-ground dry biomass parameter of soybean. Bradyrhizobium biofertilizer significantly enhanced the above-ground dry biomass yield (107Qt/ha) of soybean over non-fertilized (76.59Qt/ha) and chemical fertilizer (106.62Qt/ha) treatment at Wayu Tuka district. The treatment with *Bradirhizobial japonicum* (TAL-379) biofertilizer gave additional 0.47Qt/ha weight of biomass yield over chemical fertilizer at Wayu Tuka (in table 6). This finding agree with *(*Tamiru Solomon *et al.,* 2012) who said an increased above-ground dry biomass was observed with treatment of rhizobial inoculation of TAL-379 strain.

Grain yield

Significantly higher grain yield (49.23Qt/ha) was obtained from *Bradirhizobial japonicum* (TAL-379) biofertilizer than with no fertilizer which recorded (36.42Qt/ha) and with chemical N fertilizer which recorded (48.28Qt/ha) in table 5. Analysis of varian ce has shown that application of *Bradirhizobial japonicum* (TAL-379) biofertilizer had affected significantly (P<0.05) yields of soybean than the treatment with no fertilizer and chemical N fertilizer at Wayu Tuka district. The treatment with Bradyrhizobium biofertilizer gave additional 0.96Qt/ha weight of Soya bean yield over chemical fertilizer at Wayu Tuka.

Conclusion and Recommendations

Declining Soil fertility are the major soil chemical constraints which limit crop productivity in Ethiopia. In this study, application of *Bradirhizobial japonicum* (TAL-379) biofertilizer showed a considerable difference in plant height, branch number, pod number/plant, yields and yield components of soybean when compared with no fertilizer and chemical N fertilizer at Wayu Tuka district. The study has shown thatto increase soybean production, application of 1Kg/ha TAL 379 strain of (Bradyhizobium japonic um) biofertilizer inoculants is recommended. Depending on the results of present study, it is important to promote the appropriate use of *Bradirhizobial japonium* (TAL-379) biofertilizer through any possible means, to paramount technology of biofertilizer to western oromia farmers especially for farmers of Wayu tuka districts. The present study therefore recommends inoculating of soybean seeds with 1Kg/ha of *Bradirhizobial japonicum* (TAL-379) biofertilizer before planting to increase grain yield at Wayu Tuka district. However in this study *Bradirhizobial japonicum* (TAL-379) biofertilizer has shown significant effect at Wayu Tuka district, it did not brings the expected significant result at Guto Gida district. So another experiment has to be repeated at this district to find out the appropriate strain of *Bradirhizobial japonicum* biofertilizer that can significantly influence plant height, branch number, pod number yields and yield components of soybean at Guto Gida district.

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Soil Resource Survey

Characterizing and Classifications of Soil Resources and Acid Soils in Bedele District of Buno Bedele Zone, South Western Oromia, Ethiopia

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Abstract *The study was conducted to characterize and classify of acid soils in Bedele district, south western Oromia, Ethiopia. Study was executed in four site of the district in which the severity of soil acidity is high relatively to others and 13 representative profiles were opened from the district. Among 13 pedons, nine meet Diagnostic criteria of Mollic horizon and the remaining four meet for Umbric horizon. Seven pedons were qualifying for Argic and sixpedons qualifying for nitic diagnostic horizon. The color of surface horizons varied from very dark brown (7.5YR 2.5/2) to reddish brown (2.5YR 4/4) whereas the color of the subsurface from brown (7.5YR 4/4) to dark reddish brown (2.5Y 2.5/3). The bulk density values ranged 0.9 to 1.286gcm-3 and Clay fractions ranged 34.28 to 76.28%. The results pH(H_2O) ranged 4.10 to 5.15 and pH(KCl) results ranged 3.2 to 4.25. OC values ranged 0.137 to 4.345% and available Phosphorus value ranged 1.81 to 14.92 mg kg^{-1}. Soils total nitrogen was varied 0.0167 to 0.357% and CEC of the soils ranged 18.01 to 46.80 $cmolckg^{-1}$ whereas CEC clay varied 22.57 to 77.85 $cmolckg^{-1}$. The PBS of the soil ranged 33.3 to 74.44 % across the all sites. Exchangeable Al ranged 0 to 21.97 cmol (+) kg^{-1}. Generally the variations in soils properties suggested theirs variation of potential productivity and management requirements for specific Soils. Based on the results of morphological, physical and chemical properties five reference soils groups were identified namely, Nitisols, Acrisoils, Alisols, Luvisols and Lixisols. The severity of soil acidity ranged from strongly to moderately acidic with a pH of <5.5 which had a significant impact on crop productivity. Integrated soil fertility management practices, using lime and acid tolerant species, crops rotations were important measure.to improve the fertility level for better crop production and productivity*.

Keywords: *Soils Acidity, crop, diagnostic horizons, reference soils groups, and soils properties productivity.*

ntroduction

Characterizing and classifying soils is the main information source for precision agriculture, land use planning and management (Yitbarek et al., 2016). It provides information for our understanding of physical, chemical, mineralogical and microbiological properties of the soils we rely on to grow crops, sustain forests and grasslands that support daily life of the society. Soil classification, on the other hands, helps to arrange our knowledge, facilitates the transfer of experience and technology from one place to another (Ogunkunle, 2004 and Mulugeta and Sheleme, 2010).

The knowledge of characterizing soil properties and potential uses is always needed for sustainable land use planning and for economic development (Yitbarek et al., 2016). Characterization and mapping of soils are much important to understand the nature of soil resources and provide detailed information on morphological, physical and chemical characteristics of soils (Yitbarek et al., 2016). In Buno Bedele Zone South Western Oromia, Ethiopia, where this studies was conducted soils were rated as very strongly acidic to strongly acidic but natures of these acid soils were not characterized and classified in depth. Therefore study was proposed to Classify and characterize acid ~~soil~~ soils of Bedele area.

Material and Methods

Description of Study Area

The study was conducted in Bedele district, Buno Bedele Zone, Oromia Regional State South Western Ethiopia that located between 8°14'30"N to 8°37'53"N, and 36°13'17"E to36°35'05"E.

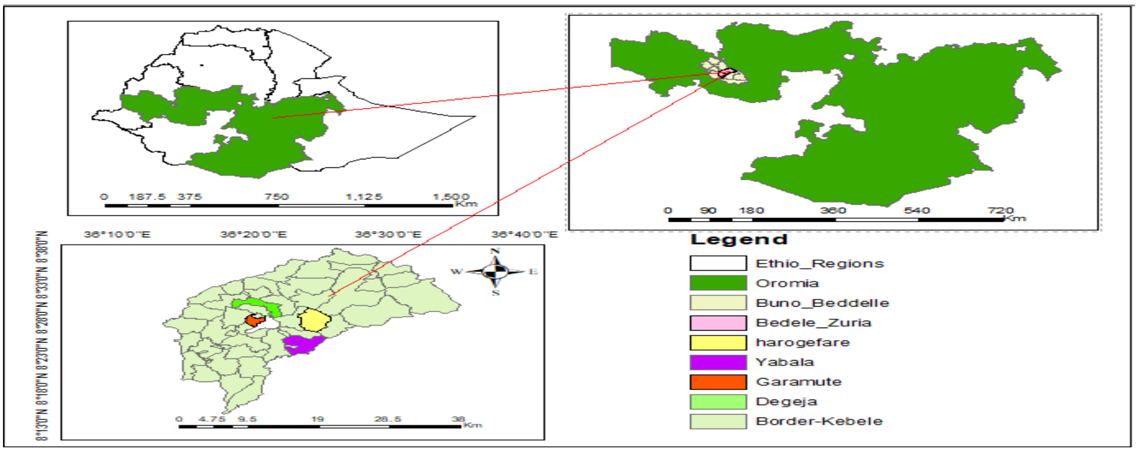

Figure 4; Map of study area

Climate: According to the Sixty-year (2005-2020) weather data recorded at Bedele Meteorological Station, area had average annual rain fall of 1867.04mm. The annual minimum and maximum temperatures of the area are 12.63oC and 26.45°C respectively (UN published data from Bedele meteorological substation, 2021).

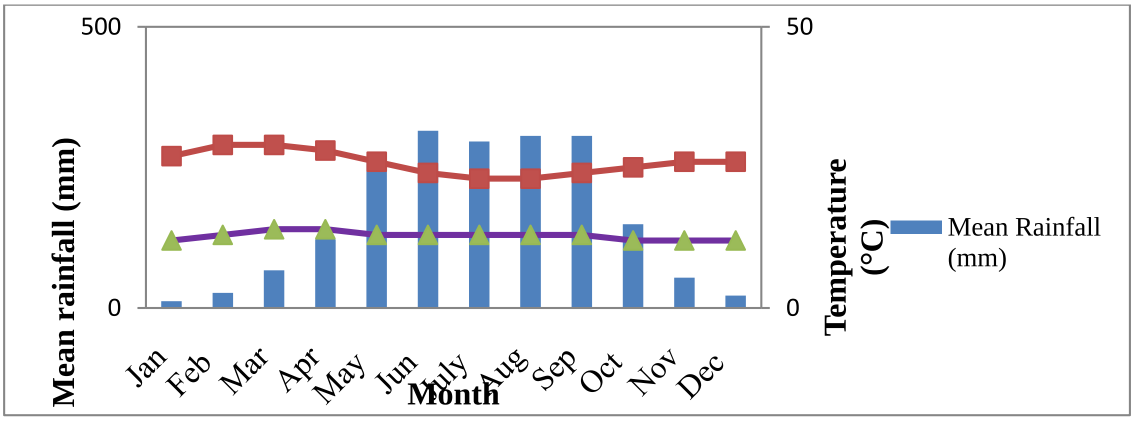

Figure 5: Mean monthly rainfalls and maximum and minimum temperature of Bedele district.

Study Sites Selections

The study was conducted at mid-altitude and highland ecological zones of the district in which soils acidity problem is critical problem. Four site of the district (Giramute, Degaja, Yeballa and Haro Gefere) in which the severity of soil acidity is high relatively to others was selected.

Soil Profile Sites Selections

Before starting of the field soil descriptions, the boundaries of each site were delineated using digital map of Oromia region, base maps of the study area was prepared by overlying land use and land cover, geomorphology, contour/elevation and slopes of study area using ArcGis 10.3 for each site. The reconnaissance survey was conducted throughout the area before dud soil profiles. Total of 48 observations was conducted using auger inspections. Soils within each site were examined and differentiated based on observable site and soil characteristics such as slope, soil depth, color and texture following free survey method. The locations of each observation points were geo-referenced by using GPS. Based on soils characteristic observed at field (slope, soil color), soil pH, soils texture, bulk density and organic carbon result that obtained from augur observations three representative soil pedons, 1.5m x 1.5m x 2m (Length x Width x Depth), per each site were opened one per each slope categories means upper slope, middle slope and lower slope of the area however one additional pedon was opened at Degeja site.

Laboratory analysis

Soil texture was determined using hydrometer method (Day, 1965). Bulk density (BD) was determined from the weight of undisturbed (core) soil samples dried in an oven at 105 ^{0}C (Baruah and Barthakur, 1997). The average soil particle density (PD) (2.65 gcm^{-3}) was used for estimating total porosity. Soil textural classes were read from the textural triangle (WRB, 2014). The pH of the soils was measured using a pH meter in 1:2.5 ratio of soil to liquid suspension. The liquids used were distilled water pH (H_2O) and 1M KCl pH(KCl) according to the procedure outlined by van Reeuwijk (2002). Organic carbon was determined using the wet oxidation method (Walkley and Black, 1934). Total N was determined by the micro-Kjeldahl method and exchangeable bases (Ca^{+2}, Mg^{+2}, K^{+}, and Na^{+}) in the soil were extracted with 1 M ammonium acetate (NH4OAc) solution at pH 7.0 van Reeuwijk (2002).Total exchangeable acidity was determined by saturating the soil samples with 1 M KCl solution and was titrated with 0.02 M NaOH as described by Rowell (1994). From the same extract, exchangeable Al^{+3} in the soil samples was determined by application of 1 M NaF, which forms a complex with Al^{3+} and releases NaOH and then NaOH was back titrated with a standard solution of 0.02 M HCl (Sahlemedhin and Taye, 2000), available soils phosphorus were determined according to Bray II (Bray and Kurtz. 1945)

Pedon Descriptions, Soil Sampling and Soil Classification

Information on the site surrounding the pedons were described in terms of elevation, slope (positions, form and inclination), lithology, drainage class, landforms, micro-relief and erosion features following guidelines for field soil description (FAO, 2006). Morphological characteristics such as horizons boundaries (distinctness and topography), roots, soil structure, consistence and color matrix of each horizon were recorded in moist conditions using Munsell Soil Color Charts (Munsell, 2015). Based on the morphological properties and the laboratory analysis, the soils of each study area were classified according to WRB (IUSS Working Group, 2014).

Disturbed and undisturbed soils samples were collected from every identified horizons using knife and Core sampler respectively. Soils of the study area were classified based on field and laboratory data obtained from thirty pedons and horizons identified in the field according to (FAO, 2006) and the World Reference Base for soil resources (IUSS WRB Working Group, 2014) classifications systems.

Data analysis

Linear regression was employed to analyze the relationship between reference lime requirement and Buffers lime requirement methods. Similarly linear regression was used to analysis the correlation of soil parameters with reference lime requirement. All Statistical analyses were done using stata statistical software. Statistics/Data Analysis 15.0 StataCorpLLC(1985-2017)

Results and Discussions

Site Characteristics of Pedons

Site characteristics of the study area around pedons in respective sites were described based on their slope, drainage class, and land use, surface characteristic and physiographic features as indicated below Table: 1. Degeja site Pedons 2 and 4 were on landscapes with slopes of 15 and 5% at foot slope and middle slope positions respectively. Whereas Pedons 1and 3 were on landscapes with slopes of 8 and 12% at summit and back slope position respectively. At Gera Mute site Pedons 1and 2 were on landscapes with slopes of 8 and 15% at summit, shoulder whereas Pedons 1 was on landscape with slope of 5% at foot slope position respectively. At Yeballa site Pedons 2 and 3 were on landscapes with slopes of 14 and 9% at middle and summit slope positions whereas Pedon 1 was on landscape with slope of 3% at toe slope positions respectively. At Haro Gefere site Pedons 2 and 3 were on landscapes with slopes of 8 and 14% at shoulder were as Pedons 1 was on landscape with slope of 3% at summit slope position respectively. Drainage characteristics in all pedons were well drained across the study sites. Land uses at Degeja site pedons 1and 4 were shrubs land, while around pedon 2 annual arable field cropping following with fallowing were the major land use system and pedon 3 is grassland. At Gera Mute site Pedon 1 and 2 is Forest Gravilia plantations and grazing land with scattered wood land use respectively whereas Pedon 3 was under annual arable field cropping. At Yeballa site Pedons 2 and 3 represented shrubs and grazing land use respectively whereas Pedons 1 represented annual arable field cropping but there is trend of land use change from crops land to eucalyptus plantations in the area. Land use at Haro Gefere site was annual arable field cropping for all pedons but similar land use change trend was observed as that of yeballa changing crops land to eucalyptus plantations land was observed due to three basic reasons: first decline of soils fertility, second termite problems that destroy field crops and the third reasons is economic return obtained from eucalyptus plantations

Table 1: Information on the site

Pedons	Coordinate		Altitude(masl)	S g	Slope forms	Slope position	Land uses
	Latitu de	Longit ude					
BB/B/D-1	08^{0}28'56.9	036^{0}21'27.8	2070	8	S	Upper summit	shrub
BB/B/D-2	08^{0}30'22.5"	036^{0}20'48"	1863	5	**S**	lower(foot)	Cultivated
BB/B/D-3	08^{0}30'37.2"	036^{0}19'26.5"	1882	12	**s**	lower(foot)	Grazing
BB/B/D-4	08^{0}30'12.4"	036^{0}19'55.5"	1944	15	**s**	middle slope	shrub
BB/B/G-1	08^{0}28'38.0"	036^{0}20'08.6"	2106	8	S	Summit slope	forest
BB/B/G-2	08^{0}28'15.9"	036^{0}20'01.2	1988	15	S	Middle slope	Fallow
BB/B/G-3	08^{0}27'57.3"	036^{0}19'36.9"	1913	5	**s**	Lower/foot slope	Cultivated
BB/B/Y-1	08^{0}23'33.9"	036^{0}23'23.1"	1861	5	s	lower (foot)slope	Cultivated
BB/B/Y-2	08^{0}24'04.5"	036^{0}23'28.1"	1931	14	s	Middle slope	shrubs
BB/B/Y-3	08^{0}25'23.4"	036^{0}23'25.1"	1950	9	s	upper(Summit)	Grazing
BB/B/H-1	08^{0}27'05.7"	036^{0}23'27.4"	1957	3	**s**	summit slope	Cultivated
BB/B/H-2	08^{0}27'19.3"	036^{0}24'37.3"	1989	7	s	Upper/ summit	fallow land
BB/B/H-3	08^{0}27'03.5"	036^{0}23'45.1"	1983	15	s	Middle/back slope	Cultivated

Note:BB=buno bedele, B= bedele, D=degeja ,G=Gera Mute,Y=Yeballa, H=Haro gafare and S=straight

Morphological Properties of Soils

Almost all Pedons had an A-Bt horizon sequences except pedon 1 in Gere Mute which was on shrubs land on summit site of mute hill that had A-Bt-C horizon sequences. Pedons the studies area had different A horizons thickness may be due to land use and slope positions that influence accumulations and decomposition of OM. On the other hand cultivation and erosion have damaged certain part of the A-horizon. Relatively pedons 2, 4, 6, 7, 11 and 12 had thin A horizons than other. Pedons 2,6,8,9,10,11,12and 13 had horizon boundaries diffuse, smooth horizon boundaries in Ap maybe due to tillage disturbance while the remaining five had gradual smooth horizon boundaries and gradual and clear in the middle and bottom (Bt) of pedons due to migration of solutes and fine material from the overlying eluvial horizon (A) and accumulated in underlying illuviation horizons (Bt).The variation in horizon depth and boundaries revealed that theirs variation in pedogenic processes that resulted from variation of landform and land uses (Graham, 2006).

There is variation in soil color hue from 10YR to 2.5YR at moist state in both surface and subsurface horizons. The color of surface horizons varied from very dark brown (7.5YR 2.5/2) to reddish brown (2.5YR 4/4) whereas the color of the subsurface horizons varied from brown (7.5YR 4/4) to dark reddish brown (2.5Y 2.5/3) surface horizon have darker color than subsurface horizons due to higher soil organic matter content at surface than subsurface. Soil color deference resulted from difference soil organic matter contents, moisture content of the soils and variations of oxidations reductions reactions and also related to pedological processes (FAO, 2006). Similar to the current finding many researchers for Ethiopian soils in different parts of the country reported that the (Ali *et al.,* 2010; Desalegn *et al.,* 2015; Abdenna *et al.,* 2018, Yitbarek *et al,* 2016 and Reggasa, 2015).

Soil structures at eluvial horizons (A) were weakly to moderately develop grade with fine to medium size and granular to angular blocky type. At illuviation horizons (Bt) soil structures were moderately to strongly develop grade with medium structural size and sub angular blocky to angular blocky type Table: 2. Moist consistence of surface horizons ranged from very friable to friable and firm to very firm consistence at subsurface. The variations of consistence were resulted from high OM contents at surface and high clay contents in subsurface horizons. Soil consistence at wet state in the surface horizons were slightly sticky to sticky and slightly plastic to plastic and very sticky at the surface and subsurface horizons in all pedons. The overall surface consistence result showed that the soils were workable at moist and wet conditions at all slope positions without difficulty.

Abundance of roots distributions ranged from many to common in upper positions of A horizon and few to very few upper positions of B horizons and lower positions of B horizons in each pedons respectively. The size of roots ranged from course to medium fine to very fine in upper positions A horizon and upper positions of B horizons maybe due to microbial activity and mostly to very fine in the lower position of B horizons in each pedon as indicated in Table: 2.

Table 10: Morphological characteristicsof the studied pedons

Pedons ID	*Horizon*	*Depth CM*	*Boundary (D,T)*	*Consistency*		*Structure*			*Cutans*			*Soil color at moist state*	
				Moist	Wet	Grade	Size	Type	Abund	Size	Nature	Notation	Standard Name
BB/B/DP-1	Ah	0-10	G,S	FR	ST/PL	WE	F	GR	M	F	H	2.5YR4/4	Reddish Brown
	AB	10-25	D,S	FI	ST/VPL	WE	F	GR	FW	F	Cl	2.5YR3/4	Dark Reddish Brown
	Bt1	25-60	G,S	FR	VST/VPL	MO	ME	SAB	C	ME	Cl	2.5YR3/3	Dark Reddish Brown
	Bt2	60-87	D,S	FI	VST/VPL	MO	ME	SAB	C	ME	Cl	2.5YR3/4	Dark Reddish Brown
	Btsw1	87-130	D,S	VFR	SST/SPL	MO	ME	SAB	M	Co	Cl	2.5YR4/6	Red
	Btsw2	130-200+	_	FR	ST/PL	MO	ME	SAB	M	Co	Cl	2.5YR4/8	Red
BB/B/DP-2	AP	0-15	D,S	FI	ST/PL	WE	ME	GR	N	N	_	7.5YR3/3	Dark Brown
	AB	15-40	C,S	FI	ST/PL	Mo	ME	AB	Fw	F	Cl	2.5YR4/3	Reddish Brown
	Btw	40-85	D,S	VFR	SST/SPL	Mo	ME	SAB	C	ME	Cl	2.5YR3/4	Dark Reddish Brown
	Bt1	85-150	C,S	FR	SST/SPL	ST	ME	SAB	M	ME	Cl	10YR3/4	Brown
	Bt2	150-200+	C,S	VFR	ST/PL	ST	ME	SAB	M	Co	Cl	10YR3/3	Dark Brown
BB/B/DP-3	Ah	0-10	G,S	VFI	NST/NPL	WE	F	GR	N	-	-	2.5YR4/4	Reddish Brown
	AB	10-20	C,S	FR	SST/SPL	WE	F	GR	N	_	_	2.5YR4/3	Reddish Brown
	Bt	20-65	C,S	VFI	VST/VPL	MO	ME	SAB	FW	F	Cl	2.5YR3/4	Dark Reddish Brown
	Bt1	65-95	D,S	FR	ST/PL	MO	ME	SAB	C	F	Cl	2.5YR3/4	Dark Reddish Brown
	Btsw1	95-120	D,S	FI	ST/PL	MO	ME	SAB	C	F	Cl	2.5YR4/6	Red
	Btsw2	120-200+	_	FR	ST/PL	MO	ME	SAB	M	Co	Cl	2.5YR4/6	Red
BB/B/DP-4	Ah	0-20	G,W	FR	SST/SPL	WE	ME	GR	N	N	_	7.5YR3/3	Dark Brown
	AB	20-50	C,S	FR	ST/PL	Mo	ME	AB	FW	F	Cl	7.5YR3/4	Dark Brown
	Bt1	50-95	D,S	FI	ST/VPL	Mo	ME	SAB	C	ME	Cl	5YR3/4	Dark Reddish Brown
	Btw	95-200+	C,S	FR	VST/VPL	ST	ME	SAB	M	ME	Cl	2.5YR3/6	Dark Red

Pedons ID	Horizon	Depth CM	Boundary (D,T)	consistency		Structure			Cutans			Soil color at moist state	
				Moist	wet	Grade	Size	Type	Abunda	Size	Nature	Notation	standard Name
BB/B/GP-1	Ah	0-13	G,S	VFR	SST/SPL	WE	ME	GR	C	Co	H	7.5YR3/2	Dark Brown
	AB	13-30	C,W	FR	SST/SPL	WE	ME	AB	FW	F	Cl	7.5YR3/3	Dark Brown
	Bt1	30-75	C,S	VFR	ST/PL	Mo	ME	SAB	C	Co	Cl	2.5YR3/3	Dark Reddish Brown
	BtS	75-120	C,S	VFI	NST/NPL	ST	ME	SAB	c	Co	Cl	2.5YR4/4	Dark Reddish Brown
	BC	120-200+	_	FR	SST/SPL	WE	ME	SAB	FW	F	Cl	7.5YR4/4	Brown
BB/B/GP-2	AP	0-10	D,S	VFR	SST/SPL	WE	ME	GR	M	F	hu	5YR2.5/2	Dark Reddish Brown
	AB	10-45	C,S	FR	ST/PL	WE	ME	AB	M	F	Cl	5YR3/2	Dark Reddish Brown
	Bt1	45-90	C,W	FI	ST/PL	WE	ME	AB	M	F	Cl	2.5YR4/3	Reddish Brown
	Bt2	90-130	G,S	FR	ST/PL	WE	ME	AB	M	F	Cl	2.5YR3/3	Dark Reddish Brown
	Btw	130-200+	_	FR	SST/SPL	MO	ME	AB	M	F	Cl	2.5YR2.5/2	very Dusky Red
BB/B/GP-3	AP	0-12	D,S	VFR	SST/PL	ST	ME	GR	N	N	_	5YR4/3	Dark Reddish Brown
	AB	12-48	C,S	FR	ST/PL	Mo	ME	GR	FW	F	Cl	5YR3/3	Dark Reddish Brown
	Btg1	48-85	G,S	FR	ST/PL	WE	F	SA	C	Co	Cl	5YR3/3	Dark Reddish Brown
	Btg2	85-120	D,S	FI	ST/VPL	WE	F	SA	M	Co	Cl	2.5YR3/4	Dark Reddish Brown
	Btg3w	120-200+	_	FI	VST/VPL	WE	F	SA	M	Co	Cl	2.5YR3/2	Dusky Red
BB/B/YP-1	Ah	0-10	G,S	VFR	SST/PL	WE	ME	GR	N	N	_	5YR3/3	Dusky Red
	AB	10-25	C,S	FR	ST/PL	Mo	ME	AB	FW	F	Cl	5YR3/4	Dusky Red
	Bt1	25-65	D,S	FR	ST/PL	Mo	ME	SAB	C	ME	Cl	2.5YR4/3	Reddish Brown
	Bts	65-110	C,S	FI	VST/PL	ST	ME	SAB	M	ME	Cl	2.5YR4/4	Reddish Brown
	Bt2	110-200+	C,S	VFI	VST/PL	ST	ME	SAB	M	Co	Cl	2.5YR4/3	Dark Reddish Brown
BB/B/YP-2	AP	0-8	D,S	SFR	SST/STP	WE	ME	GR	N	N	_	7.5YR2.5/2	Very Dark Brown
	AB	8-32	C,S	VFR	SST/STP	Mo	ME	AB	FW	F	Cl	7.5YR2.5/2	Very Dark Brown
	Bt1	32-53	D,S	FR	VST/VPL	Mo	ME	SAB	C	ME	Cl	5YR3/2	Dark Yellowish Brown
	Bt2	53-110	C,S	FR	VST/VPL	ST	ME	SAB	M	ME	Cl	5YR3/2	Dark Yellowish Brown
	Bts	110-200+	C,S	FR	VST/VPL	ST	ME	SAB	M	Co	Cl	5YR4/6	Yellowish Red

Pedons	Horizon	Depth CM	Boundary (D,T)	Consistency		Structure			Cutans			Soil color at moist state	
				Moist	Wet	Grade	Size	Type	Abun	Size	Nature	Notation	Standard Name
BB/B/YP-3	AP	0-10	D,S	VFR	SST/SPL	WE	F	GR	M	F	Hu	7.5YR4/4	Brown
	AB	10-25	D,S	SFR	SST/SPL	WE	F	GR	FW	F	Cl	2.5YR3/4	Reddish Brown
	Bts1	25-60	G,S	FR	ST/PL	MO	ME	SAB	C	ME	Cl	2.5YR4/4	Reddish Brown
	Bt1	60-87	D,S	FR	ST/PL	MO	ME	SAB	C	ME	Cl	2.5YR3/6	Dark Red
	Bts2w	87-105	D,S	FR	ST/PL	MO	ME	SAB	M	Co	Cl	2.5YR4/8	Red
	Bt2	105-200	_	FR	ST/PL	MO	ME	SAB	M	Co	Cl	5YR5/8	Yellowish Red
BB/B/HP-1	AP	0-21	D,S	VFR	SST/SPL	WE	ME	GR	N	N	_	7.5YR4/2	Brown
	AB	21-70	C,S	FR	ST/PL	Mo	ME	AB	FW	F	Cl	2.5YR3/4	Dark Reddish Brown
	Bt	70-121	D,S	FR	ST/PL	Mo	ME	SAB	C	ME	Cl	2.5YR3/4	Dark Reddish Brown
	Bt1	121-148	C,S	FI	ST/PL	ST	ME	SAB	M	ME	Cl	2.5YR2.5/4	Dark Reddish Brown
	Bt2	148-200+		FI	VST/VPL	ST	ME	SAB	M	Co	Cl	2.5YR2.5/4	Dark Reddish Brown
BB/B/HP-2	AP	0-8	D,S	FR	SST/SPL	WE	F	GR	M	F	Hu	5YR4/4	Reddish Brown
	AB	8-45	D,S	FR	SST/SPL	WE	F	GR	FW	F	Cl	5YR3/4	Dark Reddish Brown
	Bts1	45-70	G,S	FI	ST/PL	MO	ME	SAB	C	ME	Cl	2.5YR4/4	Reddish Brown
	Bts2	70-115	D,S	FI	ST/PL	MO	ME	SAB	C	ME	Cl	2.5YR6/4	Light Reddish Brown
	Bts3	115-170	D,S	FI	ST/PL	MO	ME	SAB	M	Co	Cl	5YR5/6	Yellowish Red
	Bts4	170-200+	_	FI	ST/PL	MO	ME	SAB	M	Co	Cl	5YR5/8	Yellowish Red
BB/B/HP-3	AP	0-10	D,S	FR	SST/SPL	WE	ME	GR	N	N	_	2.5YR4/4	Reddish Brown
	AB	10-30	C,S	FI	ST/PL	Mo	ME	AB	FW	F	Cl	2.5YR3/4	Dark Reddish Brown
	Bt1	30-60	D,S	FI	ST/PL	Mo	ME	SAB	C	ME	Cl	2.5YR3/4	Dark Reddish Brown
	Bt2	60-100	C,S	VFI	VST/VPL	ST	ME	SAB	M	ME	Cl	5YR3/4	Dark Reddish Brown
	Bt3	100-200+	-	VFI	VST/VPL	ST	ME	SAB	M	Co	Cl	2.5YR3/6	Dark Red

CS= clear smooth; D, S= diffused smooth, GS =gradual smooth;FR = friable; VFR =very friable; FI= firm; VFI = Very firm ST =sticky; SST = slightly sticky; VST = very sticky; PL=plastic; SP = slightly plastic; VPL = very plastic; Cl= clay. WE = weak; ST = strong; MO = moderate; VST = very strong; F= fine; VM = very fine to medium; VF =very fine;ME=medium;CO=coarse;GR=granular; SAB=sub angular blocky; AB =angular blocky;M=many; C = comman;FW=few and VFW=very few.

Physical Properties of Soils

Particle Size Distribution, Bulk Density and Porosity

The textural classes for surface horizons were clay loam to clay, for the subsurface horizons it was clayey in all pedonsTable: 3. The percentage of sand and silt fractions decreased while clay fractions increased towards middle bottom of pedons which is indicative of clay illuviation in all Pedons except BB/B/GP-1 and BB/B/HP-2 in which sand fractions slightly increased with increasing depth of the pedons. The ratios of silt to clay were decreased from top to bottom in all pedons except BB/B/GP-1 which increased at the bottom of pedons. Generally, the ratio of silt to clay ranged from 0.1 to 0.9. For surface and subsurface horizons silt to clay ratios of the soils ranged from 0.31 to 0.90 and 0.1 to 0.69 respectively. Similar results reported by Abdena *et al.* (2018) for Diddessa watersheds of Southern Ethiopia.

The percentage of clay fractions in soils of the studies area was ranged from 34.28 to 51.28% at surface horizons and from 44.28 to 76.28% for the subsurface horizons. Similarly, higher clay contents both at surface and a subsurface horizon was reported for soils of the studies area by (Reggasa, (2015) and Abdena*et al.* (2018). The mean value of bulk density of the study area soils was 1.16gcm-3. Generally, bulk density values were increased as depth increases which might be associated with decreasing of organic matter, mineral types and increasing of compactions due to overlay load (USDA, 2008) as cited by Yitbarek *et al*, (2016). The range of the bulk density values of the surface soil was from 0.9 to 1.13gcm-3and for the subsurface ranged from 1.04 to 1.286gcm-3. The results of bulk density for soils of all pedons were in the range of moderate (USDA, 2008), which suggests root penetration is not severely restricted. The results of total soils porosity of studies area was ranged from 51 to 66 %.Surface horizons results were ranged from 58 to 66% and at subsurface ranged from 51 to 62% the lowest and highest value respectively which suggested that soils of the studies area were porous (USDA,2008) as cited by Yitbarek *et al*, (2016).

Table 11: Some Physical properties of soils of 13 pedons with their respective horizons

Pedons	Horizon	Particle distributions			Sit/Clay	Texture Class	Bulk Density	% Porosity
		Clay	Silt	Sand				
Pedon-1	Ah	34.78	30.50	34.72	0.88	Clay loam	0.96	64
	AB	41.12	30.16	28.72	0.73	Clay loam	0.94	65
	Bt	57.88	17.40	24.72	0.30	Clay	1.00	62
	Bt1	62.14	17.14	20.72	0.28	Clay	1.02	62
	Bt2	68.16	15.12	16.72	0.22	Clay	1.06	60
	Bt3	71.11	14.17	14.72	0.20	Clay	1.14	57
Pedon-2	AP	32.71	32.57	34.72	1.00	Clay loam	0.92	65
	AB	40.77	32.51	26.72	0.80	Clay loam	0.94	65
	Bt	55.75	19.53	24.72	0.35	Clay	0.99	63
	Bt1	59.92	17.36	22.72	0.29	Clay	1.01	62
	Bt2	64.08	15.20	20.72	0.24	Clay	1.07	60
BB/B/DP-3	AP	38.35	26.93	34.72	0.70	Clay loam	1.13	58
	AB	45.29	26.99	27.72	0.60	Clay	1.14	57
	Bt	59.01	24.27	16.72	0.41	Clay	1.15	57
	Bt1	64.56	20.72	14.72	0.32	Clay	1.16	56

	Bt2	68.59	16.69	14.72	0.24	Clay	1.2	54
	Bt3	72.88	10.40	16.72	0.14	Clay	1.2	54
Pedon-4	AP	34.49	30.79	34.72	0.89	Clay loam	0.9	66
	AB	40.97	34.31	24.72	0.84	Clay loam	1.1	57
	Bt	58.13	21.15	20.72	0.36	Clay	1.1	55
	Bt1	62.87	20.41	16.72	0.32	Clay	1.1	55
Pedon-5	Ah	34.71	30.57	34.72	0.88	Clay loam	0.9	65
	AB	41.95	31.33	26.72	0.75	Clay loam	0.9	65
	Bt	48.99	26.29	24.72	0.54	Clay	0.9	65
	Bt1	53.48	17.80	28.72	0.33	Clay	0.9	64
	Bt2	56.60	17.68	25.72	0.31	Clay	0.9	63
Pedon-6	AP	41.68	32.60	25.72	0.78	Clay loam	0.9	65
	AB	51.80	31.48	16.72	0.61	Clay	1.0	61
	Bt	56.65	16.63	26.72	0.29	Clay	1.0	59
	Bt1	58.67	18.61	22.72	0.32	Clay	1.1	55
	Bt2	64.67	12.61	22.72	0.19	Clay	1.1	55
Pedon-7	AP	48.43	18.85	32.72	0.39	Clay	0.9	65
	AB	61.23	22.05	16.72	0.36	Clay	1.0	62
	Bt	63.42	21.86	14.72	0.34	Clay	1.0	60
	Bt1	60.50	22.78	16.72	0.38	Clay	1.0	60
	Bt2	60.77	22.51	16.72	0.37	Clay	1.2	54

Soil chemical properties

Pedons	Horizon	Particle distribution			Sit/Clay	Texture Class	Bulk Density	Porosity
		%Clay	%Silt	%Sand				
Pedon-8	AP	5.15	31.13	33.72	0.89	Clay loar	0.99	63
	AB	1.42	26.86	31.72	0.65	Clay loar	1.02	62
	Bt	3.76	21.52	24.72	0.40	Clay	1.03	61
	Bt1	0.31	19.97	19.72	0.33	Clay	1.04	61
	Bt2	4.99	18.29	16.72	0.28	Clay	1.05	60
Pedon-9	Ah	7.53	31.75	30.72	0.85	Clay loar	0.90	66
	AB	2.51	28.77	18.72	0.55	Clay	0.91	66
	Bt	0.92	20.36	18.72	0.33	Clay	0.92	65
	Bt1	6.02	11.26	22.72	0.17	Clay	1.00	62
	Bt2	0.35	10.93	18.72	0.16	Clay	1.04	61
Pedon-10	AP	2.27	29.01	28.72	0.69	Clay loar	0.94	64
	AB	5.72	27.56	26.72	0.60	Clay	0.96	64
	Bt	6.52	16.76	16.72	0.25	Clay	1.08	59
	Bt1	2.58	16.70	20.72	0.27	Clay	1.12	58
	Bt2	0.67	18.61	20.72	0.31	Clay	1.18	55

	Bt3	0.90	10.38	28.72	0.17	Clay	1.29	51
Pedon-11	AP	5.08	32.20	22.72	0.71	Clay	1.11	58
	AB	4.00	23.28	22.72	0.43	Clay	1.19	55
	Bt	8.11	23.17	18.72	0.40	Clay	1.20	55
	Bt1	4.27	23.01	12.72	0.36	Clay	1.24	53
	Bt2	6.96	18.32	14.72	0.27	Clay	1.24	53
Pedon-12	AP	1.83	23.45	34.72	0.56	Clay loar	0.95	64
	AB	4.31	24.97	30.72	0.56	Clay	0.99	63
	Bt	0.34	20.94	28.72	0.42	Clay	1.09	59
	Bt1	4.38	16.90	28.72	0.31	Clay	1.15	57
	Bt2	2.34	14.94	22.72	0.24	Clay	1.17	56
	Bt3	9.78	16.50	33.72	0.33	Clay	1.18	55
Pedon-13	AP	6.86	34.42	28.72	0.93	Clay loar	0.96	64
	AB	7.61	27.67	24.72	0.58	Clay	0.96	64
	Bt	5.75	22.53	21.72	0.40	Clay	1.04	61
	Bt1	3.60	21.68	14.72	0.34	Clay	1.07	60
	Bt2	5.49	11.79	12.72	0.16	Clay	1.09	59

The results revealed that the pH-H_2O of soil at surface horizons ranged from 4.64 to 5.11, whereas the subsurface horizons values were ranged from 4.10 to 5.15 Table: 4, the pH-KCl results were ranged from 3.68 to 4.14 and 3.2 to 4.25 for surface and subsurface horizons, respectively. Both pH water and pH-KCl for all pedons was categorized as strong acidic and the magnitude decreased down with increasing in depth in all pedons. ΔpH[pH(H_2O)-pH(KCl)] for soils of all pedons was positive which suggested that high negative charge density and high CEC than anion exchange capacity and indication of high level of extractable Al. pH measured in KCl were lowered by 0.81 to 1.3 units when compared with results of pH measured in H_2O. Similarly, positive ΔpH was reported by Ali *et al,* (2010) and Abdena *et al.* (2018), respectively.

The OC content of the soils at surface horizons was ranged from 1.36 (BB/B/YP-3) to 4.35 % (BB/B/GP-4) representing the lowest and highest value respectively. The lowest soils OC content was recorded at the bottom of all pedons with value that ranged from 0.137(in pedon BB/B/DP-1) to 0.80 %(BB/B/GP-1) may be due to low biological activity. However, low level of OC in the surface horizon were observed in pedons BB/B/GP-2, BB/B/YP-3 and BB/B/HP-2 on grazing land which might resulted from complete removal of grass biomass by animals, termite problems in the studies area and related previous history of continuous cultivations. Generally, the majority of surface horizons organic carbon contents of soils of the studies area were rated (2-4.1%), as medium based on the rating by Ethio SIS (Karltun, 2013) except BB/B/DP-4 (>4.1%)which rated as high whereas BB/B/YP-3 and BB/B/HP-2 rated as low (>2%), respectively (Karltun, 2013). However the organic carbon content of subsurface horizons is within low (1.5-2%) to very low (<1.5%) (Karltun, 2013).

Similar trends were observed for soils Nitrogen content that was varied from 0.0167 to 0.357% the lowest and highest value respectively. The Nitrogen content of the surface horizons was higher as compared to the subsurface soil horizons and it followed similar pattern with that of organic matter in all the studied pedons indicated that there is a strong correlation between organic matters with TN in the soil system. The total N contents of both surface and subsurface horizons was rated as mostly deficient (<0.5%) as indicated in (FAO, 2006) whereas Total Nitrogen contents of the studies area were rated as low to medium accordingly to London criteria (Landon, 1991).

Available Phosphorus value ranged from 1.81 to 14.92 mg kg-1 the lowest value and the highest, respectively. The lowest value was recorded at the depth of 150-200cm Degeja profile two whereas the highest recorded from surface horizons of Haro Gafare profile one which may resulted due to residual effect. Generally available P values declined with depth which could be attributed to decrease in soil OM, as was also asserted by their positive significant correlation (r = 0.44, p< 0.01). The increase in clay content with depth could have also contributed to decrease in available P (r =-0.49, p< 0.01), this was confirmed by the correlation analysis with negative relationship. Similar results was reported by Teshome *etal*.,(2016) even though the result was not confirmed by the correlation analysis. Based on the rating of available P suggested by London (1991), the available P content of the soils in both surface and subsurface horizons of all the pedons was ranged as low (<15 mg kg-1)as P availability limited by strongly acid characteristics of the soils in acid soils environment. Similar results were reported by different researchers (Melese et al., 2015; Daniel and Tefera, 2016; Kebede *et al.*, 2017).

The Cation exchange capacity of the soils was variable from site to site and almost showed irregular trend with soil depth in all pedons. Generally, cation exchange capacity (CEC) of the soils ranged from 18.01 to 46.80 $cmol_c kg^{-1}$clay, which rated from medium to very high (FAO, 2006). Soil CEC value decreased with depth in DP1, DP2, YP3 and HP2 which may be associated with decreasing of SOM with soils depth. Similar finding was reported by (Abay and Sheleme, 2012, Daniel and Tefera, 2016 and Abdena *et al,* 2018).

Irregular pattern of CEC with soil depth could be associated with organic matter and clay distributions in the profiles. Similar finding of irregular patterns of CEC values was reported by Fekadu *et al*.,(2018)and Mulugeta *et al.* (2018). Similarly, the value of CEC clay showed irregular trend as soils depth increased in all pedons and the values varied from 17.76 to 70.26cmolc kg-1 that suggest the existence of different clay mineralogy within the studies area. Similarly, decreasing in CEC clay values as soils depth increase was reported by Abdena *et al,* (2018) for soils of Didessa watershed. The contents of exchangeable cations were varied from pedon to pedons in which the contents decreased with increasing soil depth, maybe due to nature of parent material or might associated with leaching of basic cations below due to high rainfall. The contents of Ca varied from 3.41 to 21.027 that ranged from low to very high and Mg contents that ranged from medium to high 1.23 to 6.77 cmol (+) kg^{-1} (Hazelton and Murphy (2007), whereas exchangeable K and Na varied from 0.0304 to 1.11 and 0 to 0.137cmol (+) kg-1. The percent base saturation of the soil ranged from 33.3 to 74.44 % across the all sites. Moderate percent base saturation value (74.44%) was recorded even the soil strong acid which may associated with soil CEC value and sum of exchangeable base. Generally the overall results of PBS study area range very low to moderate (Hazelton and Murphy, 2007). The results of exchangeable aluminum extracted by unbuffed salt of 1N KCl variable from site to site and showed increasing trends with depth in all pedons that ranged from 0 to 21.97cmol (+) kg-1. The finding in line with, Zenebu *et al.* (2018) who reported similar trend for soils of Shiebench district in Bench Maji Zone (Zenebu *et al.*,2018).

Soil chemical properties of 13 Pedons

Pedons ID	Horizon	pH-H_2O	pH-KCl	Exchangeable base				Ex.Ac	Ex.Al	EBS	CEC-Soil	CEC-Clay	PBS	%OC	%TN	Av.P (mg/kg)
				Ca	Mg	K	Na									
Pedon-5	Ah	4.82	3.68	20.51	6.27	0.07	0.12	11.19	8.66	75.70	41.40	57.90	65.13	4.02	0.35	12.95
	AB	4.65	3.72	21.03	5.95	0.24	0.02	11.46	9.98	73.20	36.60	43.22	74.44	1.78	0.15	13.07
	Bt	4.62	3.58	14.75	5.72	0.05	0.05	16.60	10.42	66.37	36.40	35.13	56.50	1.49	0.11	7.28
	Bt1	4.87	3.81	15.35	6.28	0.45	0.00	11.20	10.69	67.38	46.80	70.26	47.18	1.04	0.10	13.55
	Bt2	4.96	4.10	15.87	6.77	0.25	0.09	12.86	0.00	100.00	40.00	60.08	57.46	0.80	0.10	13.19
Pedon-6	AP	4.85	3.86	8.06	5.89	1.11	0.12	12.33	0.00	100.00	32.89	43.97	46.14	2.15	0.20	12.69
	AB	5.15	4.25	7.04	6.27	0.07	0.02	12.11	10.59	55.87	31.43	52.12	42.67	1.62	0.14	11.81
	Bt	4.78	3.92	5.23	5.48	0.04	0.00	13.86	11.65	47.99	25.83	44.67	41.60	0.64	0.06	10.42
	Bt1	4.51	3.47	5.02	5.90	0.36	0.00	14.76	13.77	45.03	26.18	49.05	43.09	0.60	0.05	10.85
	Bt2	4.60	3.60	4.39	5.58	0.15	0.00	15.44	14.74	40.70	24.42	52.90	41.43	0.54	0.03	9.68
Pedon-7	AP	5.11	4.05	9.10	5.32	0.34	0.13	11.07	0.00	100.00	27.90	22.59	53.42	3.23	0.30	11.83
	AB	4.64	3.68	6.60	4.93	0.34	0.11	12.40	3.41	77.84	25.84	22.18	46.40	1.89	0.12	10.38
	Bt	4.58	3.62	6.23	4.68	0.95	0.12	13.65	6.02	66.54	23.21	20.84	51.58	1.66	0.10	9.23
	Bt1	4.71	3.76	5.98	5.00	0.62	0.09	7.57	3.72	75.87	20.79	26.43	56.23	0.74	0.05	6.80
	Bt2	4.68	3.74	12.22	5.02	0.23	0.02	6.49	2.53	87.36	26.15	39.94	66.87	0.48	0.03	6.94
Pedon-8	AP	4.93	3.96	6.00	3.59	0.28	0.07	7.62	7.29	57.68	22.22	17.76	44.70	3.32	0.27	11.57
	AB	4.87	3.83	6.01	2.75	0.37	0.07	7.70	7.22	56.03	21.85	21.05	42.12	2.50	0.20	10.40
	Bt	4.84	3.74	5.67	1.95	0.23	0.07	9.88	6.65	54.38	21.46	21.47	36.92	1.60	0.22	8.73
	Bt1	4.74	3.75	5.61	1.24	0.27	0.09	7.32	5.33	57.51	20.81	20.53	34.65	0.92	0.10	8.34
	Bt2	4.65	3.74	5.62	2.24	0.23	0.02	8.08	3.56	69.51	19.32	22.07	42.02	0.26	0.03	5.03
Pedon-9	Ah	4.95	3.86	8.04	5.67	0.24	0.14	5.53	1.61	89.73	19.19	22.91	73.42	3.97	0.32	10.92
	AB	4.90	3.82	6.92	5.47	0.23	0.11	4.45	2.69	82.57	20.18	18.43	63.09	3.89	0.31	9.92
	Bt	4.88	3.85	6.09	4.78	0.15	0.11	5.20	4.63	70.65	19.08	22.24	58.39	2.17	0.21	8.43
	Bt1	4.84	3.83	6.09	4.67	0.16	0.07	9.74	5.89	65.09	22.17	19.66	49.56	1.93	0.14	7.83
	Bt2	4.10	3.20	5.86	4.31	0.57	0.05	7.57	6.21	63.48	21.74	26.76	49.63	0.76	0.10	7.80

Pedons	Horizon	$pH-H_2O$	pH-KCl	Exchangeable Base				Ex.Ac	Ex .Al	EBS	CEC-Soil	CEC clay	PBS	%OC	%TN	Av.P (mg/kg)
				ca	Mg	K	Na									
Pedon-1	Ah	5.09	4.02	15.80	5.05	0.61	0.09	4.71	2.78	88.56	31.65	41.65	68.11	3.89	0.36	5.13
	AB	5.01	3.99	13.64	4.69	0.08	0.09	6.84	5.29	77.75	28.36	35.48	65.21	2.91	0.28	4.51
	Bt	4.95	3.93	8.71	4.46	0.52	0.02	9.12	5.42	71.66	23.61	28.35	58.08	1.37	0.15	3.94
	Bt1	4.96	3.90	6.88	5.04	0.58	0.02	11.08	4.47	73.70	24.89	27.23	50.35	1.04	0.11	3.92
	Bt2	4.91	3.86	5.90	3.55	0.16	0.00	12.37	4.77	66.84	21.31	21.66	45.11	0.94	0.09	3.96
	Bt3	4.88	3.81	4.32	2.97	0.15	0.00	12.47	6.60	52.99	19.76	24.24	37.63	0.14	0.02	3.32
Pedon-2	AP	4.89	3.86	14.67	5.45	0.31	0.07	6.31	3.58	85.14	30.45	61.67	67.34	2.66	0.27	9.45
	AB	4.85	3.78	18.83	5.46	0.16	0.05	8.44	3.39	87.84	36.77	46.92	66.61	2.07	0.15	4.85
	Bt	4.76	3.73	9.78	5.20	0.61	0.09	6.52	4.68	77.01	24.05	32.48	65.21	1.55	0.10	2.13
	Bt1	4.74	3.75	6.48	5.53	0.26	0.05	5.45	4.04	75.30	20.13	26.96	61.14	1.29	0.09	2.10
	Bt2	4.70	3.68	4.63	5.62	0.18	0.05	9.97	5.57	65.30	20.41	29.21	51.36	0.18	0.01	1.81
Pedon-3	AP	4.97	3.90	16.58	5.21	0.15	0.12	9.58	3.53	86.20	36.78	50.89	59.96	2.78	0.27	7.82
	AB	4.90	3.75	15.89	6.13	0.13	0.12	8.50	5.43	80.40	33.10	51.10	67.30	1.24	0.15	6.07
	Bt	4.71	3.78	10.15	6.39	0.21	0.07	8.66	9.32	64.34	27.59	38.64	60.97	1.23	0.12	5.79
	Bt1	4.52	3.51	7.77	5.88	0.06	0.03	10.81	9.40	59.36	23.73	32.91	57.89	0.64	0.06	5.03
	Bt2	4.58	3.47	8.69	6.37	0.16	0.07	11.56	8.44	64.43	26.22	33.48	58.30	0.58	0.03	4.59
	Bt3	4.67	3.63	9.03	5.92	0.03	0.05	12.65	7.99	65.29	26.03	32.63	57.77	0.32	0.02	3.91
Pedon-4	AP	4.68	3.68	5.55	5.28	0.15	0.02	9.67	5.75	65.67	24.93	18.01	44.13	4.35	0.30	11.64
	AB	4.64	3.61	4.22	4.18	0.21	0.05	13.74	10.36	45.55	21.51	24.74	40.29	1.80	0.17	8.07

	Bt	4.65	3.70	3.41	3.52	0.27	0.02	17.84	17.09	29.70	21.32	22.57	33.86	1.13	0.11	7.76
	Bt1	4.58	3.41	3.49	3.58	0.45	0.09	21.87	20.96	26.64	22.70	25.87	33.53	0.38	0.03	6.57

Pedons ID	Horizon	pH-H_2O	pH-KCl	Exchangeable Base				Ex.A	EX.Al	EBS	CEC-Soil	CEC-Clay	PBS	%OC	%TN	Av.P (mg/kg)
				Ca	Mg	K	Na									
Pedon-10	AP	4.98	3.96	5.87	4.59	0.36	0.11	8.42	4.28	71.87	23.14	40.15	47.26	1.36	0.11	9.01
	AB	4.93	3.86	5.72	4.86	0.35	0.09	12.19	7.34	60.02	23.08	43.88	47.75	0.70	0.07	7.67
	Bt	4.81	3.79	7.48	4.16	0.46	0.07	12.09	7.20	62.82	23.36	28.31	52.07	0.66	0.07	7.40
	Bt1	4.72	3.83	5.73	3.99	0.36	0.05	19.46	18.20	35.73	25.78	26.13	39.26	0.64	0.05	7.14
	Bt2	4.63	3.70	5.57	4.47	0.42	0.04	23.09	21.97	32.33	27.59	33.54	38.05	0.58	0.03	5.49
	Bt3	4.60	3.65	5.79	4.27	0.33	0.00	24.35	10.33	50.15	26.55	28.21	39.14	0.36	0.02	3.90
Pedon-11	AP	4.73	3.82	9.63	4.26	0.50	0.11	7.72	2.21	86.79	24.03	30.84	60.33	2.70	0.29	14.92
	AB	4.79	3.90	11.24	4.30	0.34	0.11	8.02	5.32	75.03	26.93	40.16	59.39	1.35	0.15	10.55
	Bt	4.69	3.70	6.70	4.44	0.33	0.00	10.24	6.21	64.86	22.69	28.13	50.55	1.15	0.09	6.51
	Bt1	4.67	3.70	6.32	4.62	0.30	0.02	11.34	8.52	56.92	23.92	27.20	47.09	0.90	0.06	5.63
	Bt2	4.96	3.96	9.89	5.28	0.54	0.04	12.43	11.02	58.85	28.32	33.21	55.64	0.28	0.03	9.49
Pedon-12	Ah	4.76	3.85	5.37	5.12	0.53	0.13	6.46	2.06	84.38	19.18	23.95	58.12	1.95	0.21	12.44
	AB	4.95	4.05	5.14	4.94	0.42	0.07	7.15	2.48	80.97	19.17	28.26	55.15	1.25	0.15	12.16
	Bt	4.74	3.94	5.22	5.00	0.36	0.02	6.42	2.07	83.68	19.84	25.58	53.44	1.07	0.11	11.25

	Bt1	4.82	3.78	5.23	5.00	0.51	0.02	7.34	0.00	100.00	19.88	24.55	54.14	0.94	0.10	5.59
	Bt2	4.81	3.97	5.04	4.84	0.21	0.09	7.11	0.00	100.00	19.34	24.21	52.64	0.86	0.09	5.60
	Bt3	4.68	3.68	4.83	4.67	0.36	0.07	7.70	3.46	74.15	18.01	27.90	55.12	0.58	0.07	4.42
Pedon-13	AP	4.85	3.75	4.82	4.67	0.21	0.04	7.12	3.48	73.69	19.31	25.46	50.45	2.16	0.21	12.45
	AB	4.85	3.78	5.63	5.34	0.45	0.02	7.58	0.00	100.00	19.47	20.87	58.76	1.97	0.22	8.26
	Bt	4.78	3.73	5.97	5.62	0.29	0.02	7.51	0.00	100.00	21.21	25.77	56.11	1.55	0.15	7.40
	Bt1	4.91	3.84	4.34	4.28	0.22	0.02	12.06	5.28	62.68	19.00	21.10	46.64	1.49	0.15	6.79
	Bt2	4.98	4.08	5.41	5.15	0.32	0.00	12.08	5.54	66.28	20.80	21.89	52.34	0.60	0.05	6.50

Soils Classification

The studied soils wereclassified according to world Reference Base for soil resource (IUSS Working Group WRB, 2015) system of soil classification. Among thirteen pedons nine pedons meets Diagnostic criteria of Mollichorizon, while the remaining four pedons had criteria that meet Diagnostic criteria of Umbric horizon according to(WRB, 2014). Seven pedons the studies area had subsurface horizons that qualifying for Argic subsurface diagnostic horizons while the other six pedons qualifying for Nitic diagnostic horizons.

Table Soil classifications of according WRB classification systems.

Pedon ID	WRB system of soil classification
BB/B/DP_1	Hypereutric Mollic Rodic Nitisols(humic).
BB/B/DP_2	Rodic Albic Endostagnic Luvisol(humic, Hypereutric).
BB/B/DP_3	Hypereutric Rodic nitisols(humic,Hypermagnesic).
BB/B/DP_4	RhodicAcrisols (Epieutric, humic, Magnesic).
BB/B/GP_1	EndoSkeletic Albic Rodic Luvisol(humic, Hypereutric).
BB/B/GP_2	Albic Alisols(Epieutric,Humic,Hyperalic and Magnesic).
BB/B/GP_3	Hypereutric Rodic Nitisols (Endostagnic, humic).
BB/B/YP_1	HypereutricUmbricRodicNitisols (Clayic,Humic).
BB/B/YP_2	RodicLixisols (Clayic ,Humic, Hypereutric).
BB/B/YP_3	RodicAlisols(Epieutric,Humic, Hyperalic).
BB/B/HP_1	Eutric Mollic Rodic Nitisols (Clayic, humic).
BB/B/HP_2	Rodic EndoAlbicEndostagnic Luvisol (Humic, HypereutricMagnesic)
BB/B/HP_3	Hypereutric Mollic Rodic Nitisols(humic).

Conclusions and Recommendations

The soils were thoroughly examined and distinguished based on observable site and soil characteristics including slope, soil depth, and texture following free survey method. Thirteen representative profiles were opened and described across four kebeles of the study area.

The color of surface horizons varied from very dark brown (7.5YR 2.5/2) to reddish brown (2.5YR 4/4) whereas the color of the subsurface horizons varied from brown (7.5YR 4/4) to dark reddish brown (2.5Y 2.5/3). The bulk density values ranged 0.9 to 1.286gcm^{-3}. Clay fractions ranged from 34.28 to 76.28%. The results pH(H_2O)ranged from 4.10 to 5.15. The pH(KCl) results ranged 3.2 to 4.25.OC contents values ranged for surface from 1.361 to 4.345% and for the subsurface from 0.137 to 0.802%. Available Phosphorus value ranged from 1.81 to 14.92 mg kg-1 the lowest value and the highest, respectively. Soils total nitrogen content was varied from 0.0167 to 0.357% and cation exchange capacity of the soils ranged from 18.01 to 46.80 cmolckg^{-1}.

The values of CEC clay varied from 22.57 to 77.85 cmolckg^{-1}. The contents of Ca and Mg varied from 3.41 to 21.027 and 1.23 to 6.77 cmol (+) kg-1, respectively, whereas exchangeable K and Na varied from 0.0304 to 1.11 and 0 to 0.137cmol (+) kg-1. The percent base saturation of the soil ranged from 33.3 to 74.44 % across the all sites. Exchangeable Al contents ranged from 0 to 21.97 cmol (+) kg-1.

Among thirteen pedons nine pedons meet Diagnostic criteria of Mollic horizon, while the remaining four pedons had criteria that meet Diagnostic criteria of Umbric horizon. Seven pedons the studies area qualifying for Argic subsurface diagnostic horizon, while the other six pedons qualifying for Nitic diagnostic horizons. Based on the results of morphological, physical and chemical properties of the soils of study area five reference soils groups Nitisols, Acrisoils, Alisols,Luvisols and Lixisols were identified according to WRB.

Almost total land of study area found at midland and highland was dominated with acids soils of Nitisols, Acrisoils and Alisols soils reference groups. The severity of soil acidity for study area ranged from strongly to moderately acidic with a pH of <5.5 which had a significant impact on crop productivity that resulted may be from Al toxicity and low soil availability of P. Most of the study area highlands are characterized by heavy rainfall and prone to soil acidity due to removal of ample amount of exchangeable heavy cations through leaching, crop mining and runoff. Generally, using the soils according to their potential and suitability was important for sustainable agricultural production. Therefore, Special emphasis should also be given to integrated soil fertility management practices such integrated applications of lime with organic and inorganic fertilizers and using of optimum rates of fertilizers applications, using acid tolerant species and crops rotations to improve the fertility level of the soils for better crop production and productivity in the study area. Additionally physical land suitability evaluations in the area to optimize and sustain crop productions are important.

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Evaluation of Lime Requirement Determination Methods for Acid Soils of Bedele District of Buno Bedele Zone, South Western Oromia, Ethiopia

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Abstract

The study was conducted to evaluate lime requirement Determination methods for acid soils in Bedele district, South Western Oromia, Ethiopia. Study was executed in four site of the district in which the severity of soil acidity is high relatively to others and 12 representative composite soils samples were collected from the district. The efficiency of two buffer methods Shoemaker, McLean, and Pratt (SMP) and original Mehlich) was evaluated for estimating the amount of lime requirement to achieve targeted pH (H_2O) 6.5. The value of lime estimated by 60-day incubation to achieve targeted pH(H_2O) 6.5 had positive relationship with buffering capacity of soils, exchangeable Al, exchangeable acidity, clay and organic matter (R^2=0.97 ,0.68, 0.55, 0.43, 0.35) and negative relationship with pH(H_2O), pH(KCl), percent base saturation, exchangeable Base, exchangeable Ca^{+2} Mg^{+2} and exchangeable Ca^{+2} (R^2=0.80, 0.70, 0.66, 0.36 0.36,and ,0.34) the results suggested that the lime requirement to targeted of 6.5 pH value influenced by soil properties both positively and negatively. Original Mehlich appears to be the most precise for estimating LR with low standard error of estimate (SE=0.28and 0.44) and high coefficient determination (R^2=97 and 93) followed by SMP buffer. The Mehlich buffer was advantages over SMP buffer with less adverse sound effects on pH meter electrodes, safe from hazardous chemical, simple and accurate for routine laboratory practice to estimate lime requirements of acid soils in Bedele area.

Keywords: *Incubation, Mehlich buffer, McLean, and Pratt (SMP), exchangeable Acidity and lime requirement.*

Introduction

Soil acidity is among the main land degradation problem worldwide that estimated over 11 million ha of land is exposed to soil acidity particularly tropical and sub-tropical regions of the world (Eswaran et.al., 1997). Worldwide, about 32% of all arable land is acid which figure claims to be 50% in tropics because of in this region high rainfall and temperature that lead high rate of weathering, leaching of basic cation from soils and hydrolysis of secondary high-activity clay minerals such as vermiculite and smectite that releases much aluminum (Eswaran*et.al.*, 1997 and Mesfin, 2007). Most of these acidic soils are found in tropical and subtropical African countries such as Tanzania, Kenya, Uganda, Ethiopia, etc. In Ethiopia 43% of the total arable land is acidic (Behailu, 2015).

Soil acidity is one among the main soil chemical constraints which limit agricultural productivity with in the mid and highlands of Ethiopia particularly within the western highland of Ethiopia where excessive rainfall together with practices that remove appreciable amounts of exchangeable basic cations from surface of soil (Chimdi, 2012). In order to secure sustainable crop production and reasonable yield, acidic soils need to be corrected by addition of agricultural lime to a pH range which is suitable for better yield of crop productions (Mesfin, 2007Godsey*et.al.* 2007and Chimdi, 2012).

The lime requirement varies depending upon soil characteristics such as soil texture, cation exchange capacity (CEC), specified change in pH, buffering capacity of the particular soil and organic matter content that are the main variables in determining lime requirement (Godsey *et.al.*, 2007). Lime was vital and commonly used acid soil management practices in western and southwestern a part of oromia regional state, particularly Bedele area where soil acidity was critical constraint of agricultural productivity. However managing acid soils by lime: rapidity, accuracy, simplicity and environmental compatibility of waste generated by method that predict lime requirement for acid soil management practices are prerequisite. Therefore, activity was initiated with objectives of to evaluate the precision of SMP buffer, original Mehlich buffer (Mehlich, 1976) and exchangeable Acidity Kamprath (1984) lime requirement methods for predicting lime required to specific target pH values for Bedele area soils.

Materials ad Methods

Description of the Study Area

The study was conducted in Bedele district, Buno Bedele zone, Oromia Regional State, South Western Ethiopia. Geographically, located between 8^0 150’- $8^0$350’N and 36^0 15’-36^0 35’E as shown below on Fig. 1.

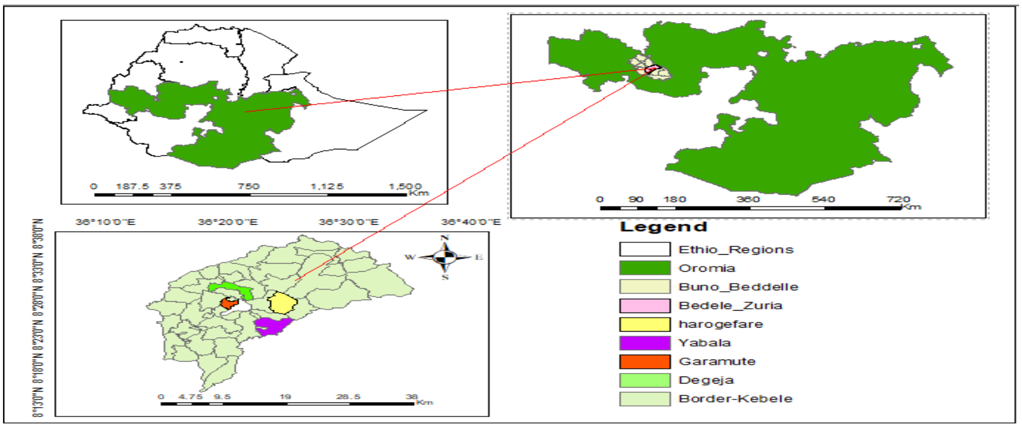


Figure 6; Map of study area

Climate: Agro ecologically, the district is divided into three ecological zones namely highland (0.06%), mid-altitude (81.34%) and low-land (18.6%). Altitude in the district ranges from 1300 to 2000m a.s.l. The study area had average annual rain fall of 1867.04mm with 12.63^{o}C and 26.45^{o}C minimum and maximum annual temperatures respectively (un published data from Bedele meteorological substation, 2021).

Sites selections

The study was conducted at mid and high altitude ecological zones of the district in which soils acidity were critical problem. 12 composite soils samples was collected from four site of the district (Giramute, Degaja, Yeballa and Haro Gefere) in which the severity of soil acidity is high relatively to others based on previous soil acidity result of the site that conducted by Bedele agricultural research center for soil fertility maps of the district.

Laboratory analysis

Soil texture was determined using the bouyoucos hydrometer method (Day, 1965). Bulk density (BD) was determined from the weight of undisturbed (core) soil samples dried in an oven at 105 ^{o}C (Baruah and Barthakur, 1997). The average soil particle density (PD) (2.65 gcm^{-3}) was used for estimating total porosity. Soil textural classes were read from the textural triangle (WRB, 2014). The pH of the soils was measured using a pH meter in 1:2.5 ratio of soil to liquid suspension. The liquids used were distilled water pH (H_2O) and 1M KCl[pH(KCl)] according to the procedure outlined by van Reeuwijk (2002).. Organic carbon was determined using the wet oxidation method (Walkley and Black, 1934). Total N was determined by the micro-Kjeldahl method and exchangeable bases (Ca^{+2}, Mg^{+2}, K^{+}, and Na^{+}) in the soil were extracted with 1 M ammonium acetate (NH4OAc) solution at pH 7.0 van Reeuwijk (2002).Total exchangeable acidity was determined by saturating the soil samples with 1 M KCl solution and was titrated with 0.02 M NaOH as described by Rowell (1994). From the same extract, exchangeable Al^{+3} in the soil samples was determined by application of 1 M NaF, which forms a complex with Al3+ and releases NaOH and then NaOH was back titrated with a standard solution of 0.02 M HCl (Sahlemedhin and Taye, 2000), available soils phosphorus were determined According to Bray II (Bray and Kurtz. 1945)

Lime Requirement Determinations

Incubations experiments

Tran & van lierop,(1982) suggested that it's possible to use two month incubations as reference methods as they identified that pH of soils stabilized within two months because the soil pH values measured after the 2nd and 3rd month of incubation were practically identical. Similarly Aitken *et al.,* (1990) used 6 weeks soil-$CaC0_3$-moist incubations in order to determine pH buffer capacity of eastern Queens land soil and Abay *etal.,* (2020) also reported pH change was completed in five weeks for Ethiopian soils.

For this experiment twelve composite soils sample from depth of 20cm was collected for lime requirement determinations methods evaluations purpose. All soils sample had soil pH values less than 5.5 (pH_2O) and incubated for two month at Bedele soils laboratory in isolated room with six reagent grade of $CaCO_3$ rates including control (0 25%, 50%, 100%, 150% and 200% recommended lime amounts per hectares for each soils by based on exchangeable acidity method currently used by Bedele soil laboratory to recommend lime requirement for acid soils to achieve targeted pH (H_2O) at 5.5) in three replications. After Two months the amount of lime required to achieve targeted pH (H_2O) of 5.5 and 6.5 for each soil were determined from the graph plotted between pH versus $CaC0_3$ doses as the amount of $CaC0_3$required to raise pH-H_2O of the soil to 6.5 at 1:2.5 soils to liquid ratio in distilled water by taking the inverse slopes of the regression equations used to construct the lime-response curves (Mclean *etal.,* 1966).

For laboratory incubation the predicted $CaCO_3$ was weighed and added to a plastic cups volume of 250ml with 100g of air-dried soils. The cups were rolled on the top of table for 5 minutes to ensure homogeneity between the $CaCO_3$ and soils. After mixing the soils and lime the mixture were sealed with plastic lids and cotton wool was plugged in a 5mm hole to ensure gas exchange. During the 60 days incubation period the soils were placed in an isolated room with a mean daily temperature of 21-26^{o}C during March 22, 2020 - May 21, 2020. The soils moisture was kept approximately at 80% field capacity (FC) value that obtained estimated by the equation developed for determine soils field capacity from soils texture (Mohammad, 2013) which is about 38% volume of soil by reweighing the sample each week. Soils bulk density was used to convert mass of soils to volume basis. Thus the soils of the studies wetted weekly with distil water of 14ml which equal to 80% of field capacity (FC) to avoid a reducing environment. Soils air dried after 60 days and grinded to pass 2mm sieve then pH was measured using a 1:2.5 soil to water ratio using a standard glass electrode. Lime-response curves was constructed by results obtained from the incubation procedure by plotting the soils pH change due to the addition of liming material to 100g of soil.

Soils buffer experiments

The Soil pH measurements were made in 1:2 soils to distill water ratio for buffer preparation with three replicates in order to reduce error. The buffer of SMP buffer (Shoemaker *etal.,* 1961) improved by Lierop(1990) and original Mehlich buffer of (Mhelich,1976) were separately prepared following their own standard procedures. For original Mehlich buffer of (Mhelich, 1976)Ten ml of each buffer was added in prepared pH water (1:1:1 soil/water/buffer) ratio whereas (1:1:2 soil/water/buffer) ratio SMP buffer (Shoemaker *et al.*,1961) improved by Lierop(1990).In additions to this two buffers methods lime requirement methods by Exchangeable Acidity method (Kamprath, 1984) in which the amount of Lime requirement $CaCO_3$ (Kg/ha) to neutralize acidity at the depth of 20cm which currently used by Bedele agricultural research center and other soil testing laboratory for estimations of field lime requirement based on assumptions of all soils have equal bulk density of 1.5gcm^{-3} were evaluated for the soils of study area. For this study Bulk density of 1.5gcm^{-3} value was used instead of actual bulk density of each soil in order to evaluate Acidity method (Kamprath, 1984) lime requirement currently used by Bedele agricultural research center.

For buffer method the amount of lime requirement were estimated from a published Mehlich equations(Mehlich,1984)as outlined in (Sikora and Moore, 2014)were as SMP Buffers was obtained by relating buffer pH to the target pH of 6.5 after the buffer pH is determined using Table published on (Lierop,1990).

Data analysis

Linear regression was employed to analyze the relationship between lime requirement determined by reference method and Buffers methods using stata statistical software. Statistics/Data Analysis 15.0 StataCorpLLC(1985-2017)

Results and Discussions

Lime Requirement Determined by 60 Days Incubation Method to neutralize acidity of the Soils to the Targeted pH

For purpose of this studies twelve composite samples of acid soils were collected from the studies area to the depth of 0-20cm. Soils were incubated for two month with six incrementally levels of $CaCO_3$ (0.0-16 Mg ha^{-1}). The soils incubated during March 22, 2020 - May 21,200 in Bedele laboratory isolated room. Theirs decline in soil pH value in all control samples which may be associated with substantial amount of nitrification that occurred during incubation. Hoskins and Erich (2008) also suggested that many biological and chemical processes, independent of lime application, can affect pH and exchangeable acidity during incubation.

The linear regressions analysis of pH response of soil to treatments with incrementally increasing levels was linear with coefficient of determination value ranged from 0.938 to 0.99. From the results of the linear regressions analysis of pH response of soil to treatments with incrementally increasing levels of $CaCO_3$ slopes of the regression equations ranged from 0.138 to 0.204 pH units per 1Mgha^{-1} $CaCO_3$ rate addition, these results suggest that their differences in soil buffering capacity among the soils of studies area Table: 1.

The amount of LR in Mg of $CaCO_3$ ha^{-1} to achieve targeted pH (water) for the soils of Bedele soils that derived from linear regressions analysis of pH response of soil to treatments with incrementally levels of $CaCO_3$ equations ranged from 3.45 to 6.242 and 7.555 to 13.42Mg of $CaCO_3$ ha$_{-1}$, to obtain a target pH of 5.5 and 6.5 pH water respectively Table: 1. The soil with low slope had the highest buffering capacity among the studied soils when compared with soils with high regression slope.

Table 12: Linear regressions of pH response of soil to lime applied

Soil no	*Lr at pH5.5*	*Lr at pH 6.5*	*Bc*	*Equations*	R^2	*R*	*Se*
1	4.033	8.332	4.299	0.2326x+4.5622	0.968	0.984	0.025
2	4.067	8.469	4.403	0.2271x+4.5763	0.936	0.967	0.034
3	4.727	9.935	5.208	0.192x+4.5922	0.990	0.995	0.009
4	4.303	9.696	5.394	0.1854x+4.702	0.982	0.991	0.014
5	6.164	13.427	7.262	0.1377x+4.6512	0.977	0.989	0.010
6	4.121	8.636	4.515	0.2215x+4.5871	0.959	0.980	0.026
7	4.628	10.070	5.444	0.1837x+4.6497	0.991	0.996	0.009
8	3.405	7.555	4.149	0.241x+4.4697	0.990	0.990	0.016
9	5.402	10.807	5.405	0.1850x+4.501	0.939	0.969	0.024
10	4.436	9.429	4.993	0.20027x+4.612	0.973	0.986	0.019
11	4.794	9.983	5.189	0.1927x+4.5760	0.987	0.993	0.011
12	6.242	12.846	6.605	0.1514x+4.555	0.989	0.994	0.008

Note LR=lime requirement $Mgha^{-1}$ BC= buffering capacity SE=standard error of estimate

Soil characteristics and their Relationships with the Amount of Estimated lime By Reference Method

For evaluations purpose twelve composite samples of acid soils was collected from the studies area to the depth of 0-20cm. Soils texture analyzed were a ranged from Clay loam to clay textural class with clay ranging from 38.28 to 51.28%. Soil pH values pH(H_2O) of 4.42-4.8 or pH(KCl) ranged from 3.39 to 3.97, exchangeable acidity 2.84 to 5.18 cmolc kg^{-1}, exchangeable Aluminum 1.39 to 3.83 cmolc kg-1, CEC ranged from 22.89 to 36.76 cmolc kg^{-1}, percent of base saturations ranged from 32 to 73% and OM ranged from 2.22 to 4.49% as it indicated in with other soils chemicals properties.

The value of lime estimated by 60-day incubation to achieve targeted pH(H_2O) 6.5 had positive relationship with buffering capacity of soils, exchangeable Al, exchangeable acidity, clay and organic matter (R^2=0.97 ,0.68, 0.55, 0.43, 0.35) and negative relationship with pH-H_2O, pH(KCl), percent of base saturation, Exchangeable Base, exchangeable Ca^{+2} Mg^{+2} and exchangeable Ca^{+2} (R^2=0.80, 0.70, 0.66, 0.36 0.36,and ,0.34) however CEC of the soils had positive relationships but statistically not significant. The results suggested that the lime requirement to achieve targeted of 6.5 pH value influenced by soil properties both positively and negatively. In order to compare the interactions between soils properties and the amount of lime required to achieve targeted pH value correlation analysis was used. Correlations results of some soil properties with the amount of lime requirement estimated by 60 days soils-lime incubations were indicated in Table: 2. in these studies Soils properties correlated both negatively and positively with the amount of lime estimated by 60 days soils-lime incubations to achieve targeted pH water 6.5.

Significant correlation relations was obtained between percent of clay ,organic matter contents ,percent of acid saturations ,Al saturations, exchangeable acidity, exchangeable Al and Soils buffering capacity with incubations LR method (r=0.65,0.588, 0.78, 0.83, 0.74, 0.82 and 0.98 at P-value <0.05) respectively. Similar to the current finding was reported for eastern Botswana and acid soils of Palouse region (Machacha, 2011 and Mcfarland et al., 2020). However, clay contents had high relationships than OM with the amount of lime determined by 60 days soils-lime incubations to achieve targeted pH(H_2O) 6.5 due to high coefficient of determinations than organic matter (R^2 =0.43 and 0.35 respectively for clay and OM). Soil properties such as pH(H_2O), pH(KCl),Total Exchangeable Base, exchangeable Ca^{+2} and exchangeable Ca^{+2} + Mg^{+2}, percent of base saturation, ECEC were negatively significant and correlated with LR estimated reference method(r=-0.90, -0.84, -0.60 ,-0.58,-0.60,-0.79 and -0.50 at P-value < 0.05) respectively. However Mg^{+2} and ECEC were negatively correlated with lime requirement with reference but not significant.

Similar finding was reported from the research conducted on acids soils of eastern Botswana and acid soils of the Palouse region as soils buffering capacity significantly correlated with the amount of lime determined by reference method by (Machacha, 2011, Mcfarland et al., 2020). However, current finding was in contradicting with result on soils of eastern Botswana that indicated poor correlation between initial soil pH and amount lime estimated by soils-lime incubated for two month (Machacha, 2011). The results suggested that exchangeable aluminum is the principal component of exchangeable acidity in soils of low base saturation. Strong correlations with was organic matter also obtained that might be due to the dissociation of the hydroxyl and carboxyl groups that produce H^+ which influences the amount lime required to neutralize acidity. The results suggest that the amount of lime requirement to achieve targeted pH was highly influenced by Soils buffering capacity might be due to dependence of lime requirement on the soil pH buffer capacity and the initial pH. Generally among the soil properties percent of clay, organic matter contents, exchangeable acidity and exchangeable Aluminum ,CEC and buffering capacity of the soils positively influence the amount of lime required to neutralize soil acidity whereas soil properties like initial Soils pH(Both H_2O and KCl), percentage base saturation, ECEC and exchangeable base were influence negatively.

Table 13: Correlations results some Soils properties and lime requirement Estimated by 60 days Incubations

	60 day incub LR at	pHH2O	pH KCl	%OM	Ex.acidity	Exc.Al	Ca	Mg	K	Na	Ca+Mg	TEB	cid saturat	AL saturat	ECEC	CEC-Soil	ase Saturat	% Clay	%Silt	%Sand	ering capa
60 day in	1.00																				
pHH2O	-0.90	1.00																			
pH KCl	-0.84	0.86	1.00																		
%OM	0.59	-0.48	-0.56	1.00																	
Ex.acidity	0.74	-0.79	-0.86	0.54	1.00																
Exc.Al	0.82	-0.74	-0.68	0.64	0.77	1.00															
Ca	-0.58	0.59	0.32	-0.53	-0.52	-0.63	1.00														
Mg	-0.49	0.43	0.43	-0.13	-0.45	-0.30	0.59	1.00													
K	-0.07	-0.08	-0.05	-0.52	-0.06	-0.06	0.28	0.04	1.00												
Na	-0.10	0.03	-0.01	0.35	0.08	0.16	-0.08	0.43	-0.26	1.00											
Ca+Mg	-0.60	0.59	0.37	-0.49	-0.54	-0.61	0.99	0.71	0.25	0.01	1.00										
TEB	-0.60	0.59	0.36	-0.50	-0.54	-0.60	0.99	0.71	0.29	0.00	1.00	1.00									
%Acid sa	0.79	-0.81	-0.68	0.54	0.82	0.76	-0.88	-0.73	-0.16	-0.09	-0.91	-0.91	1.00								
%AL satu	0.83	-0.75	-0.59	0.61	0.69	0.91	-0.86	-0.56	-0.15	0.02	-0.86	-0.86	0.90	1.00							
ECEC	-0.49	0.47	0.20	-0.43	-0.37	-0.49	0.97	0.68	0.31	0.02	0.98	0.98	-0.82	-0.79	1.00						
CEC-Soil	0.51	-0.49	-0.56	0.22	0.42	0.62	0.08	0.16	0.55	0.04	0.10	0.12	0.15	0.34	0.23	1.00					
%Base Sa	-0.81	0.82	0.63	-0.53	-0.73	-0.83	0.88	0.61	-0.03	0.04	0.89	0.88	-0.94	-0.95	0.80	-0.36	1.00				
% Clay	0.65	-0.65	-0.45	0.45	0.29	0.65	-0.46	-0.18	-0.16	0.09	-0.44	-0.44	0.47	0.69	-0.42	0.34	-0.54	1.00			
%Silt	0.21	-0.10	-0.17	0.02	0.46	0.17	-0.35	-0.50	-0.31	-0.28	-0.40	-0.41	0.48	0.27	-0.35	-0.33	-0.24	-0.21	1.00		
%Sand	-0.65	0.55	0.47	-0.33	-0.60	-0.61	0.63	0.57	0.38	0.17	0.66	0.67	-0.76	-0.73	0.60	0.04	0.60	-0.54	-0.71	1.00	
Buffering	0.98	-0.88	-0.82	0.63	0.72	0.84	-0.55	-0.43	-0.06	-0.07	-0.56	-0.56	0.75	0.82	-0.45	0.56	-0.79	0.66	0.12	-0.58	1.00

Comparisons Reference method with other lime determination Methods.

Current LR recommendations for acid soils managements to achieve targeted pH 5.5 at pH-H_2O made by all soils laboratory under Oromia agricultural research institute was Exchangeable acidity method in which lime requirement(Mgha^{-1}) were calculated exchangeable acidity *1.5 to achieve targeted pH 5.5 at pH(H_2O). The 60-day incubation was used as standard method to evaluate whether Exchangeable acidity, Mehlich and SMP buffers was accurately predicting the LR of Bedele soils

Table 14: Lime requirements estimated by different Methods as compared to 60 days

Soils	*SMP Buffer*		*Original Mehlich*		*InLR*	*LR EA*	*InLR*
No	BpH	LR 6.5	BpH	LR 6.5	LR 6.5	LR 5.5	LR 5.5
1	5.98	7.5	5.71	7.568	8.3324	4.398	4.033
2	5.96	7.5	5.73	7.388	8.469	4.727	4.067
3	5.76	9.5	5.61	8.435	9.9351	7.123	4.73
4	5.86	8.5	5.62	8.358	9.696	6.836	4.303
5	5.55	11.6	5.22	11.809	13.427	7.774	6.164
6	5.95	7.5	5.7	7.666	8.636	7.371	4.12
7	5.83	9.5	5.58	8.704	10.07	7.153	4.63
8	6.14	6.6	5.79	6.863	7.555	4.259	3.405
9	5.66	10.5	5.56	8.877	10.807	7.733	5.402
10	5.9	8.5	5.63	8.253	9.429	7.076	4.434
11	5.84	9.5	5.6	8.546	9.983	6.267	4.794
12	5.57	11.6	5.24	11.633	12.846	7.695	6.242

BpH=soils-buffer pH, LR= lime requirement (Mgha-1) and EA=exchangeable acidity.

Exchangeable acidity Method at pH(H2O) 5.5: Exchangeable Acidity based lime required methods which currently used by Bedele agricultural research center and other soil testing laboratory for estimations of field LR based on assumptions of all soils have equal bulk density of 1.5gcm^{-3} was evaluated for the soils of study area.

The value of lime required to achieve targeted pH a soil pH of 5.5 (H_2O) for all soils of studies area with the 60-d LR was ranged from 4.033 to 6.24 Mg ha^{-1} whereas the value By Exchangeable acidity method was ranged from 4.259 to 7.774 Mg ha^{-1}. The value of lime required to achieve targeted pH of 5.5(H_2O) by this method were generally overestimated for all soils of studies area Table: 3.

The value of lime overestimated was ranged from 0.365 to 3.249 Mgha^{-1} was observed for this studies area soils. The results indicated that lime recommended based on exchangeable acidity method overestimate lime about 9.1 to78.8% when compared with the value obtained from 60-d incubations LR to achieve targeted pH a soil pH of 5.5 (H_2O).This results indicated that the amount of lime recommended for farmers to achieve targeted pH a soil pH of 5.5 (H_2O) overestimated by this method.

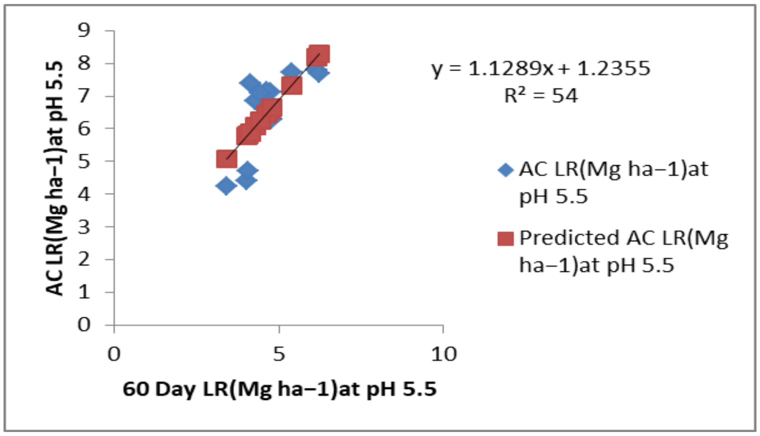


Figure 7: Comparison of LR predicted by exchangeable acidity at pH(H_2O) of 5.5 with 60-day

Table 15: Linear regression analysis when determining the effectiveness of Different Buffers (y) in estimating LR compared with the 60-d LR (x) for 12 soils

Buffers Methods	Target pH	Slope	y intercept	r	R^2	SE
SMP	6.5	0.8737	0.3545	0.96	0.93	0.44
Mehlich 1976	6.5	0.866	0.0733	0.985	0.97	0.28
Ex.Acidity Methods	5.5	1.129	1.24	0.733	0.54	0.94

Note: for all regression p-value significant at < 0.01

SMP Buffer (Shoemaker et al. 1961) at pH 6.5: The linear regression relationship between measured soil–SMP buffer pH and the amount of lime required to achieve targeted pH 6.5 (Mg ha^{-1}) determined from modified table by Lierop(1990)was highly significant (r^2=0.96) with negative correlations coefficient(r=-0.97) and standard error of estimations (0.35).

Comparison of SMP buffer method estimating LR to achieving a soil pH of 6.5 (H_2O) with the 60-d lime requirement was highly significant at p-value less than 0.01 for this studies area soils with positive relationships by having coefficient of correlations(r=0.96), R^2=0.93and standard error of estimate 0.44 as indicated in Figure :5 and Table :4.

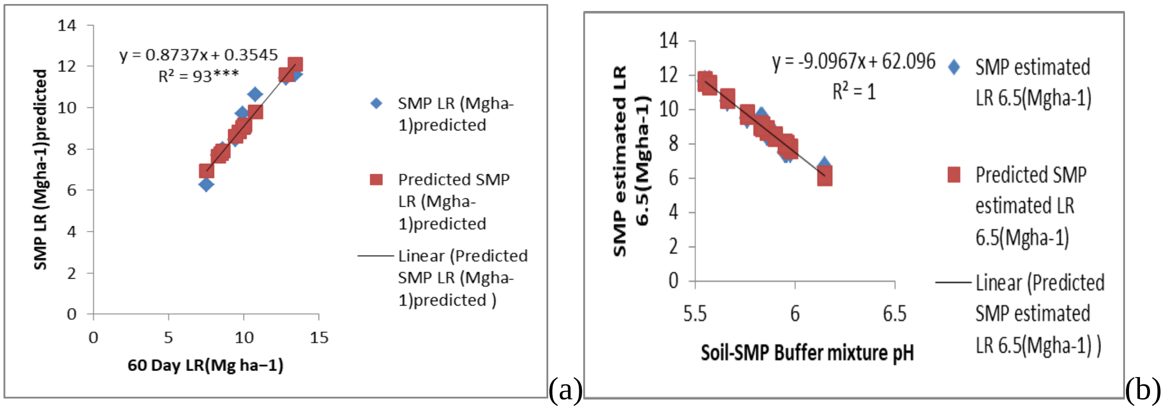


Figure 8: (a) Comparison of LR predicted by SMP with 60-d LR to a target pH of 6.5 and (b) regressions of LR

predicted by SMP Buffer vs. Soil- SMP Buffer mixture pH.

The value of lime required estimated by SMP Buffer was to achieve targeted soil pH of 6.5 (H_2O) for all soils of ranged from 6.6 to 11.6 Mgha^{-1} which underestimated when compared with value estimated by reference method. Underestimated value ranged from 0.31 to 1.8346Mgha^{-1}. SMP buffer generally underestimated about 2.84% to 13.61% of lime recommended by 60 days soils-lime incubation to achieve targeted pH of 6.5(H_2O). The linear regression equation was generated when compared the amount of lime predicted by SMP Buffer with lime value estimated by 60-day $CaCO_3$ incubation. the regression resulted in the linear relationship: Y (LR SMP Buffer) = 0.8737 (LR 60-day $CaCO_3$) + 0.3545, r2 = 0.93***., which indicates that SMP Buffer predicted, on average, 87.4% of the LR estimated by 60-day $CaCO_3$ incubation, which was considered the reference method for determining the lime requirement of acid soils.

Here the y intercept of the relationship was very low with a value of 0.3545, which indicated that the SMP Buffer method relatively overestimate the lime requirements value for soils with low LRs. The slope of the relationship 0.8737was lower than 1, indicating that SMP Buffer method estimates values that were relatively lower than 60-day $CaCO_3$ incubation. The results suggested that SMP buffer were generally underestimated lime requirements for the studies area, as indicated by a y intercept of 0.3545Mgha^{-1} compared with the value estimated by reference method to achieve targeted pH of 6.5(H_2O). Generally y intercepts (0.3545) >0 and slope values (0.8737) <1 indicated that SMP buffer estimate LR at relatively high LR values or overestimate relatively low LR values. The results revealed that SMP buffer underestimate the lime requirement to achieve targeted pH of 6.5(H_2O) when soils LRs were >2.9Mgha^{-1} or overestimate when soils lime requirements were <2.9Mgha^{-1}. Similar to the current finding results of high correlation between LRs predicted by SMP buffer method and soils-lime incubation for acids was reported (Machacha, 2005, Godsey*etal*., 2007, Wolf *et al*., 2008) and Tesfaye*etal.*,2020).

Original Mehlich Buffer (Mehlich 1976) at pH 6.5: The linear regression relationship between soil–original mehlich buffer pH(H_2O) measured and the amount of required to achieve targeted pH 6.5 (Mgha^{-1})that determined from modified Mehlich equation (1984) was highly significant (R^2=0.99) with negative correlations coefficient(r=-0.99) and standard error of estimations (0.037) as indicated on Figure: 7 and Table: 9. The value of lime required estimated to achieve targeted soil pH of 6.5 (H_2O) for all soils of studies area by Original Mehlich Buffer was ranged from 6.86 to 11.81 Mgha^{-1}. The value of underestimate lime required to achieve targeted pH (H_2O) for all soils of studies area was ranged from 0.69

to 1.93Mgha^{-1}. Which predicted averagely about 82.14 to 90.8% or it predicted averagely 87.42%of lime recommended by reference method.

The linear regression equation was generated when compared the amount of lime predicted by OM Buffer with lime value estimated by 60-day CaCO3 incubation. the regression resulted in the linear relationship: LR (O M) = 0.87LR (60-day CaCO3) + 0.0726, r2 = 0.97***, coefficient of correlations r=0.99 and standard error of estimate (0.278) which indicates that OM Buffer predicted, on average, 86.6% estimated by 60-day CaCO3 incubation. Here the y intercept of the relationship was very low with a value of 0.0726, which indicated that the OM Buffer method relatively overestimate the LRs value for soils with low LRs. The slope of the relationship 0.8661 was lower than 1, indicating that OM Buffer method estimates values that were relatively lower than 60-day CaCO3 incubation.

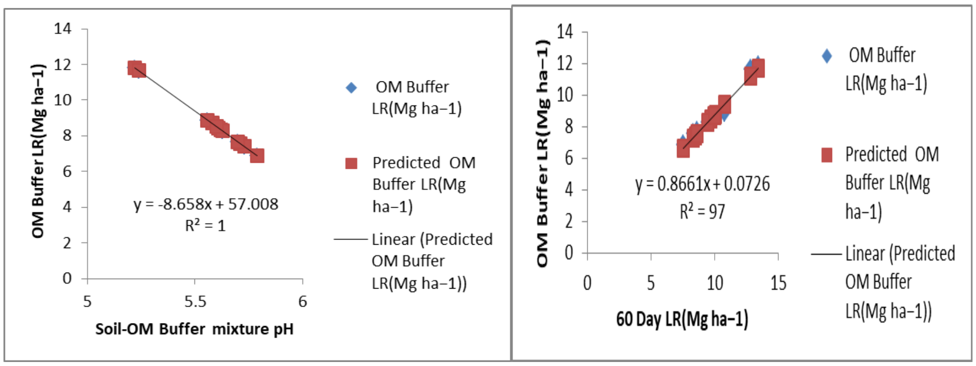


Figure 9: (a) Comparison of LR predicted by OMB with 60-d LR to a target pH of 6.5 and (b) regressions of LR predicted by OMB vs. Soil-OMB mixture pH.

Calibration of the Buffers

The lime rates needed to bring the different soils to target pH values of 6.5 were determined from the lime response equations. The regression equations obtained between the lime application rates and soil pH after two months of incubation was linear as indicated in previous section Table 5. The relationships provide an indication of slightly difference in buffering capacities of the soils studies area. The amount of $CaCO_3$ applied during to incubation resulted relatively above targeted of pH (H_2O) 6.5 of soil pH values after incubation. This indicates that the results obtained from incubation study used to calibrate the buffer solutions successfully.

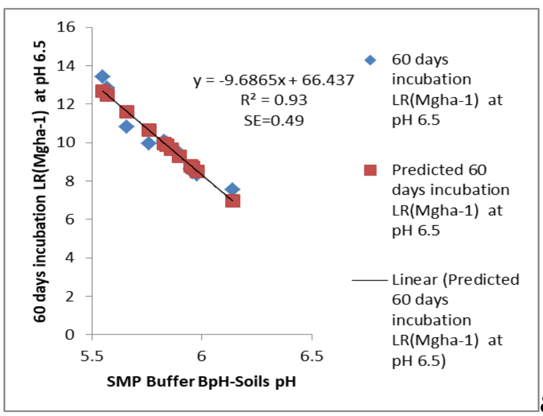
Based on the amount of lime requirements value determined from the incubation to achieve targeted pH of 6.5 for each soils study and corresponding buffer pHs of the soils linear and culvinary regression equations were developed. The Accuracy of the calibrated equations were assessed with comparing LR values from obtained from calibrated equations with LR rate determined from $CaCO_3$ two month incubation Tables 5. Sali and Nuwamanya (1981) and Viswakumar*et al.*, (2010) were used a similar table to verify the accuracy of four buffer methods of LR predictions.

Table 16: Lime requirement $Mgha^{-1}$ of 12 soils for a target pH of 6.5 determined by calibrated linear and culvinary regression equations as compared with the reference method.

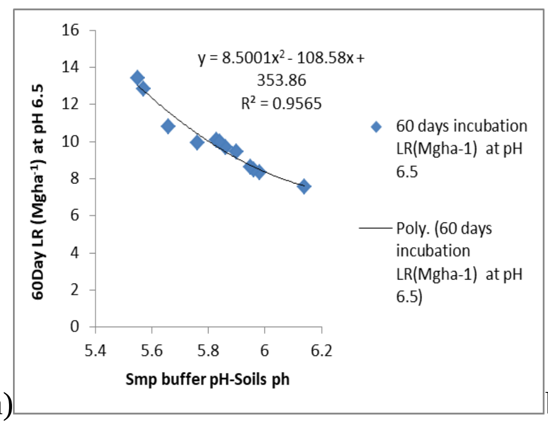
Soils No	Incubation	SMP buffer*	SMP Buffer**	OM Buffer*	OM Buffer**
1	8.33	8.49	8.52	8.70	8.58
2	8.47	8.69	8.66	8.51	8.31
3	9.94	10.63	10.45	9.67	9.85
4	9.70	9.66	9.47	9.57	9.73
5	13.43	12.66	13.06	13.45	13.21
6	8.64	8.78	8.73	8.80	8.71
7	10.07	9.95	9.74	9.96	10.20
8	7.56	6.94	7.63	7.93	7.44
9	10.81	11.59	11.60	10.16	10.42
10	9.43	9.27	9.12	9.48	9.61
11	9.98	9.85	9.65	9.77	9.97
12	12.85	12.47	12.78	13.26	13.10
Mean	9.93	9.92	9.95	9.94	9.93

Note: (*) indicated the value of $CaCO_3$ $Mgha^{-1}$ obtained from leaner regression and (**) from culvinary regression for respective buffer.

The Accuracy SMP buffer in estimating lime requirement is assessed with comparing LR values obtained from calibrated equations with LR rate determined by incubation. In both case this buffer pH values obtained as better predicted the LR as determined by incubation. However, for some soils the LR determined by these methods was slightly greater than the value of determined by incubations maybe due to pH instability during pH measurement.



a)



b)

Figure 10: (a) Linear and (b) culvinary regression SMP buffers-Soil pH and Lime value determined by reference method.

Averagely for the target pHs of 6.5 SMP estimated about 99.9% of the LR value determined by CaCO3 incubation when calculated by the linear regression equation. However the buffer over estimate 0.2% when calculated by culvinary regression equation when compared with the value determined by reference method even though the coefficient of determination increased from 93 to 96 in culvinery regression fig: 5

Similar to the others buffers methods original Mehlich buffer estimated averagely for the target pHs of 6.5 about 100% of the LR value determined by $CaCO_3$ incubation when calculated by culvinery regression equation. However the buffer overestimated about 0.11% when calculated by linear regression equation when compared with the value determined by reference method. The coefficient of determination increased from 97 by linear regression to 99 by culvinery regression fig: 6

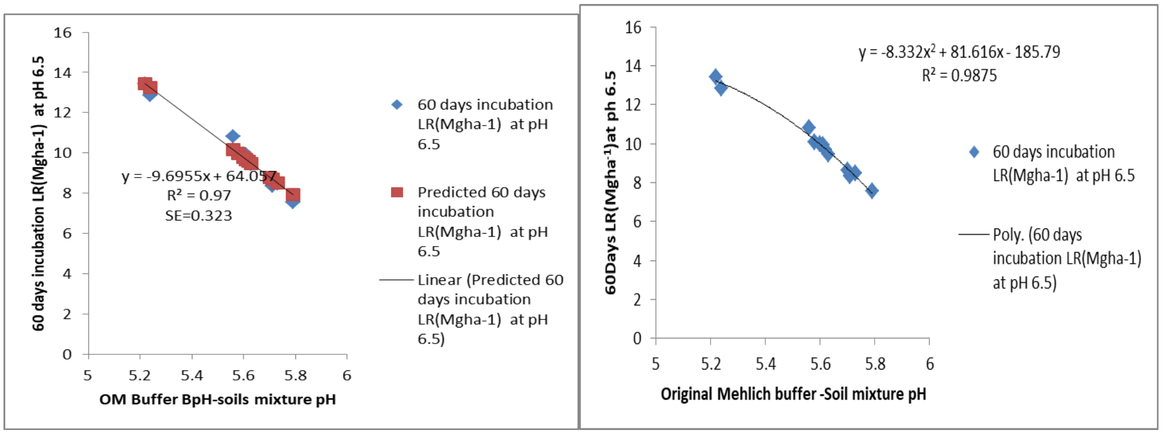


Figure 11:(a) Linear and (b) culvinary regression OM buffers-Soil pH and Lime value determined by reference method.

Conclusions and recommendations

Exchangeable acidity method overestimated LR to achieve targeted pH at pH(H_2O) of 5.5 for all soils when compared the amount predicted reference method that ranged from 0.365 to 3.249 Mg ha-1. Over estimation of lime determination lead to over application of lime which is uneconomical and may affect crop growth by inhibiting the availability of certain plant nutrients for example P and Zn. When lime is inadequately applied amelioration is not accomplished and the availability of nutrients such as Mn may reach toxic levels, hence repressing crop development.

Both Buffers evaluated here had high positive coefficient of correlation with reference method (r= 98.5and 0.96) and coefficient determination (R2=97and 93) with different standard error of estimate (SE=0.28 0.44) for original Mehlich and SMP Buffer method respectively. However Originals Mehlich appears to be the most precise for estimating LR for soils of the Bedele followed by SMP buffer. Shoemaker, McLean, and Pratt performed well but resulted in chronic problems with electrode reference junction degradation, stability of pH readings time, and generation of hazardous waste due to this disadvantage the buffer not appropriate for routine use.

The Original Mehlich buffer had Advantage over Shoemaker, McLean, and Prattbuffer for routine practice, with less adverse sound effects on pH meter electrodes and the removal of unsafe chemical disposal. The author finally suggested that using Mehlich buffer for estimating amount of lime requirement for specific targeted pH rather than using Exchangeable acidity method that not economical either of time and resource in addition to overestimating lime for specific targeted pH. Further evaluation of these buffer methods under field conditions also important us this research conducted under laboratory condition.

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Characterization, Classification and Mapping of Soils of Bedele District, South West Ethiopia

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Abstract

The study was conducted to characterize classify and mapping soils in Bedele district, south west Ethiopia. Twenty representative pedons were opened and described across the study area. The soils of Bedele district was characterized and classified based on the results obtained from soil morphological description at field and laboratory analyzed. From Twenty pedons three meet Diagnostic criteria of Mollic horizon and the remaining 17 meet for Umbric horizon. Twelve pedons were qualifying for Argic, three pedons qualifying for nitic diagnostic horizon, one qualifying for Vertic diagnostic horizon and one qualifying for Cambic diagnostic horizon The results indicated that theirs variations in morphological, physical, and chemical properties of the soils. The value of Organic carbon ranged from 0.15 to 3.7%. The value Exchangeable Acidity ranged from 0.24 to 23.67cmolckg-1. The value of Exchangeable Aluminum ranged from 0 to 19.43 cmolc kg^{-1}). The results revealed that the pH-H_2O of soil ranged from 3.8 to 7.28 were categorized extreme acidic to strong acidic except pedon1 which is slightly acidic to neutral. The percentage of clay content varied from 22 to 84% where soils are sandy clay loam to clayey in texture. Generally variations in soils properties suggested theirs variation of potential productivity and management requirements for specific Soils. Based on the results of morphological, physical and chemical properties eight reference soils groups were identified namely, (I) Nitisols, (II) Acrisols, (III) Alisols, (IV) Luvisols (V) Lixisols (VI) Cambisols, (VII) Leptosols and (VIII) Vertisols based on World Reference Base.

Keywords: *Pedons, diagnostic horizons, Nitisols, Acrisols, Alisols, Luvisols, Lixisols Vertisols Cambisols, Leptosols, chemical properties*

Introduction

Soils have diverse morphological, physical, chemical and biological properties. As a result, they differ in their responses to management practices, their inherent ability to deliver ecosystem services, as well as their resilience to disturbance and vulnerability to degradation (FAO, 2017). Characterization and classification of soils have therefore paramount importance in using those resources based on their capability and to manage them in sustainable manner. Soil information obtained through systematic identification and grouping use for effective planning of different land uses, as they provide information related to potentials and constraints of the land (Lufega and Msanya, 2017).

Characterizing and classifying soils is the main information source for precision agriculture, land use planning and management (Yitbarek et al., 2016). It provides information for our understanding of physical, chemical, mineralogical and microbiological properties of the soils we rely on to grow crops, sustain forests and grasslands that support daily life of the society. Soil classification, on the other hands, helps to arrange our knowledge, facilitates the transfer of experience and technology from one place to another (Chekol and Mnalku, 2012; Mulugeta and Sheleme, 2010 and Adhanom and Teshome, 2016).

The knowledge of characterizing soil properties and potential uses is always needed for sustainable land use planning and for economic development (Yitbarek et al., 2016). Characterization and mapping of soils are much important to understand the nature of soil resources and provide detailed information on morphological, physical and chemical characteristics of soils (Yitbarek et al., 2016).

The soils have not been characterized and classified for sound land management at Bedele district where agriculture has been widely practiced for thousands of years. Farmers continue to use the land with limited input to improve soil fertility. Moreover, the prevailing land use system and management interventions are not supported with information that shows the potentials and constraints of soil resources. This decline in production and productivity has threatened the food and nutrition security of the community in the study area. In order to use the limited land resources more efficiently, site-specific management recommendations based on site-specific information are very much required. Therefore, there is a dire need to characterize soils to pinpoint their constraints and potentials, and classify and map to depict their geographical distribution in the study area. This study was therefore, initiated to characterize the morphological, physical and chemical properties of soils, and classify and map the soils of Bedele district.

Material and Methods

Description of Study Area

The study was conducted in Bedele District, Buno Bedele Zone, Oromia Regional State South Western Ethiopia. The district is located between 8°14'30"N to 8°37'53"N, and 36°13'17"E to 36°35'05"E 483 km to south-west of Addis Ababa. It covers 74,497.425 hectares of which 47,986, 9.477, and 10,120 hectares are cultivated, forest and grazing land respectively (BDAO, 2020). The altitude of the district ranged from 1013 to 2390 m.a.s.l.

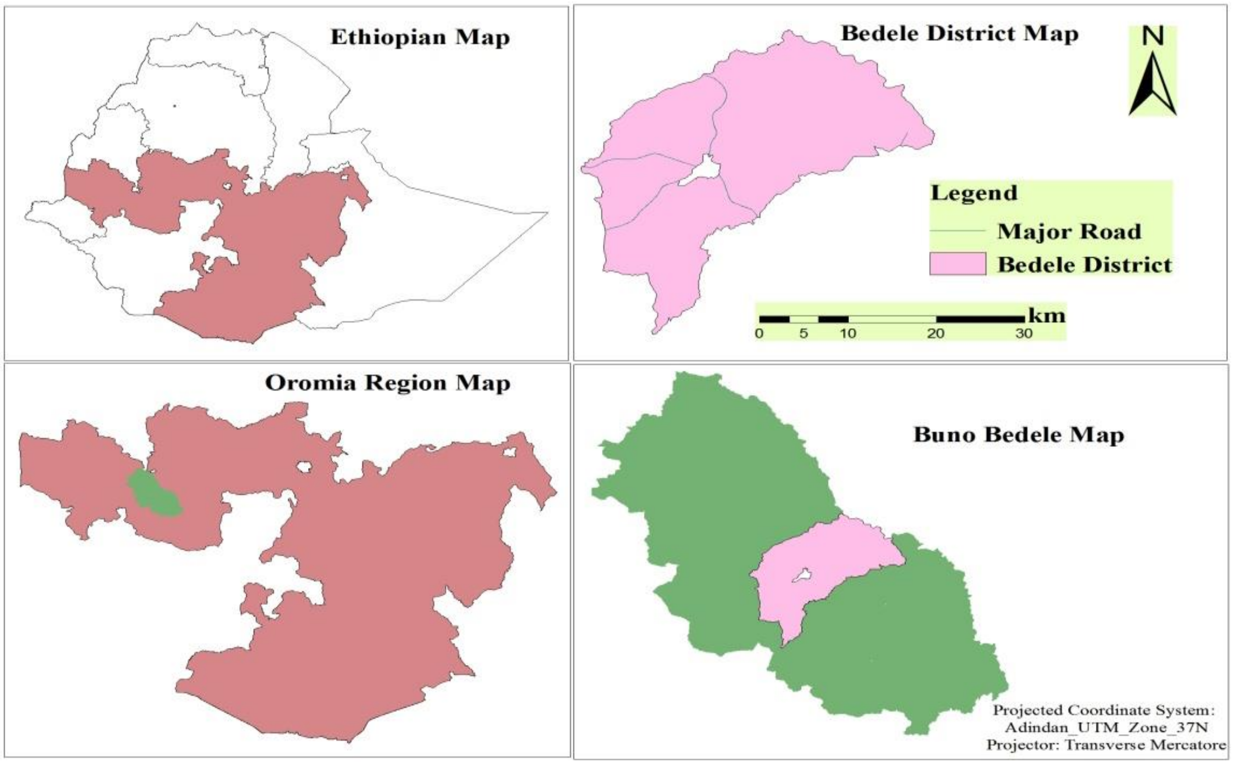

Figure 1: Description of Study Area

Climate

According to the fourteen-year (2005-2018) weather data recorded at Bedele Meteorological Station, the average annual rain fall of 1942mm and the monthly mean minimum and maximum temperature are 13 and 26^0 C, respectively. The rainy season extends from April to October and the maximum rain is received in the months of May, June, July, August and September with the mean monthly rainfall exceeding 301mm (BMeS, 2019).

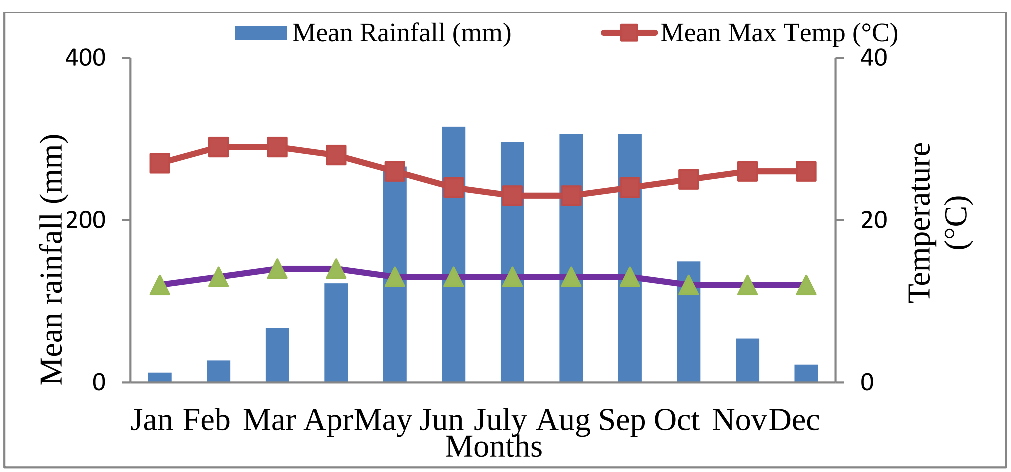

Figure 12: Mean monthly rainfalls and maximum and minimum temperature of Bedele district.

Pre-fieldwork preparation phase

Before starting the actual field work soil mapping unit were produced by overlying land unit, FAO soil classification 1974 (Geomorphological soil), dominant soils landscape and slope class were determined from the 30 m-resolution digital elevation model (DEM) using ArcGIS 10.3 (Figure 3). All predefined auger observations and profile pits were exported to Google earth map and Garmin GPS for final field works. The necessary soil survey facilities and formats such as the FAO guidelines for soil profile and auger description (FAO, 2006), Munsell soil color chart (Munsell color company, 2015), WRB soil classification manual (WRB Working Group, 2014), GPS, Clinometer, soil profile and auger description sheets were collected and prepared during this phase.

The fieldwork phase

Field work was conducted in two stages: auger observation and soil profile description and soil sampling.

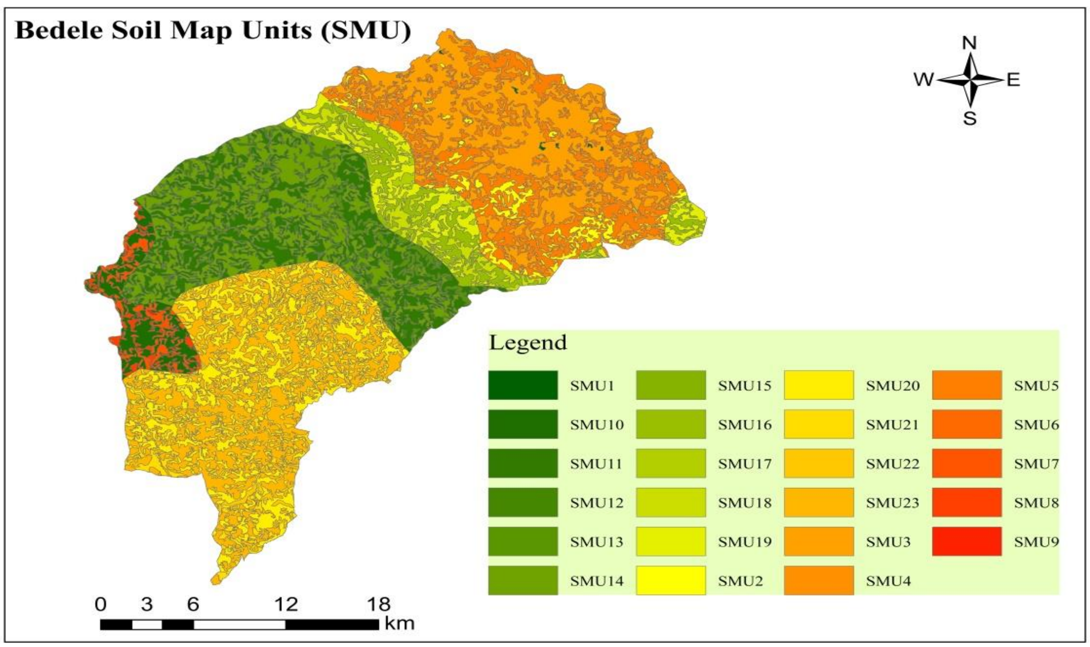

Figure 3. Soil Mapping Units of the Bedele district

Soil Samples Preparation and Laboratory Analyses

Disturbed soil samples were air dried and prepared physiochemical analyzed following standard procedure (vanReeuijk, 2002) because this manual was recommended World Reference Base for Soil Resources (IUSS Working Group WRB, 2015). Soil texture was determined using the Bouyoucos hydrometer method (Day, 1965). Soil textural classes were read from the textural triangle (WRB, 2014).The pH of the soils was measured using a pH meter in 1:2.5 ratio of soil to liquid suspension according to the procedure outlined by (van Reeuwijk 2002). Organic carbon was determined using the wet oxidation method (Walkley and Black, 1934). Exchangeable bases (Ca^{+2}, Mg^{+2}, K^{+} and Na^{+}) in the soil were extracted with 1 M ammonium acetate (NH_4OAc) solution at pH 7.0 (van Reeuwijk 2002). Total exchangeable acidity was determined by saturating the soil samples with 1 M KCl solution and was titrated with 0.02 M NaOH as described by (Rowell 1994). From the same extract, exchangeable Al^{+3} in the soil samples was determined by application of 1 M NaF, which forms a complex with Al^{+3} and releases NaOH and then NaOH was back titrated with a standard solution of 0.02 M HCl (Sahlemedhin and Taye, 2000).

Soil Classification

The soils of district were classified into different Reference Soil Groups and further classified Second Levels by combining set of principal and supplementary qualifiers with reference soil Groups following World Reference Base for Soil Resources (IUSS Working Group WRB, 2015).

Results and Discussions

Site Characteristics of Pedon*s*

Site characteristics of the study area around pedons in respective soil units were described based on their slope, drainage class, and land use, surface characteristic and physiographic features as indicated below (Table 1). The district was classified into twenty soils mapping unit based on Geomorphological soils and slopes of the studies area. Among twenty soils units sixteen soils map unit were found on middle and lower slope positions where eight soils mapping unit were on middle slope positions with slopes of 2 to 32% and the remaining eight were found on lower slope positions with slopes of 2 to >60%, however the rest four soils mapping units were upper slope positions with slopes of 8 to 60%. The slope of the study area was ranged from flat to very steep slope (>60%) and also the slope form was concave, terraced and straight. The study areas of soil were mostly well drained and were cultivated for rain fed and fallow farming system. The drainage characteristics in all pedons were well drained across the study area except four pedons (2, 4, 9 and 13) had Imperfectly Drainage characteristics. Land use of the study area at all Pedon sites were rain fid cultivation land followed by fallow cultivations system at some pedons except soil mapping units 3 natural forest land and woodland.

Morphological Properties of Soils

Most of pedons had a Bt horizon except those has a shallow soil depth and calcic horizon at soil mapping unit 1. Also some of pedons has a C horizon including pedons 3, 7, 8, 11, 13, 14, 15 and 16, except Pedon 15 who hasn't clay (t) horizon due continuous rock fragment with unlimited depth. The colors of surface horizons at dry were very dark grey (Gley 1 3/N), black, red and brown and mostly at moist the color was changed to dark. Whereas the color of the subsurface horizon at dry and moist varied from dark reddish brown (2.5YR 2.5/4) to dark brown (7.5YR 4/6). The surface horizons were darker as compared to subsurface horizons that mainly could be due to accumulation and decomposition of organic materials and specific process of mineralization that related to addition process of organic matter to the soil. The structure of the surface horizons ranged from weak (WE) to strong (ST) in grade. Fine to coarse sizes and

Table1 Selected site Characteristics of soil mapping units in Bedele district

SMU	Locations		Elevation	Slope (%)	Slope form	Slope Position	Drainage class	Land use
	Latitude (N)	Longitude (E)	(m.a.s.l)					
1	08º32'53.5''	036 º 31'30.3''	1344	>60	Straight	Bottom Slope	Well drained	Fallow
2	08 º 31'22.9''	036 º 26'49.9''	1452	0-2	Concave	Lower Slope	Imp. Drained	Cultivation
3	08 º 37'24.0''	036 º 28'16.3''	1666	16-32	Concave	Crest	Well drained	Natural Forest
4	08 º 33'44.7''	036 º 27'39.8''	1374	16-32	Straight	Bottom Slope	Imp. Drained	Cultivation
5	08 º 23'47.9''	036 º 16'29.8''	1963	16-32	Straight	Middle Slope	Well drained	Cultivation
6	08 º 24'28.2''	036 º 15'48.8''	1880	2-8	Concave	Middle Slope	Well drained	Cultivation
7	08 º 27'15.3''	036 º 13'40.0''	1814	2-8	Terraced	Bottom Slope	Well drained	Cultivation
8	08 º 27'58.0''	036 º 18'52.2''	nd	2-8	Terraced	Middle Slope	Well drained	Cultivation
9	08 º 31'18.9''	036 º 21'44.6''	nd	2-8	Terraced	Lower Slope	Imp. Drained	Fallow
10	08 º 30'46.5''	036 º 22'19.6''	1811	2-8	Concave	Middle Slope	Well drained	Cultivation
11	08 º 28'29.2''	036 º 19'39.8''	nd	32-60	Terraced	Middle Slope	Well drained	Cultivation
12	08 º 34'16.3''	036 º 20'51.6''	1904	32-60	Concave	Upper Slope	Well drained	Other Land Uses
13	08 º 27'40.9''	036 º 26'29.5''	1938	32-60	Concave	Upper Slope	Imp. Drained	Cultivation
14	08 º 30'28.5''	036 º 23'49.8''	1568	32-60	Straight	Bottom Slope	Well drained	Cultivation
15	08 º 28'55.4''	036 º 26'23.7''	1895	32-60	Concave	Lower Slope	Well Drained	Cultivation
16	08 º 32'50.2''	036 º 22'59.4''	1918	8-16	Concave	Middle Slope	Well drained	Fallow
17	08 º 25'25.3''	036 º 21'47.4''	1963	8-16	Straight	Middle Slope	Well drained	Cultivation
18	08 º 20'31.6''	036 º 19'19.3''	1952	8-16	Straight	Middle Slope	Well drained	Cultivation
19	08 º 22'03.5''	036 º 19'08.8''	1942	8-16	Concave	Lower Slope	Well Drained	Cultivation
20	08 º 19'19.4''	036 º 19'07.5''	2006	8-16	Concave	Upper Slope	Well drained	Cultivation

Table 2: Morphological description of represented Soil Map Units of Bedele district

SMU (Pedons)	Depth (cm)	Horizon	Color		Structure	Consistency			Root	Boundary
			Dry	Moist	Grade/size/Type	Dry	Moist	Wet	Abundance	Distinct/Top
Pedon 1	0-18	Ah	GLEY1 3/N	GLEY1 3/N	ST/CO/AB	EHA	EFI	VST	M/VF	D/S
	18-121	B	GLEY1 3/N	GLEY1 3/N	ST/CO/PL	EHA	EFI	VST	M/VF	G/W
	121-141	Bt1	GLEY1 3/N	5YR4/1	ME/CO/AB	HA	FI	ST	C/VF	G/S
	141-177	Bk1	5Y4/1	10YR5/2	WE/CO/AB	HA	FR	ST	F/VF	G/S
	177-200	C	5Y5/1	2.5YR4/1	WE/CO/AB	SHA	FR	SST	N	NB
Pedon 2	0-13	Ap	10YR2/1	5YR2.5/1	MO/ME/GR	SHA	FR	VST	M/F	C/S
	13-26	ABt1	7.5YR4/2	5YR3/3	MO/ME/AB	SHA	FR	VST	M/F	G/S
	26-40	Bt2	7.5YR3/4	5YR3/1	MO/ME/GR	SHA	FR	VST	C/VF	G/S
	40-130	Bt3	2.5YR4/4	5YR3/3	MO/ME/GR	SHA	FR	VST	F/VF	D/S
	130-200	Bt4	2.5YR4/6	5YR3/4	MO/ME/GR	SHA	FR	VST	N	NB
Pedon 3	0-3	Ah	7.5YR4/3	5YR3/2	WE/FI/GR	SO	FR	ST	N	A/S
	3-6	AB	7.5YR4/2	5YR3/3	MO/FI/GR	SO	FR	ST	M/F-M	C/S
	6-38	BC	7.5YR4/4	5YR3/4	MO/FI/GR	SO	FR	ST	M/F	C/I
	38-87	C	5YR4/6	5YR3/4	WE/FI/GR	SO	FR	ST	C/F	NB
Pedon 4	0-12	Ap	5YR4/3	5YR3/3	ST/FI/GR	SHA	FR	ST	F/VF	G/S
	12-44	ABt1	2.5YR3/4	2.5YR3/4	ST/CO/SBA	SHA	FR	ST	V/VF	D/S

	44-89	Bt2	2.5YR3/6	2.5YR2.5/4	ST/FI/AB	SHA	FR	ST	N	C/S
	89-200	Bt3	2.5YR3/6	2.5YR2.5/4	WE/FI/AB	SHA	FR	ST	N	NB
Pedon 5	0-20	Ap	2.5YR4/4	2.5YR3/4	MO/ME/GR	SHA	FR	SST	F/F-C	C/S
	20-100	AB	2.5YR3/6	10YR3/4	MO/ME/GR	LO	FR	SST	C/M	C/S
	100-140	BtFe	2.5YR3/6	2.5YR4/8	MO/ME/GR	SHA	FR	ST	F/F	C/S
	140-200	Bo	7.5YR6/8	5YR4/6	MO/ME/GR	SHA	FR	NST	N	NB
SMU6	0-14	Ap	5YR3/3	2.5YR3/2	MO/FI/SBA	SHA	FR	ST	V/VF	C/S
	14-58	ABt1	2.5YR3/2	7.5YR2.5/2	MO/FI/AB	HA	FR	ST	C/V	C/S
	58-125	Bt2	2.5YR2.5/3	5YR3/4	MO/ME/AB	HA	FR	ST	F/V	C/S
	125-180	Bt3	2.5YR2.5/4	5YR3/3	MO/ME/AB	HA	FR	ST	V/VF	C/S
	180-200	Bt4	2.5YR2.5/4	2.5YR2.5/4	MO/FI/AB	HA	FR	ST	N	NB
Pedon 7	0-10	Ap	7.5YR4/3	5YR3/2	ST/ME/AB	HA	FR	ST	N	C/S
	10-37	ABt1	5YR4/4	2.5YR2.5/4	MO/FI/AB	SHA	FR	ST	C/VF	D/S
	37-75	Bt2	5YR4/6	2.5YR3/4	WE/FI/AB	SO	FR	ST	C/VF	G/S
	75-108	Bt3	7.5YR4/4	2.5YR3/6	ST/FI/AB	SHA	FR	ST	F/VF	C/S
	108-150	Bt4	7.5YR4/3	5YR4/4	WE/FI/AB	SO	FR	ST	F/VF	C/S
	150-200	C	5YR5/4	7.5YR4/3	WE/FI/AB	SO	FR	ST	F/VF	NB
Pedon 8	0-15	A	2.5YR3/2	2.5YR3/2	ME/CO/GR	HA	FI	SST	F/C	C/S
	15-45	Ap	5YR4/3	2.5YR3/3	ME/CO/GR	SHA	FR	SST	F/C	D/S
	45-70	B	2.5YR3/2	2.5YR3/2	ME/CO/GR	SHA	FR	SST	F/C	G/S

	70-130	Bt	2.5YR3/3	2.5YR3/4	WE/CO/GR	SHA	FR	SST	V/C	C/S
	130-200	C	2.5YR2.5/4	2.5YR3/6	WE/CO/GR	SHA	FR	SST	V/C	NB
Pedon 9	0-15	Ap	7YR3/4	2.5YR4/3	ST/ME/AB	HA	FR	SST	C/M	G/S
	15-60	AB	7YR4/4	2.5YR4/4	ST/ME/AB	HA	FR	SST	F/C	D/S
	60-125	B	5YR3/4	2.5YR3/4	MO/ME/AB	HA	FR	ST	V/C	C/S
	125-200	Bt	5YR3/4	2.5YR3/6	MO/ME/AB	HA	FR	SST	N	NB
Pedon 10	0-19	Ap	7.5YR2.5/1	2.5YR2.5/1	MO/ME/GR	HA	FR	ST	C/VF	C/S
	19-48	ABt1	7.5YR3/2	2.5YR2.5/2	ST/ME/AB	HA	FR	ST	C/VF	D/S
	48-120	Bt2	7.5YR3/1	2.5YR2.5/2	ST/ME/AB	HA	FR	ST	C/VF	C/S
	120-170	Bt3	7.5YR3/1	5YR3/2	ST/ME/AB	HA	FR	ST	F/VF	C/S
	170-200	Bt4	7.5YR3/2	5YR3/3	ST/ME/GR	HA	FR	ST	N	NB
Pedon 11	0-15	A	7.5YR4/3	5YR3/1	ST/CO/BL	HA	FR	ST	C/C	C/S
	15-60	E	5YR3/2	5YR3/1	ST/CO/AB	HA	FR	ST	F/C	C/S
	60-90	B	7.5YR3/2	7.5YR2.5/2	ST/CO/AB	HA	FR	ST	V/C	C/S
	90-165	Bt	10YR3/2	7.5YR2.5/3	MO/CO/AB	SHA	FR	ST	N	D/S
	>165+	C	5YR3/3	7.5YR3/3	MO/CO/AB	SHA	FR	ST	N	NB
Pedon 12	0-8	Ah	2.5YR2.5/2	5YR3/2	MO/ME/AB	HA	FR	ST	C/F	C/S
	8-50	AB	5YR3/2	5YR3/3	MO/ME/AB	HA	FR	ST	F/VF	D/W
	50-110	BC	10YR4/2	10YR3/6	MO/ME/GR	HA	FR	ST	F/VF	C/W
	110-200	CR	10YR7/2	7.5YR3/2	MO/ME/AB	HA	FR	ST	N	NB

Pedon 13	0-12	Ap	10YR4/3	10YR4/2	MO/FI/GR	HA	FR	ST	C/VF	G/S
	12-34	AB	10YR4/2	10YR4/2	MO/ME/AB	HA	FR	ST	F/VF	C/S
	34-84	C	10YR4/4	10YR4/3	WE/FI/GR	SO	FR	ST	N	C/B
Pedon 14	0-12	Ap	10YR4/3	5YR3/2	MO/ME/GR	HA	FI	ST	F/VF	C/S
	12_61	ABt1	5YR4/3	2.5YR3/2	ST/ME/AB	HA	FR	ST	V/VF	D/S
	61-90	Bt2	2.5YR3/2	2.5YR3/2	ST/ME/AB	SHA	FR	ST	V/VF	D/S
	90-123	Bt3	GLEY1 3/N	2.5YR2.5/2	MO/ME/AB	SHA	FR	ST	V/VF	C/W
	123-200	C	7.5YR3/2	5YR3/2	WE/ME/AB	SO	FR	ST	N	NB
Pedon 15	0-8	Ap	7.5YR4/2	5YR3/2	MO/ME/GR	HA	FR	ST	C/VF	D/S
	8-20	AB	7.5YR2.5/2	5YR3/3	MO/ME/GR	HA	FR	ST	C/VF	C/W
	20-100	BC	7.5YR4/4	7.5YR4/4	WE/FI/AB	SHA	FR	ST	F/VF	C/I
	100-200	C	7.5YR4/3	5YR3/4	WE/FI/AB	SHA	FR	ST	N	NB
Pedon 16	0-20	Ah	5YR3/3	5YR3/3	ST/ME/SBA	HA	FR	ST	C/VF	C/S
	20-45	ABt1	5YR4/4	5YR4/6	ST/ME/SBA	SHA	FR	ST	C/VF	D/S
	45-75	Bt2	5YR3/4	5YR3/4	ST/ME/SBA	SHA	FR	ST	F/VF	D/S
	75-125	Bt3	5YR4/4	5YR3/4	ST/ME/AB	SHA	FR	ST	V/VF	D/S
	125-170	Bt4	5YR4/4	5YR4/4	MO/ME/AB	SHA	FR	ST	N	C/S
	170-200	C	10YR6/4	7.5YR4/4	MO/ME/AB	SHA	FR	ST	N	NB
Pedon 17	0-24	Ap	2.5YR4/6	2.5YR3/3	ST/CO/AW	HA	VFR	ST	M/C	G/S
	24-45	AB	2.5YR2.5/4	2.5YR2.5/4	MO/ME/SA	SHA	FR	SST	C/M	G/S

	45-57	B	2.5YR3/6	2.5YR3/6	WE/FI/SB	SHA	FR	ST	F/F	G/S
	57-84+	Bt	2.5YR2.5/3	2.5YR2.5/4	MO/ME/SN	HA	FI	ST	V/VF	NB
Pedon 18	0-16	Ap	7.5YR4/4	5YR3/2	MO/FI/GR	HA	FR	ST	M/F	C/S
	16-43	ABt1	5YR3/3	2.5YR3/2	WE/FI/SBA	SHA	FR	ST	C/VF-M	D/S
	43-87	Bt2	2.5YR3/3	2.5YR2.5/2	WE/FI/SBA	SHA	FR	ST	F/VF-M	C/S
	87-134	Bt3	2.5YR2.5/3	2.5YR2.5/4	MO/ME/GR	HA	FR	ST	V/VF	G/S
	134-200	Bt4	2.5YR3/6	2.5YR3/6	ST/ME/AB	HA	FR	ST	V/VF	NB
Pedon 19	0-8	Ap	5YR4/4	2.5YR3/3	MO/FI/GR	SHA	FR	ST	M/F	C/S
	8_40	ABt1	2.5YR3/3	2.5YR3/3	MO/FI/GR	SHA	FR	ST	C/VF	C/S
	40-110	Bt2	2.5YR2.5/3	2.5YR3/2	MO/ME/GR	SHA	FR	ST	C/VF	C/S
	110-145	Bt3	2.5YR3/6	2.5YR2.5/4	ST/ME/AB	HA	FR	ST	F/VF	D/S
	145-174	Bt4	2.5YR4/4	2.5YR2.5/4	ST/ME/AB	HA	FR	ST	F/VF	G/S
	174-200	Bt5	2.5YR4/4	2.5YR2.5/4	ST/ME/AB	HA	FR	ST	N	NB
Pedon 20	0-12	Ah	5YR3/3	5YR3/3	MO/ME/AB	HA	FR	ST	M/VF	C/S
	12-30	ABt1	5YR3/3	5YR3/2	MO/ME/AB	HA	FR	ST	M/VF	C/S
	30-90	Bt2	2.5YR4/4	2.5YR3/4	MO/ME/AB	HA	FR	ST	C/VF	C/S
	90-130	Bt3	5YR4/4	5YR3/4	ST/ME/AB	HA	FR	ST	F/VF	G/S
	130-165	Bt4	5YR4/4	5YR4/6	ST/ME/AB	HA	FR	ST	F/VF	G/S
	165-200	Bt5	7.5YR4/6	5YR4/3	ST/ME/AB	HA	FR	ST	V/VF	NB

dominated by angular blocky and granular in its type. Pedon 1 also additionally has platy soil type. In some pedons the soil has strong grade due to compaction which comes from over grazing. The consistency of the soil of the study area at dry ranges from soft to extremely hard but in most case it has hard consistency due high clay content of soil and also at moist friable and firm. It was slightly sticky to very sticky consistency at wet. This change in consistency associated with a change in texture. The root abundance decreased with depth, many at surface and mostly no root at lower horizons. The root abundance was greater at fallow than cultivated land due to disturbance of plant roots. The root abundance also limited by depth and coarse fragment. The horizon boundaries characterized by clear, gradual, diffuse and smooth topography in different Pedons.

Soil Physical and Chemical Properties of the Study area

Soil Particle size determinations

The results of particle size determination revealed that the soils of the area had clay texture at surface horizons except pedons (2 and 13) and pedons (6, 10, 12 and14) that had sandy clay loam and Clay loam respectively. Similarly results of clay texture was observed at Sub-surface horizons except for the (Pedons 1,3,12,13,14 and16) that had sandy clay loam texture at the middle and lower positions of Sub-surface horizons (Table 3). The percentage of clay content varied from 22 to 68% in the surface horizons and 22 to 84% in subsurface horizons. Generally clay percentage showed irregular trend with as soil depth increased except in six pedons (2, 6, 8, 11, 17 and 19) that increased with soils depth. The textural differentiation might be caused by Lessivage process both at surface and subsurface horizons, surface erosion of clay, upward movement of coarser particles due to swelling and shrinking and biological activity (WRB, 2006 and 2015).

Sand and Silt contents percentage varied from 20 to 48% and 7 to 38%, respectively, whereas their respective values varied from 2 to 60% and 4 to 36% in the subsurface horizons. The results of coarse texture at surface horizons was similar with the finding many researchers for Ethiopian soils in different parts of the country (Ali et al., 2010; Desalegn et al., 2015; Abdenna et al., 2018, Yitbarek et al, 2016 and Eyasu, 2016). The ratios of silt to clay showed irregular trend as soil depth increased similar fashion of clay fractions. Generally, the ratio of silt to clay ranged from 0.1 to 1.73 in surface horizons while 0.05 to 0.97 subsurface horizons. However, irregular trend clay fractions and silt to clay as soil depth increased was in contradict with results of (Ali et al., 2010; Desalegn et al., 2015; Abdenna et al., 2018, Yitbarek et al, 2016 and Eyasu, 2016) reported for Ethiopian soils.

Soil Chemical Properties

Soil reactions

The results revealed that the pH-H_2O of soil at surface horizons ranged from 4.14 to 5.75, whereas the subsurface horizons values were ranged from 3.8 to 7.28. The pH-H_2O value for all pedons was categorized as strong acidic and the magnitude of acidity increased down with increasing in depth in all pedons except Pedon 1. Pedon 1 had acidic to alkaline reaction and pH (H_2O) increased from 5.75 to 7.28 with depth due to presence of $CaCO_3$ in the Bk horizon, similar report was reported (Abdenna et al., 2018).

Exchangeable Acidity

The results indicated that Exchangeable Acidity at surface horizons ranged from 0.46 to 23.67 cmolc kg^{-1}, whereas the subsurface horizons values were ranged from 0.24 to 21.64 cmolc kg^{-1}. The value Exchangeable Acidity showed irregular trend as depth increased. The value decreased at middle and increased at the lower positions in all pedons except Pedon 1. Pedon 1 had due to presence of $CaCO_3$ in the Bk horizon, similar report was reported by (Abdenna et al., 2018).

Exchangeable Aluminum

The value of Exchangeable Aluminum at surface horizons ranged from 0 to 19.43 cmol kg^{-1}, whereas the subsurface horizons values were ranged from 0 to 16.05 cmolc kg^{-1}. The value Exchangeable Acidity showed irregular trend as depth increased.

Organic carbon

The value of Organic carbon at surface horizons ranged from 0.28 to 3.7%, whereas the subsurface horizons values were ranged from 0.15 to 2.96%. The value Organic carbon showed decreasing trend as depth increased which might be associated with biological activity. The results of decreasing in organic carbon with depth in line with the finding of (Ali et al., 2010; Desalegn et al., 2015; Abdenna et al., 2018, Yitbarek et al, 2016 and Eyasu, 2016).

Exchangeable Bases

The results Exchangeable Bases values were different from Pedon to pedons. The contents of exchangeable Ca varied from 0.57 to 16.42 and 0.57 to 29.99 cmolc kg^{-1}, surface and subsurface horizons, respectively. The contents of exchangeable Mg varied from 0.4 to 9.58 and 0.38 to 12.25 cmol kg^{-1}, surface and subsurface horizons respectively. The contents of exchangeable K varied from 0.07 to 4.43 and 0.04 to 4.43 cmol kg^{-1}, surface and subsurface horizons respectively. The contents of exchangeable Na varied from 0.03 to 0.83 and 0.03 to 2.64 cmol kg^{-1}, surface and subsurface horizons respectively.

Table 3. Soil Chemical and Physical properties of represented Soil Map Unit at Bedele district

SMU (Pedons)	Chemical Properties													Particle Distributions				Textural Class
	Horizon	pH (H_2O)	EA (cmol kg^{-1})	EAl (cmol kg^{-1})	OC (%)	Exchangeable Bases (cmol kg^{-1})				CEC (cmol kg^{-1})	CECc (cmol kg^{-1})	EBS (%)	PBS (%)	Sand (%)	Clay (%)	Silt (%)	Si:C	
						Ca	Mg	K	Na									
Pedon 1	Ah	5.75	0.85	0.00	2.16	16.33	9.58	1.14	0.28	56.25	90.16	100.00	48.59	20	54	26	0.48	C
	AB	6.6	0.84	0.36	0.74	20.59	9.63	2.90	0.91	55	87.36	98.94	61.87	28	60	12	0.20	C
	Bk1	7.28	0.63	0.00	1.12	24.12	10.57	3.03	1.15	56	96.43	100.00	69.41	30	54	16	0.30	C
	Bk2	7.21	0.83	0.00	1.06	28.12	11.05	1.96	1.02	58	80.96	100.00	72.66	58	30	12	0.40	SCL
	BC	7.11	0.62	0.00	0.15	29.99	12.25	2.06	1.17	60	70.29	100.00	75.77	60	22	18	0.82	SCL
Pedon 2	Ap	5.63	0.87	0.00	2.71	16.42	4.30	2.49	0.09	30.68	96.28	100.00	75.95	40	22	38	1.73	SCL
	ABt1	4.78	1.87	0.00	1.63	6.85	3.20	1.62	0.07	22.8	56.98	100.00	51.51	34	30	36	1.20	CL
	Bt2	4.98	2.06	0.28	1.37	8.10	3.01	1.60	0.13	23.6	49.51	97.84	54.40	30	38	32	0.84	CL
	Bt3	4.96	1.66	0.00	1.58	6.65	2.41	1.42	0.09	22.6	42.70	100.00	46.75	26	40	34	0.85	C
	Bt4	5.05	1.26	0.00	0.70	7.01	3.00	2.44	0.33	26.93	48.99	100.00	47.44	28	50	22	0.44	C
Pedon 3	Ah	5.05	0.47	0.33	2.35	10.02	3.25	2.29	0.09	35.35	64.62	97.93	44.27	36	42	22	0.52	C
	AB	4.87	0.46	0.00	3.16	8.30	2.76	0.60	0.05	28.8	44.38	100.00	40.69	36	40	24	0.60	C
	BC	4.73	7.06	5.61	2.07	2.86	1.26	0.30	0.05	18	17.33	44.32	24.82	50	62	18	0.56	SCL
	C	4.5	11.26	9.28	0.96	1.09	0.57	0.55	0.05	19	46.00	19.61	11.92	46	34	20	0.59	SCL
Pedon 4	Ap	4.8	0.66	0.00	2.07	12.86	4.86	1.96	0.07	39.04	53.00	100.00	50.57	20	60	20	0.33	C
	ABt1	4.8	1.66	0.00	0.98	8.57	3.49	0.68	0.03	29	41.24	100.00	44.05	16	62	22	0.35	C
	Bt2	4.83	1.26	0.00	0.98	8.91	3.45	0.71	0.05	32.98	35.20	100.00	39.79	6	84	10	0.12	C
	Bt3	4.96	2.67	0.83	0.68	8.32	3.37	0.60	0.09	27	37.31	93.72	45.88	6	66	28	0.42	C
Pedon 5	Ah	5	1.66	0.00	2.69	3.47	2.30	2.72	0.04	32.01	38.97	100.00	26.64	26	68	7	0.10	C
	AB	4.94	1.86	0.00	1.35	4.88	3.18	1.04	0.03	28.66	35.22	100.00	31.84	32	58	11	0.19	C
	BtFe	4.75	2.06	0.00	0.67	4.56	3.79	1.52	0.09	29.46	34.74	100.00	33.83	14	78	9	0.12	C
	Bo	5.27	1.66	0.00	0.67	5.97	3.99	1.57	0.11	33.01	45.07	100.00	35.27	16	68	17	0.25	C
Pedon 6	Ap	4.6	2.85	0.00	1.77	8.23	3.51	0.30	0.05	34.15	73.58	100.00	35.42	36	38	25	0.66	CL
	ABt1	4.78	2.45	0.00	2.15	8.44	3.71	2.62	0.83	28.2	38.32	100.00	55.29	28	54	17	0.31	C
	Bt2	5	0.45	0.00	0.71	9.32	3.27	0.20	0.09	23	30.15	100.00	56.04	18	68	13	0.19	C
	Bt3	4.98	1.26	0.14	1.02	7.21	2.62	0.17	0.09	23.41	29.16	98.63	43.12	16	68	15	0.22	C
	Bt4	4.61	2.25	2.09	0.71	6.42	2.07	0.20	0.18	23	27.73	80.89	38.54	8	74	17	0.23	C
Pedon 7	Ap	4.78	0.66	0.00	1.58	2.72	3.99	4.43	0.27	42.87	66.68	100.00	47.55	36	64	10	0.16	C
	ABt1	4.81	7.46	5.94	0.69	5.40	2.24	1.29	0.09	19	25.92	60.31	47.48	34	56	10	0.18	C
	Bt2	4.77	5.67	4.61	0.33	5.99	2.41	1.32	0.18	17	21.99	68.24	58.21	14	72	14	0.19	C

	Bt3	4.54	2.05	1.73	1.41	6.19	2.81	0.40	0.05	25.8	29.82	84.51	36.63	20	70	10	0.14	C
	Bt4	4.66	1.05	0.00	0.70	6.94	4.07	0.30	0.09	35.43	49.95	100.00	32.18	18	66	15	0.23	C
	C	5	0.45	0.00	0.78	8.73	4.33	0.32	0.09	28.4	49.35	100.00	47.47	16	52	31	0.60	C
Pedon 8	A	4.15	4.85	3.25	3.70	6.08	1.97	1.34	0.07	27.46	32.28	74.41	34.45	29	45	26	0.58	C
	Ap	4.48	4.64	2.44	2.75	8.26	2.41	0.35	0.03	27.45	37.12	81.88	40.24	28	48	24	0.50	C
	B	4.5	4.25	3.26	2.01	9.50	2.46	0.27	0.03	28.21	30.27	79.00	43.47	12	70	18	0.26	C
	Bt	4.4	9.66	7.66	1.33	6.17	1.80	0.25	0.03	25.81	27.14	51.82	31.92	12	78	10	0.13	C
	C	4.32	6.06	2.26	0.66	4.76	2.62	0.22	0.03	25.70	29.99	77.16	29.70	12	78	10	0.13	C
Pedon 9	Ap	4.34	4.25	1.66	2.77	6.46	3.49	0.68	0.03	27.05	28.92	86.53	39.43	18	60	22	0.37	C
	AB	4.31	9.65	8.06	1.83	3.65	2.95	0.17	0.03	23.41	23.63	45.76	29.04	12	72	16	0.22	C
	B	4.16	15.64	15.24	1.40	1.11	1.11	0.17	0.03	15.12	15.49	13.72	16.02	22	66	12	0.18	C
	Bt	3.8	9.64	9.24	0.56	1.25	1.17	0.25	0.03	21.50	27.14	22.57	12.53	16	72	12	0.17	C
Pedon 10	Ap	5.16	0.85	0.00	1.94	3.15	7.47	1.62	0.22	33.38	88.66	100.00	37.37	40	30	29	0.97	CL
	ABt1	5.21	0.84	0.00	0.37	15.77	8.92	0.96	0.35	35	58.11	100.00	74.31	18	58	23	0.40	C
	Bt2	5.17	0.83	0.00	1.80	20.14	8.82	0.94	0.22	38	54.66	100.00	79.26	18	58	23	0.40	C
	Bt3	5.12	0.84	0.00	1.01	17.98	7.86	0.81	0.14	35.4	66.36	100.00	75.65	30	48	21	0.44	C
	Bt4	5.26	0.44	0.00	1.47	18.03	7.76	0.78	0.09	53.3	96.34	100.00	50.03	28	50	21	0.42	C
Pedon 11	A	4.81	0.85	0.00	1.68	10.67	4.55	2.36	0.11	31.00	52.32	100.00	57.08	28	48	24	0.50	C
	E	4.74	13.05	11.05	1.41	9.03	4.14	1.65	0.07	25.89	43.68	57.38	57.48	20	48	32	0.67	C
	Bt	4.34	13.66	13.26	1.31	7.19	3.54	1.96	0.13	26.53	40.62	49.16	48.32	24	54	22	0.41	C
	Bt	4.36	17.65	16.05	0.67	6.87	3.22	1.01	0.03	24.96	33.24	40.95	44.61	18	68	14	0.21	C
	C	4.45	7.64	7.24	0.34	5.66	4.72	1.11	0.11	32.41	42.17	61.57	35.81	16	74	10	0.14	C
Pedon 12	Ah	4.78	7.44	6.28	2.92	13.31	5.79	0.43	0.09	46	99.44	75.77	42.67	44	36	19	0.53	CL
	AB	4.6	23.67	19.43	1.44	7.14	3.43	0.25	0.09	45.96	85.29	35.96	23.74	26	48	25	0.52	C
	BC	4.8	21.64	13.12	0.73	15.83	7.32	0.12	0.27	42.8	54.79	64.22	54.99	50	26	23	0.85	SCL
Pedon 13	Ap	4.69	2.87	0.70	1.99	8.19	2.49	2.75	0.22	32	83.44	95.12	42.65	48	30	21	0.70	SCL
	AB	4.67	3.87	2.04	1.90	8.89	3.07	1.83	0.18	31	71.58	87.26	45.06	32	34	33	0.97	CL
	C	5.27	5.66	3.70	1.37	11.95	6.38	1.22	0.09	32.13	97.68	84.15	61.15	48	28	23	0.82	SCL
Pedon 14	Ap	5.16	1.06	0.00	0.28	9.69	3.51	1.91	0.22	36.32	93.05	100.00	42.20	35	38	27	0.71	CL
	ABt1	5.05	0.85	0.00	1.20	12.41	4.20	0.66	0.22	36.6	55.84	100.00	47.77	23	58	19	0.28	C
	Bt2	5	1.06	0.00	0.35	13.02	4.83	1.01	0.22	38	61.29	100.00	50.24	23	60	17	0.33	C
	Bt3	4.9	0.64	0.00	1.30	13.65	5.14	1.09	0.31	32	45.75	100.00	63.11	24	61	15	0.25	C
	C	5.19	0.65	0.00	0.71	11.32	4.46	0.63	0.27	31.9	86.56	100.00	52.29	40	34	26	0.76	SCL
Pedon 15	Ap	5.07	0.86	0.00	1.72	11.91	3.49	1.22	0.18	37.67	75.32	100.00	44.58	36	42	22	0.52	C
	AB	4.84	0.48	0.00	1.32	7.98	2.93	0.48	0.14	31	54.97	100.00	37.20	30	48	22	0.46	C

	BC	4.93	1.65	0.00	1.07	9.28	3.10	0.22	0.27	28	55.09	100.00	45.94	28	44	28	0.64	C
	C	5.3	1.01	0.00	0.71	15.85	6.04	0.78	0.91	35.74	79.19	100.00	66.02	30	42	28	0.66	C
Pedon 16	Ah	4.7	2.58	0.62	2.96	8.10	3.58	0.48	0.53	33.07	37.86	95.31	38.33	22	60	18	0.30	C
	ABt1	4.67	2.86	0.00	1.05	6.60	2.37	0.20	0.18	24.4	29.62	100.00	38.30	8	70	22	0.31	C
	Bt2	4.83	1.86	0.00	1.09	5.38	2.82	0.15	0.09	30.05	33.62	100.00	28.07	10	78	12	0.15	C
	Bt3	4.87	0.24	0.00	1.03	4.35	1.62	0.09	0.18	21	24.83	100.00	29.75	16	70	14	0.20	C
	Bt4	4.82	2.26	0.17	0.77	5.04	2.53	0.15	0.18	22.8	29.57	97.87	34.61	18	68	14	0.21	C
	C	4.69	3.26	1.38	0.84	3.67	1.95	0.04	2.64	21.2	60.88	85.78	39.21	46	30	24	0.80	SCL
Pedon 17	Ap	4.85	2.86	0.06	1.68	6.12	2.19	0.63	0.07	25.21	33.30	99.34	35.77	32	58	10	0.17	C
	AB	4.6	1.26	0.00	0.67	3.33	1.82	0.07	0.03	17.14	18.97	100.00	30.61	12	78	10	0.13	C
	B	4.44	5.66	3.66	1.68	5.58	2.18	0.15	0.03	19.11	16.53	68.43	41.52	12	80	8	0.10	C
	Bt	4.52	2.86	2.66	1.00	2.93	1.87	0.09	0.03	20.91	20.71	64.88	23.52	12	84	4	0.05	C
Pedon 18	Ap	4.14	17.66	13.73	2.30	0.57	0.46	0.43	0.05	30.98	45.85	9.88	4.86	30	50	20	0.40	C
	ABt1	4.15	19.65	15.62	1.76	0.59	0.40	0.32	0.27	15.6	18.13	9.18	10.12	20	68	12	0.18	C
	Bt2	4.23	20.05	15.94	1.76	0.93	0.49	0.25	0.09	16.6	15.35	9.93	10.58	30	52	18	0.35	C
	Bt3	4.21	17.65	13.81	0.63	1.34	0.49	0.30	0.22	26.12	29.89	14.55	9.00	2	80	19	0.24	C
	Bt4	4.2	15.66	12.06	0.56	2.40	1.29	0.25	0.18	19.6	23.84	25.46	21.02	2	80	19	0.24	C
Pedon 19	Ap	4.25	11.46	8.51	1.73	3.33	1.14	1.09	0.09	27.37	35.53	39.92	20.66	28	60	13	0.22	C
	ABt1	4.24	13.66	10.26	0.70	1.95	0.79	0.38	0.14	23	27.06	24.08	14.15	12	76	13	0.17	C
	Bt2	4.21	16.86	12.00	0.91	1.63	0.74	0.25	0.09	24	26.04	18.45	11.31	6	80	15	0.19	C
	Bt3	4.22	16.66	12.83	0.70	1.45	0.61	0.25	0.18	27.3	31.08	16.27	9.13	2	80	19	0.24	C
	Bt4	4.1	13.86	9.24	1.11	1.32	0.50	0.20	0.09	18	17.63	18.54	11.68	2	80	19	0.24	C
	Bt5	4.06	13.86	10.22	0.90	1.68	0.38	0.17	0.05	21.8	*23.31*	18.21	10.44	2	80	19	0.24	C
Pedon 20	Ah	4.48	7.66	6.54	2.38	8.01	2.96	0.40	0.27	37.16	57.67	64.00	31.30	32	50	19	0.38	C
	ABt1	4.45	9.05	6.96	1.27	7.14	2.77	0.20	0.27	31.4	38.49	59.84	33.04	12	70	19	0.27	C
	Bt2	4.4	13.67	9.92	1.01	7.10	2.55	0.17	0.27	36	39.60	50.44	28.03	2	82	17	0.21	C
	Bt3	4.46	10.85	7.83	1.27	8.48	2.33	0.15	0.18	30	31.94	58.74	37.14	2	80	19	0.24	C
	Bt4	4.9	6.25	5.23	1.42	10.46	2.09	0.15	0.18	22.2	23.30	71.12	57.99	8	74	19	0.26	C
	Bt5	4.55	3.85	2.81	0.71	14.20	2.00	0.15	0.78	36.07	47.96	85.89	47.49	8	70	23	0.33	C

Note:

Cation exchange capacity (CEC) of Soils and Clay

The value of cation exchange capacity (CEC) soils of varied from Pedon to pedons and site to site. Generally the value of cation exchange capacity (CEC) of the soils ranged from 15.12 and 60 cmolc kg^{-1} (Table 3), which is medium to very high according to rating (FAO, 2008). The smallest value was recorded under Pedon 9 and highest value was recorded in subsurface of Pedon 1 of Vertisols. The value of varied from cation exchange capacity (CEC) soils 15.6 to 56.25 and 15.12 to 60 cmol kg^{-1}, surface and subsurface horizons respectively. Generally value of cation exchange capacity (CEC) of soils decreased with as soil depth increased which may be associated with organic matter and clay distributions. Generally the value of cation exchange capacity (CEC) Clay ranged from 15.35 to 99.44 cmolc kg^{-1} (Table 3). The smallest value was recorded under Pedon 18 and highest value was recorded in subsurface of Pedon 12. The value of cation exchange capacity (CEC) clay decreased as soil depth increased. The results similar with finding of in line with the finding of Abdenna et al., (2018). The value of percent base saturation of the study area soils ranged from 4.86 to 75.95% to 4.83 to 79.26 % surface and subsurface horizons respectively. The value was ranged very low to moderate (Hazelton and Murphy, 2007).

Soils Classification

The studied soils were classified according to world Reference Base for soil resource (IUSS Working Group WRB, 2015) system of soil classification. Among twenty pedons nine pedons meets Diagnostic criteria of Mollic horizon, while the remaining four pedons had criteria that meet Diagnostic criteria of Umbric horizon according to (WRB, 2014). Seven pedons the studies area had subsurface horizons that qualifying for Argic subsurface diagnostic horizons while the other six pedons qualifying for Nitic diagnostic horizons.

Table 4. Soil classifications of according WRB classification systems.

SMU	Soil type WRB system of soil classification
1	Calcic, Pellic Vertisols (Endoalbic, Mollic, Hypereutric, Gilgaic, Gleyic, Grumic, Humic, Stagnic)
2	Nudiargic, Albic, Rhodic Luvisols (Clayic, Cutanic, Hypereutric, Humic)
3	Umbric, Hypersketelic, Endodystric Leptosols (Loamic, Humic)
4	Rhodic, Umbric, Luvic, Hypereutric Nitisols
5	Nudiargic, Rhodic Luvisols (Clayic. Aric, Hypereutric, Nitic)
6	Rhodic. Umbric, Eutric Nitosols
7	Endostagnic, Nudiargic, Rhodic Luvisols (Clayic, Cutanic, Hypereutric, Humic, Nitic)
8	Nudiargic, Rhodic Luvisols (Clayic, Cutanic, Hypereutric, Humic, Nitic)
9	Rhodic Acrisols (Alumic, Clayic, Cutanic, Epieutric, Humic, Nitic)
10	Endostagnic, Albic, Chromic Luvisols (Clayic, Cutanic, Differentic, Hypereutric, Humic)
11	Albic, Chromic Alisols (Alumic, Clayic, Epieutric, Humic)
12	Umbric, Eutric Leptosols (Loamic, Humic)

13	Skeletic, Umbric, Hypereutric Leptosols (Loamic)
14	Endostagnic, Nudiargic, Albic, Chromic Luvisols (Clayic, Hypereutric, Nitic)
15	Leptic, Rhodic, Eutric Cambisols (Geoabruptic, Clayic, Humic)
16	Endostagnic, Nudiargic, Endoalbic, Rhodic Luvisols (Clayic, Aric, Hypereutric)
17	Endostagnic, Nudiargic, Albic, Rhodic Lixisols (Clayic, Aric, Cutanic, Hypereutric, Humic)
18	Endostagnic, Nudiargic, Epialbic, Chromic Acrisols (Alumic, Clayic, Cutanic, Humic)
19	Nudiargic, Epialbic, Rhodic Alisols (Alumic, Clayic, Cutanic, Epieutric, Humic, Nitic)
20	Rhodic, Umbric, Alic, Dystric Nitisols (Alumic)

Conclusions

Field Examination was carried out to characterize and classify soils of Bedele district, south western Ethiopia. The soils were thoroughly examined and differentiated based on observable and measurable soil characteristics both in field and laboratory. Twenty representative pedons were opened and described across the district. The results of the study revealed that theirs variations of soils morphological, physical, and chemical properties across the district, which suggested that there is in variation potential in productivity and management requirements for specific soils in the study area. Based on the results of morphological, physical and chemical properties eight reference soils groups (I) Nitisols, (II) Acrisols, (III) Alisols, (IV) Luvisols (V) Lixisols (VI) Cambisols, (VII) Leptosols and (VIII) Vertisols were identified according to WRB. Therefore, using the soils according to their potential and suitability was important for sustainable agricultural production. Special emphasis should also be given to integrated soil fertility management practices, like application of optimum rates of Vermicompost, compost, Biofertilizers, and lime integrated with inorganic fertilizers containing N, P, K and S may help to reduce the level of soil acidity, and improve the fertility level of the soils for better crop production and productivity in the study area. Additionally evaluations of physical land suitability in the area to optimize and sustain crop productions important.

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Characterization, Classification and Mapping Soil Resources of Leka Dullecha District, East Wollega Zone, Western Oromia

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Abstract

Knowledge of the kinds and properties of soils is critical for decision making with respect to crop production and other land use types. This study was conducted with the aim of characterization and classification of soils of Leka Dullecha district and produces a map of these soils. Soil mapping units were classified based on slope, geology, land form, soil depth, color, structure and texture (USDA soil textural classes). The division of the study site into SMUs helped to understand the interrelations and interaction between soil properties. Seven major soil types na mely: Cambisols, Acrisols, Nitisols, Lixisols, Vertisols, Fluvisols, and Leptosols were identified in the study site. The pH value varied from 4.0 (strongly acidic) to 6.3(moderately acidic) with average value of 4.9. Mean total nitrogen was found to be 0.06% (low) and 0.41% (high) in the SMU3 and SMU10, respectively with the mean values of 0.24. Soils of all SMUs had a fairly medium to high exchangeable Ca and Mg content. The CEC of the soils ranged from 1.08 to 27.94cmol$_c$ *kg-*^{1} *with a mean value of 15.9. OC was positively and significantly correlated with TN (*r^2 *= 0.999) at* $p < 0.001$*. Besides, CEC was significantly and negatively correlated with EA (*r^2 *= -0.397) at* $p < 0.05$*. The concept of soil–landscape relationships helps to categorize highly variable soils into relatively distinct management zones. Therefore, soil classification was developed to aid in land management.*

Key Words: Classification, Characterization, Digital soil mapping unit, Major soils

Introduction

One of the major challenges to the holistic management of soils rests upon the spatial variability of soils across landscape. Hudson (1992) contended that soil survey is a scientific strategy based on the concepts of factors of soil formation coupled with soil–landscape relationships. As a result, soil–landscape interface is an integral part of geo-ecological model and can be understood through detailed soil survey and modeling. Knowledge of the kinds and properties of soils is critical for decision making with respect to crop production and other land use types. It is through precise measurement and full understanding of the nature and properties of soils as well as proper management of the nutrient and moisture requirements that one can maximize crop production to the allowable potential limits (Abayneh and Birhanu, 2006). In order to evaluate the quality of our natural resources and their potential to produce food, fodder, fiber and fuel for the present and future generations, detailed information on soil properties is required.

The art of soil survey and classification involves dividing soils of a varying landscape into more or less distinct classes that require comparatively similar management practices (Manchanda *et al.*, 2002). A report by Inman *et al.* (2005) indicated that fields that have a high degree of spatial variability in soil properties could be better managed using site specific management zones. Because of spatial variability of soils, sampling the soil at a finite number of places or points in time yields incomplete pictures and thus spaces between sampling points need to be predicted (Heuvelink and Webster, 2001).

Assessment of soil for land use planning is increasingly important due to increasing competition for land among many land uses and the transition from subsistence to market based farming in many countries (Blum and Laker, 2003). Soil classification, therefore, is the basis for efficient land suitability evaluation, planning, and management. Soil classification is important in identifying the most appropriate use of soil, estimating production potential, extrapolating knowledge gained at one location to other often relatively little known locations, and providing a basis for future research needs (Nortcliff, 2006). Soil characterization is required to classify soils, and determine chemical and physical properties not visible in field examination (Buol *et al.*, 2003).

The World Reference Base for Soil Resources (WRB) is universally accepted comprehensive soil classification system that enables people to accommodate their national classification system (FAO, 2006) and is widely adopted in Ethiopia. The FAO (1994) created soil maps at a scale of 1:2,000,000 which are too coarse in resolution to provide sufficient soil data for specific locations. Furthermore, the soil–landscape relations at a detailed scale of 1:50,000 rarely exist for Ethiopian soils in general and are non-existent in the highlands of western Ethiopia in particular. Therefore, the study was conducted with the aim of characterization and classification of soils of Leka Dullecha district and produces a map of these soils.

Materials and Methods

Site description

The study was conducted in Leka Dullecha covering 61678. 57 ha of land and suited in East Wollega zone of Oromia Regional State. Getema town, which is the capital of the District, is situated at about 356 km distance from Finfinnee. The RF type is unimodal and the annual RF ranges from 1500mm - 2500mm. The District is under intensive agriculture. The major crops grown in the area are: maize, sorghum, teff, barley, wheat, sesame, coffee and beans.

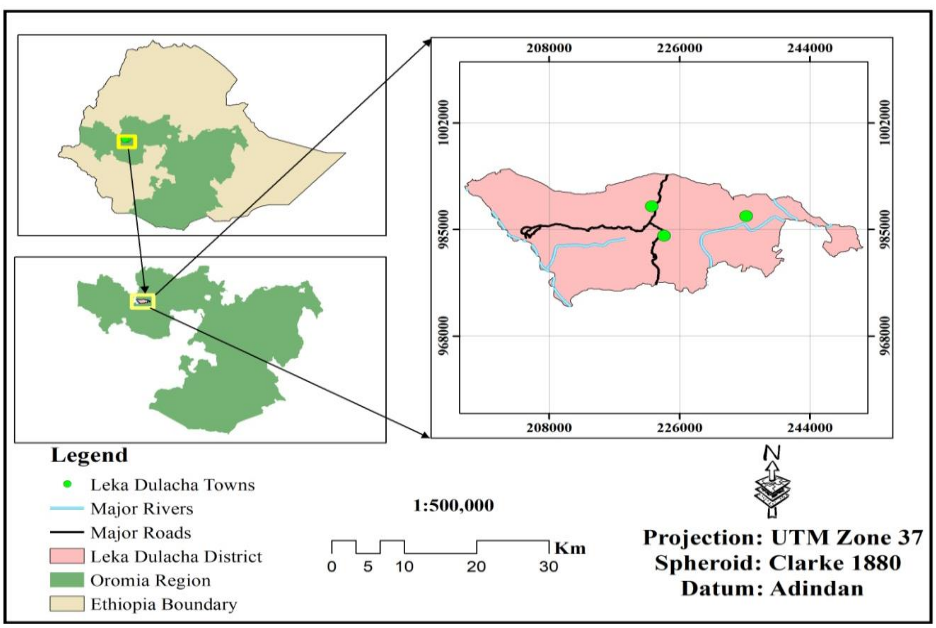

Figure 13: Location map of the study area.

Methodology

Pre-fieldwork

A base map of landform and land use land cover were created using ARC GIS 10.3 software by overlaying a 30-m resolution LANDSAT ETM+ and Google earth imagery. The slope of the study site was classified from 30-m resolution DEM using Global Mapper 13.1 software. The base maps produced for slope, landform and LULC were used for planning of the survey activities. The number of soil auguring points was estimated based on 1.5km X 1.5km grid size and distributed on the base map. The observation was aimed at verification of landscape units and delineation of the newly identified landscape units. A grid approach was used to depict soil variability in the field at finer resolution.

Fieldwork

A preliminary reconnaissance survey was conducted to have a clear visual image of topographic configuration of the study area. The conceptual model used in this study was a discrete model of spatial variation (Bregt, 1992), which assumes that the landscape can be divided into distinct polygons of 'natural' soil bodies. To map the soils of the entire study area, soil augering description following grid survey a technique was employed (Kassa *et al.,* 2015). The landscape variables such as elevation, landform, slope steepness, micro-topography, land use type, vegetation type, PMs, presence of rock outcrops, stoniness, surface crack and crusting, erosion status, surface drainage and flooding conditions at every auger observation point were described according to FAO (2006) guideline.

Additionally, soil parameters such as $CaCO_3$ content, soil depth, soil color, texture, structure, horizon development and profile stoniness were measured. Hence, combining soil and landscape information such as landform, slope, soil depth and soil texture that were obtained from characterization of auger observation points the entire study site was classified into 28 major mapping units. In each soil mapping unit (SMU), one to two soil profile pits of 1.5 X2 m were dug to at least 2 m depth. Accordingly, 29 soil profile pits were dug for the whole study site. These soil profiles were used for full description of the soils in the field and for taking soil samples from genetic depths for physical and chemical laboratory analysis (FAO, 2006). In the site, recording explanatory pedogenetic variables for every profile pits and preliminarily soil classification was performed following WRB (2007).

Post field work

Soil samples collected during the fieldwork were brought to the laboratory, air-dried, sieved to 2 mm and prepared for analysis. Soil tests were performed for selected soil physical and chemical parameters following standard laboratory methods and procedures. Final soil reclassification was made based on the laboratory result. The distribution of soils across the landscape was mapped based on the relationship between soil and landscape variables. The final soil map was produced at scale of 1:50,000.

Geo-statistical analysis and soil mapping

Geo-statistical analysis was performed using the ordinary kriging interpolation technique within the spatial analyst extension module in ArcGIS 10.4 software package to determine the spatial variability of soil properties. Hereafter, the final soil map was produced where predictions were made for a discretization grid. The conceptual model used in this study was a discrete model of spatial variation (Bregt, 1992), which assumes that the landscape can be divided into distinct polygons of 'natural' soil bodies.

Results and Discussions

Soil mapping units

Twenty-eight soil mapping units (SMUs) were identified in the site. Soil mapping units were classified based on slope, geology, land form, soil depth, color, structure and texture (USDA soil textural classes) (Figure 2). SMU 1 occurred on gentle slopes (0-2%) dominated by moderately deep to very deep effective depth (>150cm) loam soils. SMU2 moderately dissected plateau sandy clay loam, 0-2% slope, very strongly acidic, moderately deep to deep phase (Leptic-Humic Acrisols). SMU3 labeled as Leptic Acrisols constitute the largest portion (13.75%) of the total study area. They occurred on a 15-30% slope, moderately deep effective soil depth of 50-100cm, well drained, texture of sandy loam, weak fine to medium granular structure, moist surface color of black (10YR2/1). SMU 4 moderately dissected plateau sandy clay loam, 2-8% slope, slightly acidic, moderately deep to deep phase (Humic-Chromic Acrisols). SMU5 Upstream low land plains and plateau loam, sandy loam and clay loam, 2-8% slope, extremely acidic, very deep to deep phase (Umbric-Chromic Acrisols). SMU6 Upstream low land plains and plateau loam, 2-8%, very strongly acidic, very deep to deep phase (Humic-Chromic Acrisols). SMU7 moderately dissected plateau sandy loam, loam and clay loam 8-15% slope, moderately acidic, deep to very deep phase (Humic-Chromic Acrisols). SMU8 moderately dissected plateau clay, 2-8% slope, very strongly acidic, very deep phase (Chromic-Dystric Cambisols). SMU9 moderately dissected plateaux sandy loam and sandy clay loam, >30 % slope, strongly acidic, moderately deep phase (Leptic Cambisols).

SMU 10 High to mountainous relief hills, clay, 15-30% slope, very strongly acidic, deep to very deep phase (Chromic-Eutric Cambisols). SMU11 moderately dissected plateaux loam and sandy loam, 15-30% slope, strongly acidic, moderately deep to deep phase (Leptic Cambisols). SMU 12 moderately dissected plateaux clay loam, 2-8% slope, very strongly acidic, very deep phase (Mollic Cambisols). SMU13 Upstream low land plains and plateau sandy clay, 2-8% slope, moderately acidic, very deep phase (Mollic Cambisols). SMU14 High to mountainous relief hills clay, 8-15% slope, strongly acidic, moderately very deep phase (Mollic-Rhodic Cambisols). SMU15 moderately dissected plateau clay, 8-15% slope, very strongly acidic, deep phase (Mollic-Chromic Cambisols). SMU16 moderately dissected plateau sandy clay loam, 0-2% slope, very strongly acidic, deep phase (Umbric Fluvisols). SMU17 up-stream low land plains and plateau sandy clay loam, >30% slope, very strongly acidic, very shallow phase (Dystric Leptosols). SMU 18 upstream low land plains and plateau loam, 0-2% slope, extremely acidic, very deep phase (Humic Lixisols). SMU 19 High to mountainous relief hills loam, clay loam and sandy loam, 15-30% slope, strongly acidic, moderately deep to very deep phase (Humic Lixisols and Humic Chromic Lixisols). SMU20 High to mountainous relief hills loam, 2-8% slope, very strongly acidic, very deep phase (Humic-Rhodic Lixisols). SMU21 Upstream low land plains and plateau sandy loam, 2-8% slope, strongly acidic, very deep phase (Humic-Chromic Lixisols). SMU 22 moderately dissected plateaux clay loam, 0-2% slope, very strongly acidic, moderately deep to deep phase (Umbric Nitisols). SMU23 moderately dissected plateaux sandy loam and clay loam, 15-30% slope, moderately acidic, deep to very deep phase (Mollic Nitisols). SMU 24- moderately dissected plateaux clay and loam, 2-8% slope, extremely acidic, moderately deep to very deep phase (Mollic-Rhodic Nitisols). SMU25 high to mountainous relief hills clay loam, sandy clay and sandy clay loam, 8-15% slope, strongly acidic, very deep phase (Mollic-Rhodic Nitisols). SMU26 upstream low land plains and plateau loam, clay loam, 0-2% slope, very deep, extremely acidic, gilgai phase (Pellic-Mesotrophic Vertisols). SMU27 upstream low land plains and plateau clay loam, 2-8% slope, strongly acidic, very deep, gilgai phase (Mesotrophic Vertisols). SMU28 upstream low land plains and plateau clay loam, 2-8% slope, strongly acidic, deep, gilgai phase (Pellic-Mesotrophic Vertisols)

(Table 1).

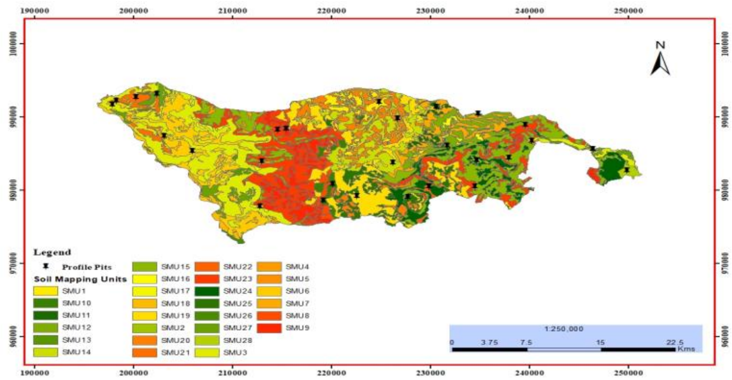

Figure 14: Distribution of soil mapping units (SMU) and profile pit points across landscape in the study area.

Major soils

In the study site, seven major soil types namely Cambisols, Acrisols, Nitisols, Lixisols, Vertisols, Fluvisols, and Leptosols. Covering 30.24% of the total area, Cambisols stand as the dominant soil type in the study site followed by Acrisols (22.12%), while Leptosol constitutes only 0.4% of the total area (Table 2 and Figure 3). Cambisols-soils containing Chromic-Dystric/Mollic-Eutric/Mollic-Rhodic surface horizon and cambic and leptic subsurface horizon were observed over different landforms (SMU 8, 9, 10, 11, 12, 13, 14 and 15) including level plain and plateaus. This indicated that Cambisols formation was not limited by landform and slope variations. Chromic- Dystric Cambisols designated by SMU8 were developed moderately dissected plateau enriched with clay where as Leptic Cambisols (Eutric) designated as SMU10 were identified at upper slope position of plateaus in the cultivated land having >30% slope. Covering 18649.64ha w/h becomes 30.24% of the total area.

Table 17: Soil mapping units, major soil types and soil series with qualifiers, and selected physical and morphological properties

SMU	Major soil types and soil series	Land cover (%)	Dominant Color		Dominant Texture	
			Surface	Sub-surface	Surface	Sub-surface
SMU1	Umbric Acrisols	1.56	7.5YR2.5/3	5YR2.5/1	L	CL
SMU2	Leptic-Humic Acrisols	0.15	7.5YR3/2	2.5YR3/6	SCL	C
SMU3	Leptic Acrisols	13.76	10YR2/1	10YR3/2	SL	SCL
SMU4	Humic-Chromic Acrisols	0.39	7.5YR3/1	5YR4/4	SCL	SCL
SMU5	Umbric-Chromic Acrisols	0.14	5YR2.5/2	5YR3/3	SL	CL
SMU6	Humic-Chromic Acrisols	7.45	5YR4/4	2.5YR3/4	L	L
SMU7	Humic-Chromic Acrisols	3.66	7.5YR3/2	7.5YR3/1	SL	SCL
SMU8	Chromic-Dystric Cambisols	1.54	5YR3/3	5YR3/4	C	SL
SMU9	Leptic Cambisols	4.87	10YR2/1	5YR3/4	SL	SL
SMU10	Chromic-Eutric Cambisols	1.01	7.5YR2.5/3	5YR3/4	C	CL
SMU11	Leptic Cambisols	0.92	7.5YR3/2	7.5YR3/1	L	L
SMU12	Mollic Cambisols	3.33	5YR2.5/2	5YR3/3	CL	L
SMU13	Mollic Cambisols	0.41	7.5YR3/2	10YR3/1	SC	L
SMU14	Mollic-Rhodic Cambisols	6.84	5YR3/3	5YR3/4	C	SL
SMU15	Mollic-Chromic Cambisols	11.32	5YR3/2	5YR3/3	C	CL
SMU16	Umbric Fluvisols	0.5	5YR3/3	5YR3/4	SC	SCL

SMU17	Dystric Leptosols	0.4	5YR3/4	a	SCL	a
SMU18	Humic Lixisols	1.15	5YR3/2	2.5YR3/4	L	C
SMU19	Humic Chromic Lixisols	9.34	5YR3/2	5YR2.5/2	SL	CL
SMU20	Humic-Rhodic Lixisols	5.88	5YR3/3	5YR3/4	L	L
SMU21	Humic-Chromic Lixisols	1.49	7.5YR3/2	5YR2.5/2	SL	L
SMU22	Umbric Nitisols	0.23	2.5YR2.5/3	2.5YR4/6	CL	C
SMU23	Mollic Nitisols	12.55	7.5YR3/3	5YR3/4	CL	C
SMU24	Mollic-Rhodic Nitisols	4.88	2.5YR3/4	2.5YR3/3	C	C
SMU25	Mollic-Rhodic Nitisols	3.4	5YR3/3	5YR3/4	C	C
SMU26	Pellic-Mesotrophic Vertisols	0.35	10YR2/1	10YR2/1	L	C
SMU27	Mesotrophic Vertisols	2.01	10YR4/3)	7.5YR3/2	CL	C
SMU28	Pellic-Mesotrophic Vertisols	0.47	10YR2/1	10YR3/1	CL	C

SMU, Soil mapping Unit; CL, Clay loam; L, Loam; SCL, Sandy clay loam; C, Clay; SL, Sandy Loam; SC, Sandy Clay; S, Sandy. Though the dominant colour was expressed based on Hue, it did not mean that soils with similar Hue had the same colour, because they differ in 'value' and 'chroma' resulting in colour variation with depth within soil profiles and among SMUs. [a]SMU 17 (Leptosols) did not show subsurface colour and texture, since subsurface horizons were absent.

The RSG of the Acrisols holds soils that are characterized by accumulation of low activity clays in an *argic* subsurface horizon and by a low base saturation level. Acrisols of the study area are the dominant soils found in the form of Humic-Chromic Acrisols, Umbric-Chromic Acrisols, Leptic Acrisols, Humic-Abruptic Acrisols, Leptic Humic Acrisols, Humic-Rhodic Acrisols, Umbric-Rhodic Acrisols, and Umbric Acrisols distributed in all the landscape units (SMU 1, 2, 3, 4, 5, 6, and 7). This soil has an areal extent of 16724.92 (27.12%) of the major soils of the districts.

Nitisols are deep, well-drained, red, tropical soils with diffuse horizon boundaries and a subsurface horizon with more than 30 percent clay and moderate to strong angular blocky structure elements that easily fall apart into characteristic shiny, polyhedric ('nutty') elements. Nitisols are strongly weathered soils. The Nitisols of the study area are found in the form of Mollic Nitisols, Umbric Nitisols and Mollic-Rhodic Nitisols covering 12992.02ha (21.06%) of the total area. Lixisols of the study area is found in the form of Humic Lixisols, Humic-Chromic Lixisols and Humic-Rhodic Lixisols designated in the soil mapping units of SMU 18, 19, 20 and 21. It covers 347, 424 hectares (12.7%) of the total area. This mapping unit has a texture of loam, 0-2% slope, very deep effective soil depth of >150cm, well drained, moderate medium sub angular blocky structure, moist surface colour of black to dark reddish brown (10YR2/1 to 5YR3/2).

It is distributed in the form of Mesotrophic Vertisols and Pellic-Mesotrophic Vertisols labeled by SMU 26, 27 and 28. Constitute 1745.44ha (2.83%) of the total study area. They occurred on gentle slopes (1–2%) dominated by very deep (>150 cm) loamy and clay soils (Table 2). They were widespread at lower slope position. Driessen and Deckers (2001) states the environment of Vertisols is depressions and level to undulating areas, mainly in tropical, semi-arid to sub humid and Mediterranean climates with an alternation of distinct wet and dry seasons. Pedoturbation and mulching of the soils are responsible for the regularity of color and clay distribution in depth of the horizons. Repeated rain and drying has resulted in the formation of this surface mulch. According to WRB, the aforementioned characteristics of the pedons qualify the soil to be classified as vertisols (2006).

Fluvisols were other major soils widely distributed along a riverside intensively cultivated during dry season and flooded during rainy season. It is found in the form of Umbric Fluvisols in moderately dissected plateau developed on volcanic materials and covering the total area of 306.17ha (0.50%) of the total area. Although Umbric Fluvisols of the SMU16 were identified in the plain and depression landforms enclosing 0–2% slope. Because of seasonal deposition of finer soil materials, they showed loamy soils deeper than 200 cm.

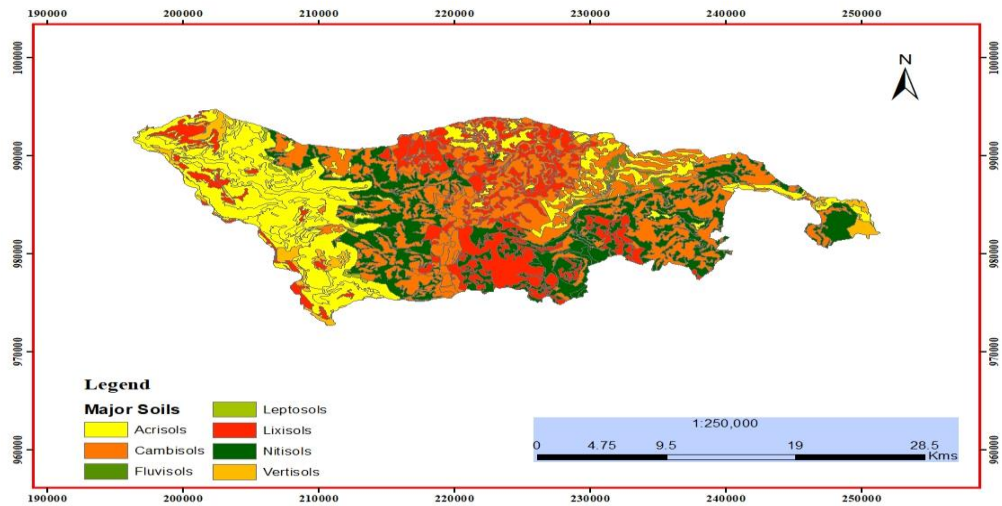

Figure 15: Map of distribution of major soils across the study area

LDP-4 and LDP-25 profiles have a shallow depth of less than 25 cm (Table 2). These soil types were found on the summit, shoulder, backslope, and upper foot slope in some cases. As a result of the lack of soil erosion management measures in the area, the soil is vulnerable or susceptible to increased soil removal or soil erosion. Based on WRB standards, shallow soils are classified as Leptosls (WRB, 2006). As soils of the study site were highly variable, it was difficult to recommend holistic management practice for the entire landscape. For this reason, the study site was classified into definite soil types at suitable scale for management.

LDP-4 and LDP-25 profiles have a shallow depth of less than 25 cm (Table 2). These soil types were found on the summit, shoulder, backslope, and upper foot slope in some cases. As a result of the lack of soil erosion management measures in the area, the soil is vulnerable or susceptible to increased soil removal or soil erosion. Based on WRB standards, shallow soils are classified as Leptosls (WRB, 2006). As soils of the study site were highly variable, it was difficult to recommend holistic management practice for the entire landscape. For this reason, the study site was classified into definite soil types at suitable scale for management.

Table 18: Soil Morphological and physicochemicals properties of each soil profiles.

Profile	Depth (cm)	Soil Horizons	Textural Class	pH (1:2.5)	EA	T.N	O.C	Av.P	Na	K	Ca	Mg	CEC	
					cmol(+)/Kg			(ppm)	cmol(+)/Kg					
LDP-1	0-25	A	CL	4.6	0.1	0.27	3.13	4.4	0.14	0.17	9.32	2.02	42.6	27
	25-65	B1	L	4.7	0.3	0.25	2.91	3.5	0.15	0.10	8.82	1.92	43.2	25
	65-105	B2	L	4.6	0.4	0.24	2.79	3.1	0.09	0.07	1.54	1.00	23.6	11
	105-200+	B3	CL	5.0	1.1	0.15	1.80	2.6	0.10	0.05	4.51	1.19	21.6	27
LDP-2	0-25	A	CL	4.9	0.88	0.191	2.21	7.00	0.24	0.50	7.77	2.91	27.4	42
	25-60	B1	C	6.1	2.24	0.096	1.12	7.88	0.20	0.23	4.93	2.00	27.3	27
	60-100	B2	C	5.1	3.536	0.062	0.72	6.56	0.21	0.29	4.83	1.82	24.6	29
LDP-3	0-30	A	L	4.8	1.36	0.289	3.35	7.88	0.17	0.16	4.42	2.55	40.0	18
	30-80	B1	L	5.2	6.87	0.229	2.65	3.06	0.24	0.31	4.60	2.46	38.0	20
	80-125	B2	CL	5.0	0.51	0.222	2.57	3.06	0.11	1.12	7.56	2.76	31.1	37
	125-200	B3	CL	5.0	3.40	0.175	2.03	10.94	0.13	0.54	7.04	2.36	43.3	23
LDP-4	0-25	A	SCL	5.0	1.97	0.227	2.63	6.56	0.22	0.61	2.83	0.87	17.6	26
LDP-5	0-30	A	C	5.2	0.61	0.187	2.17	1.75	0.13	0.30	9.78	2.63	22.0	58
	30-70	B	C	5.0	2.04	0.076	0.88	1.75	0.19	0.27	3.85	2.15	19.4	33
	70-140	BC	C	5.0	5.75	0.060	0.70	9.19	0.22	0.30	1.26	1.84	18.8	19
LDP-6	0-20	A	SL	5.8	0.4	0.52	5.99	42.0	0.15	0.57	24.16	4.40	52.6	56
	20-55	B1	SCL	5.0	0.7	0.25	2.91	43.3	0.14	0.22	13.26	2.41	39.0	41
	55-70	B2	SCL	4.4	3.1	0.17	2.00	43.3	0.18	0.20	10.66	3.01	30.8	46
LDP-8	0-30	A	SL	5.0	2.32	0.26	2.97	38.44	0.36	0.01	11.56	3.34	26.7	57
	30-65	B	SL	5.0	3.36	0.09	1.04	19.20	0.33	0.01	6.37	2.87	18.3	52
LDP-9	0-26	A	L	5.0	0.40	0.32	3.71	1.75	0.34	0.95	18.47	5.91	44.8	57
	26-85	AB	L	4.4	10.96	0.23	2.61	2.19	0.30	0.33	7.51	3.40	25.5	45
	85-135	B	C	4.5	10.16	0.16	1.88	2.63	0.29	0.06	6.92	3.73	24.6	45
	135-200+	B	C	4.6	0.80	0.03	0.34	3.50	0.31	0.01	8.48	4.93	28.9	48
LDP-10	0-38	A	L	5.0	0.32	0.50	5.83	4.38	0.27	0.01	20.51	8.34	49.5	59
	38-70	AB	L	4.4	11.92	0.23	2.71	3.94	0.25	0.01	7.66	2.06	22.1	45
	70-110	B	CL	4.3	9.92	0.17	1.98	1.75	0.25	0.01	6.30	1.98	20.8	41
	110-200		C	4.3	7.44	0.06	0.72	1.31	0.41	0.01	8.68	1.79	22.7	48
LDP-11	0-20	A	L	4.7	0.40	0.29	3.33	6.56	0.45	1.73	16.76	6.99	35.9	72
	20-40	B1	C	5.5	0.56	0.14	1.60	3.06	0.34	0.01	11.06	6.03	25.8	68
	40-110	B2	C	4.4	2.24	0.06	0.70	3.06	0.36	0.01	4.90	3.63	18.4	49
	110-200+	B3	C	5.1	3.44	0.05	0.62	2.19	0.34	0.01	3.80	2.84	15.4	45
LDP-12	0-40	A	CL	4.9	0.5	0.16	1.86	2.2	0.21	2.52	8.51	2.42	28.0	49
	40-85	B1	C	5.0	0.5	0.08	0.88	1.8	0.17	1.10	7.68	2.22	25.8	43
	85-120	B2	C	4.9	0.5	0.06	0.66	1.8	0.17	0.90	7.45	2.43	24.0	46

Horizon Boundaries (C, Clear; G, Gradual; D; Diffused) Soil texture (CL, Clay loam; L, Loam; SCL, Sandy clay loam; C, Clay; SL, Sandy Loam; SC, Sandy Clay; S, Sandy);

	120-200+	B3	C	4.9	0.6	0.03	0.38	1.2	0.17	0.22	9.99	5.26	29.6	53
LDP-13	0-45	A	L	4.0	9.4	0.30	3.47	4.4	0.32	0.01	7.96	3.72	21.06	57
	45-105	B1	CL	4.0	7.2	0.27	3.15	4.4	0.33	0.01	6.15	3.00	18.90	50
	105-145	B2	C	4.0	5.4	0.13	1.56	3.5	0.29	0.01	4.44	2.16	12.96	53
	145-190	B3	C	5.0	4.2	0.09	1.02	3.5	0.29	0.01	4.15	2.82	12.42	59
LDP-14	0-30	A	SL	5.1	0.2	0.21	2.41	10.5	0.17	0.27	11.01	2.20	29.0	47
	30-85	B1	L	4.8	0.3	0.18	2.03	5.7	0.25	0.19	9.29	1.75	28.6	40
	85-140	B2	L	4.8	0.7	0.17	1.94	5.3	0.07	0.20	2.90	0.61	35.4	11
	140-200	B3	SL	4.7	0.7	0.14	1.62	5.9	0.12	0.25	11.79	2.24	46.0	31
LDP-15	0-20	A	SCL	5.1	0.54	0.220	2.55	8.75	0.33	0.32	22.67	4.24	42.0	66
	20-80	B1	SCL	5.1	1.97	0.091	1.06	14.88	0.27	0.27	9.33	2.26	28.3	43
	80-133	B2	SCL	5.3	1.02	0.088	1.02	14.88	0.20	2.70	17.33	5.11	43.4	58
LDP-16	0-30	A	C	4.5	1.68	0.06	0.68	7.88	0.36	0.01	15.59	6.45	42.0	53
	30-80	AB	CL	4.6	1.20	0.31	3.59	5.25	0.34	0.37	20.56	6.94	45.6	62
	80-125	B1	C	4.5	0.80	0.07	0.86	6.13	0.38	0.02	16.06	6.27	34.1	67
	125-175	B2	C	4.4	2.00	0.04	0.52	5.56	0.40	0.01	13.05	7.08	34.7	59
LDP-18	0-20	A	CL	6.3	0.16	0.25	2.91	7.88	0.13	2.31	18.10	6.43	35.9	75
	20-80	AB	C	5.6	4.32	0.10	1.20	5.69	0.17	0.48	17.67	6.32	32.9	75
	80-150	B	C	5.5	0.88	0.05	0.54	2.19	0.20	0.52	14.00	5.79	26.8	77
	150-200	BC	C	5.6	2.4	0.06	0.66	1.40	0.20	0.75	15.33	5.83	28.7	77
LDP-19	0-40	A	C	5.0	8.96	0.23	2.65	3.50	0.14	0.09	9.15	3.45	22.9	56
	40-70	B1	SL	5.2	13.68	0.20	2.37	2.19	0.18	0.05	7.31	3.39	20.50	53
	70-135	B2	SL	5.1	15.76	0.16	1.90	1.31	0.16	0.04	6.74	2.62	18.9	51
	135-200	B3	SiL	5.3	14.00	0.09	1.04	1.75	0.22	0.03	7.05	3.01	19.2	54
LDP-20	0-15	A	L	5.2	0.54	0.292	3.39	40.69	0.11	0.50	19.55	7.79	61.6	45
	15-100	B1	L	5.5	0.88	0.014	0.16	42.44	0.12	0.28	21.56	6.52	53.2	54
LDP-21	0-25	A	SCL	4.9	0.40	0.10	1.16	16.63	0.21	0.01	6.40	3.66	18.4	56
	25-90	B1	C	5.0	0.24	0.04	0.52	5.69	0.22	0.32	8.89	3.52	22.0	59
LDP-22	0-25	A	SCL	5.0	1.97	0.227	2.63	6.56	0.22	0.61	2.83	0.87	17.6	26
LDP-23	0-30	A	C	4.4	1.76	0.15	1.76	3.06	0.35	0.24	12.65	5.37	33.1	56
	30-85	B1	C	4.4	1.36	0.08	0.88	2.19	0.35	0.01	9.74	4.23	28.7	50
	85-140	B2	C	4.3	0.96	0.04	0.42	1.75	0.35	0.01	10.51	4.30	26.4	57
	140-200+	B3	C	4.1	0.72	0.02	0.28	0.44	0.39	0.01	12.74	4.84	33.9	53
LDP-25	0-30	A	CL	4.1	5.36	0.19	2.23	3.50	0.21	0.16	12.41	4.29	29.5	58
	30-80	B1	C	4.1	7.12	0.12	1.36	2.19	0.20	0.01	11.01	4.48	28.7	55
	80-130	B2	C	4.0	2.72	0.09	1.02	2.19	0.23	0.01	10.90	5.19	28.4	57
	130-200+	B3	C	4.2	2.08	0.02	0.26	1.31	0.23	0.01	10.59	5.11	27.3	58
LDP-26	0-20	A	CL	5.0	0.68	0.218	2.53	3.06	0.10	1.13	7.34	2.68	34.5	33
	20-80	AB	C	5.1	0.95	0.103	1.20	5.25	0.09	0.30	5.17	1.84	29.1	25
	80-150+	B	C	5.0	1.50	0.074	0.86	2.63	0.11	0.24	4.32	1.78	30.3	21
LDP-27	0-20	A	L	4.1	5.76	0.31	3.55	8.31	0.36	0.54	5.87	2.95	20.2	48
	20-80	B	L	4.0	11.28	0.19	2.19	3.94	0.37	0.01	3.99	2.09	16.6	39

	80-200	BC	C	4.0	6.16	0.07	0.84	1.75	0.34	0.01	3.55	1.99	16.8	35
LDP-28	0-20	A	C	5.9	0.56	0.24	2.77	4.38	0.20	1.80	22.73	6.48	40.6	77
	20-55	AB	CL	5.7	6.32	0.13	1.50	3.06	0.24	0.57	22.45	7.02	38.7	78
	55-87	B	CL	5.8	6.80	0.10	1.20	2.19	0.24	0.51	18.75	7.24	35.7	75
	87-130	BC	C	5.7	6.08	0.08	0.92	1.75	0.26	0.47	19.66	7.96	43.3	65
LDP-29	0-25	A	CL	5.3	1.09	0.218	2.53	4.81	0.11	0.45	6.36	1.08	34.2	23
	25-80	AB	C	5.0	4.86	0.144	1.68	3.94	0.21	0.63	3.36	1.07	24.2	22
	80-120+	B	C	4.7	5.61	0.064	0.74	8.75	0.15	0.28	2.12	0.78	17.0	20

EA, exchangeable acids, OC, organic carbon; TN, total nitrogen; av. P, available phosphorus; CEC, cation exchange capacity;

Understanding the role of several soil properties together, and their interactions, may help to explain the cause of variation in soil productivity as defined by site-specific management zones. Management zones are needed when variation in soil characteristics that affect crop production like texture, soil fertility, acidity and so on is widespread (Delalibera *et al.,* 2012; Moshia *et al.,* 2014; Krishna, 2016). Following classification of the landscape into SMUs or management zones, critical levels and ranges of soil properties were used for management decisions. In that way, mean values of soil parameters under each SMU were compared with the critical values adopted by scholars. This comparison helped to identify the limitations and potentials of each mapping unit. That means, management requirement for each SMU would vary based on the critical levels. For instance, the pH of SMU9 was rated as strongly acidic; the pH of SMU1, SMU5 and SMU7 was slightly acidic; and the rest of the SMUs were moderately acidic based on the rating adopted by Bruce and Rayment (1982). This indicated that SMU9 was not suitable for most crops and, thus, requires application of chemical amendments such as lime. The productivity of slightly acidic SMUs might also benefit from application of chemical amendments but still they could be cultivated by growing of acid tolerant crop varieties.

Observed variation in soil properties

Individual soil properties and soil–landscape relations were best understood by classifying the study area into mapping units. After classification of the study site into SMUs, another activity performed was soil fertility evaluation for the top plow layer of the mapping units. The mapping units varied in terms of their fertility status. Analysis result showed that clay loam, loam, clay, silt clay, silt clay loam and silt loam were the most dominant surface soil textural classes in the area. Considering the entire study area as one unit (Table 3), the pH value varied from 4.0 to 6.3 with average value of 4.9. Increase in soil acidity coupled with the decrease in OC had possibly caused for K and P deficiency in most SMUs. According to Karltun *et al.,* (2013), except SMU 9 and 11 the mean values of available phosphorus were very low to low in all the SMUs. However, variation in levels of soil nutrients in the various SMUs presented in Table 1 indicates the need for variable rate fertilizer recommendations. This might be attributed to fixation of P in acid soils. Besides, the availability of P in most soils of Ethiopia continuously decline by the impacts of abundant crop harvest, land management practices and soil erosion (Dawit *et al.,* 2002; Birhanu *et al.,* 2016; Bereket *et al.,* 2018). Variation in available P content of the SMUs could be due to differences in strength of acidity, organic matter content, rocks, and amount of residual p-fertilizers found in the soils.

Table 19: Minimum, maximum, mean, standard deviation and coefficient of variation of surface soil chemical properties for surface soils of the study area

Statistic	pH (1:2.5)	EA(cmol(+)Kg^{-1})	T.N	O.C	Av.P(ppm)	Na	K	Ca	Mg	CEC	BS (%)
			%			(cmol(+)Kg^{-1})					
Min.	4	0.1	0.06	0.68	1.75	0.1	0.01	0.43	0.35	1.08	17.6
Max.	6.3	9.4	0.52	5.99	42	0.45	2.31	19.55	7.79	27.94	61.6
Mean	4.9	1.76	0.24	2.75	9.2	0.23	0.64	10.94	4.09	15.9	32.47
SD (±)	0.61	2.47	0.08	0.93	11.41	0.11	0.6	5.83	2.28	8.25	11.74
CV	0.12	1.38	0.33	0.33	1.22	0.45	0.92	0.52	0.55	0.51	0.36

EA, exchangeable acids, OC, organic carbon; TN, total nitrogen; av. P, available phosphorus; CEC, cation exchange capacity; BS, Base saturation; Min, Minimum; Max, maximum; SD, Standard deviation; CV, Coefficient of variation

The medium to high CEC in soils of the study site might be ascribed to dominance of clay soils as OC content was generally low. We found that OC, av. P and to some extent K were the most limiting soil parameters in almost all SMUs. Traditional crop residue burning after harvest and exhaustive grazing by livestock might be the main causes of extremely low soil OC in cultivated lands. High prevalence of soil erosion, possibly due to overgrazing leading to low herbaceous cover, accounts for low soil OC stocks across different land cover types (Vagen *et al.*, 2005; Vagen and Winowiecki, 2013). Agricultural practices like tillage can also accelerate depletion of soil nutrients and OC stocks (Conant *et al.*, 2007). Hence, land management practices such as conservation tillage, controlled grazing, crop residue incorporation and protecting land use change would be important strategies used to increase soil OC stock. Decrease in OC had possibly caused for K deficiency in most SMUs. According to EthioSIS (2014) ratings, mean TN was found to be 0.06% (low) and 0.41% (high) in the SMU3 and SMU10, respectively with the mean values of 0.24 % and other SMUs contain optimum TN.

On the basis of Hazelton and Murphy (2007) classification, soils of all SMUs had a fairly medium to high exchangeable Ca and Mg content. An exchangeable Ca values greater than 5 15.74 cmol (+)/kg soil is considered to be adequate for the nutrition of most crops. Based on similar author's ratings, exchangeable Ca was varied between 0.43 cmol (+)/kg (low) and 15.74 cmol (+)/kg (high) with the mean values of 10.94 cmol (+)/kg. Exchangeable magnesium which is greater than 1 cmol (+)/kg soil is believed to be adequate for plant nutrition (Metson, 1961).

Table 20: Ratings for mean values of selected surface soil chemical properties based on the critical values adopted by Hazelton & Murphy (2007) for exchangeable bases (Ca, Mg, K, Na) and CEC; Metson (1961) and OC; Havlin *et al.* (1999) for av. P; Bruce & Rayment (1982) for TN and soil pH

SMU	**pH Rating**	**T.N**	**O.C**	**CEC**	**Av. P (ppm)**	**Na**	**K**	**Ca**	**Mg**	**BS (%)**
		%		**($cmol_c$(+)Kg^{-1})**		**(cmolc(+)Kg^{-1})**				
SMU1	vsa	h	l	m	l	l	m	l	l	l
SMU2	Sa	l	vl	m	m	l	vl	m	h	m
SMU3	Ma	h	m	h	h	m	h	h	h	h
SMU4	Sla	m	l	h	l	l	l	m	h	m
SMU5	Sa	m	l	m	m	l	vl	m	h	m
SMU6	Sa	h	l	h	l	vl	h	m	m	l
SMU7	Ma	m	l	m	l	l	h	h	m	m
SMU8	Sa	m	l	m	l	l	m	l	l	l
SMU9	Sa	h	l	h	h	m	vl	h	h	m
SMU10	Sa	l	vl	vh	l	m	vl	h	h	m
SMU11	Sa	h	l	h	h	m	l	h	h	m
SMU12	Sa	h	l	vh	l	l	m	h	h	m
SMU13	Ma	h	l	vh	m	l	m	h	h	m
SMU14	Sa	m	l	m	l	l	vl	m	h	m
SMU15	Ma	m	l	vh	l	m	h	h	h	m
SMU16	Sa	m	l	vh	l	l	vl	vl	l	vl
SMU17	Sa	m	l	m	l	l	m	l	l	l
SMU18	Sa	h	l	h	l	m	h	h	h	h
SMU19	Sa	m	l	h	l	m	m	h	h	m
SMU20	Sa	h	l	vh	l	m	h	h	h	m

SMU21	Vsa	h	l	h	l	l	l	h	h	m
SMU22	Sa	m	l	h	l	vl	h	m	m	l
SMU23	Sla	m	l	h	l	l	vh	h	h	h
SMU24	Vsa	m	vl	m	l	l	m	l	l	l
SMU25	Vsa	m	l	h	l	l	vl	h	h	m
SMU26	Sa	m	l	h	m	l	m	m	h	m
SMU27	Sa	m	vl	h	l	m	l	h	h	m
SMU28	Ma	m	l	h	l	l	m	m	m	l

SMU, Soil Mapping Units; Sla, slightly acidic; Vsa, very strongly acidic; ma, moderately acidic; vl, very low; l, low; m, medium; h, high; vh, very high

The amount of exchangeable magnesium reported for the soils of the study area varied from 0.35 to 7.79 cmol (+)/kg with a standard deviation of 0.55. According to Metson (1961), the surface soils of the study area exchangeable potassium is rated from low to high. The mean values of exchangeable K (0.64cmol/kg) were optimum; there could be an increasing loss of all exchangeable cations in the study area due to continuous removal by crops without replenishment and vertical movement or leaching. Potassium uptake would be reduced as Ca and Mg are increased; conversely uptake of these two cations would be reduced as the available supply of K is increased (Havlin *et al*., 1999).

The CEC of the soils ranged from 1.08 to 27.94$cmol_c$ kg^{-1} (Table 3), and with a mean value of 15.9. They were higher in the highland areas than the lowlands. Pearson correlation matrix presented in Table 5 shows that OC was positively and significantly correlated with TN ($r^2 = 0.999$) at $p < 0.001$. Besides, exchangeable CEC was significantly and negatively correlated with EA ($r^2 = -0.397$) at $p < 0.05$. The moderate to high CEC in soils of the study site might be ascribed to dominance of clay soils as OC content was generally low. According to Brady and Weil (2002), CEC depends on the nature and amount of colloidal particles.

Table 21: Person correlation matrix among measured soil chemical properties

Variables	pH (1:2.5)	EA (cmol(+)Kg^{-1})	T.N	O.C	Av.P (ppm)	Na	K	Ca	Mg	CEC	BS (%)
			%			(cmol(+)Kg^{-1})					
pH (1:2.5)	**1**										
EA	-0.271	**1**									
T.N	0.199	-0.029	**1**								
O.C	0.182	-0.037	**0.999****	**1**							
Av.P	0.221	-0.141	**0.443****	**0.440****	**1**						
Na	-0.011	-0.089	0.280	0.278	**0.503****	**1**					
K	**0.376***	-0.300	**0.466****	**0.472****	-0.002	0.092	**1**				
Ca	0.263	-0.302	0.308	0.304	0.108	0.353	0.313	**1**			
Mg	0.269	-0.284	0.297	0.289	0.164	0.373	0.233	**0.944****	**1**		
CEC	0.266	**-0.397***	0.226	0.224	-0.057	-0.010	0.163	**0.717****	**0.686****	**1**	
BS	0.251	-0.071	0.216	0.204	0.237	**0.445***	0.244	**0.725****	**0.754****	0.115	**1**

EA, exchangeable acids, TN, total nitrogen OC, organic carbon;; Av.P, available phosphorus; CEC, cation exchange capacity; BS, Percent Base saturation.

Conclusion and Recommendations

Soil and landscape information was the basis for delineating the landscape units. 28 SMUs and Seven major soils were identified in the study area. The SMU3 comprised largest areal coverage, while SMU5 constitutes the smallest. The major soils investigated were Cambisols constituting the largest (30.24%) area of the study area; whereas Leptosols the smallest (0.4%) of the total area. The soil units were related to landform. Vertisols developed from alluvial deposits were distributed mainly on flat lands of savannah grasslands. Cambisols were observed at a variety of landforms including level plain, depressions and plateaus and over a wide range of slope gradient. On the other hand, Fluvisols were dominant at the floodplains of very gentle slope and valley position of the catenae. Strong soil variation was observed within and among SMUs.

The division of the study site into SMUs helped to understand the interrelations and interaction between soil properties. It also exposed the relationship between landform and other factors in shaping the nature of soil formed. Soil organic carbon and available phosphorus were the most limiting soil properties in all of the SMUs. Additionally, soil limits in the district include low nitrogen levels, soil acidity, poor drainage, flooding, and logging concerns. As a result, in order to boost agricultural production, distinct procedures to correct the individual problems of each soil must be taken. Overgrazing, monocropping, cultivation of steep slopes and soil erosion, and other agricultural practices were the main causes of low soil fertility. In general, the concept of soil–landscape relationships helps to categorize highly variable soils into relatively distinct management zones. Therefore, soil classification was developed to aid in land management.

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Monitoring Spatial and Temporal Variability of Soil properties on the basis of Agro-climatic Zones and Soil types in Rift valley areas, Oromia, Ethiopia

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Abstract

These study were conducted in three agro-ecological zones namely, Dega (Kofale district) and Woina dega (Nagele Arsi district) and Kola(Boset district to determine threshold values for soil parameters of varying land use, topography, season, agro-climatic zones and soil type and to determine best season of soil samples collection in West Arsi and East shewa Zones of oromia regional state. The soil sample were collected from different soil mapping units in terms of slope classes, soil type and land units and Arc GIS software applied. Soils of Dega (Kofole) were sandy clay loam; sandy loam and loam, Soil of woyina adega (Negelle Arsi) were sandy loam and loam whereas kollaa (Boset) soil were sandy loam, loamy sand followed by loam *in textural classes for the three-agro ecology zones respectively. Generally, sand size fraction dominated the study area. Soil pH values were varied among the land units at both seasons for three of agro ecology zones Soil pH of Dega ranged from strongly to moderately acidic, Woyina adega ranged as strongly acidic to moderately alkaline, Kollaa Neutral to moderately alkaline respectively. The results of this study showed that the mean of OC ranged as low to high in Dega, very low to low in Woyina adega as well as ranged as very low-to-low Kolla. The highest mean value of available phosphorus recorded were 19.09 mg kg-1 at dry season, The highest mean value of available phosphorus were recorded 18.28 mg kg^{-1}* and *the highest mean value of available phosphorus recorded were 18.72 mg kg-1 at dry season at Dega ,Woyin adega and Kolla respectively. CEC of soils under the different soil-mapping units varied from low to moderate at the Dega, ranged as medium to high at woyina adega ecological zone and high to very high range at kolla agro ecological zone of the selected (studied area). The highest mean value of exchangeable Ca^{2+} recorded were 9.88 Cmol (+)/kg at soil mapping unit (115) at moderate sloping area on Eutric Nitosols/pellic vertisols at Dega, The highest mean value of exchangeable Ca^{2+} recorded were 28 Cmol(+)/kg at soil mapping unit (22) at moderate sloping area on Eutric cambisols woyina adega* as well as *the highest mean value of exchangeable Ca^{2+} recorded were 40.3 Cmol(+)/kg at soil mapping unit (28) at moderate sloping area on Mollic andosols at dry season. Different values of exchangeable Ca^{2+}were recorded at different soil type at similar slope ranges*

Key word: ArcGIS, spatial and temporal, Agro-climatic zones

Introduction

Variation of soil properties from place to place (spatial) and with time (temporal) is one of the most inherent and unavoidable feature of the natural environment. Soil properties change in space and time and under anthropogenic activities such as different management practices and under natural conditions by soil-forming factors (Sydney and Jabro, 2011) Every element of the environment is characterized by its own variability, and at the same time, each element affects one or more other elements of the environment (Ahmed and Marc Van, 2011) be it given physical, chemical or biological processes. Soil physical and hydraulic properties vary over space and time from field to field as well as within fields. Temporal variability of the biophysical environment may occur by changes in soil characteristics and rainfall patterns over time (Strock and Cassel, 2001). Moreover, knowledge about spatial and temporal behaviour in the variability of nutrient status is the key for site-specific management trough precision agriculture techniques.

Soil properties vary spatially from a field to a larger regional scale affected by both intrinsic (soil forming factors) and extrinsic factors (soil management practices, fertilization, and crop rotation) (Cambardella and Karlen, 1999). The variation is a gradual change in soil properties as a function of landforms, geomorphic elements, soil forming factors and soil management (Buol *et al*., 1997). The variation of soil properties should be monitored and quantified to understand the effects of land use and management systems on soils. Geostatistical methods have been used successfully for predicting spatial variability of soil properties (Trangmar *et al.,* 1985; Gaston *et al.,* 1990; Cambardella *et al.,* 1994; Saldana *et al.,* 1998; Zebarth *et al.*, 2002; Lark, 2002; Dercon *et al.,* 2003).

To guide farmers and other stake holders monitoring and mapping the soil properties as per varying spatial, temporal, soil type, land use and agro-ecology zones is very critical. However, there is scarcity of spatial information on spatial and temporal variability of soil properties on the basis of agro-climatic zone in the country. In order to fill the aforementioned gaps and support the local community to suggest and estimate thresh hold values for analysis results of soil samples collected from different land use, season, agro-ecology zone and soil types the paper was proposed with the following specific objectives .

Objectives

- ✓ To determine threshold values for soil parameters of varying land use, topography, season, agro-climatic zones and soil type.
- ✓ To determine best season of soil sample collection

Material and Methods

Descriptions of the study area

The study was conducted by selecting representative three agro-climatic zones from mandate zones of Batu Soil Research Center. The study areas were selected on the basis of their agro ecologies. The selected agro ecologies were Dega, woiena Dega and Kola. These agro ecology, Kofale (dega) and Negele Arsi (woyina Dega) and Boset (Kola) district from West Arsi and East shewa Zones of Ormia Regional State.

Kofele District is found 272 kilometers far from Addis Ababa to south direction through Shashamane. Geographically Kofele district is located between 6^0 50’0” to 7^0 10’00” North latitudes and 38^0 40' 08" to 39^0 4' 0" East longitudes with total area coverage of 66097.1 hectares.

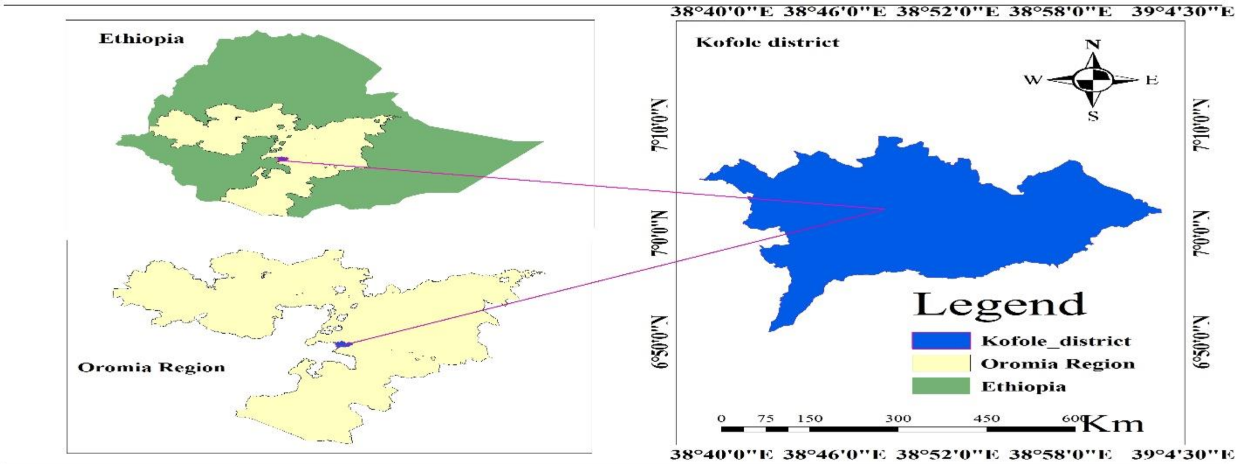

Figure 2:-Location map of study area

On the other hand, Negelle Arsi District is found in similar zone 231 kilometers far from Addis Ababa to south direction in between Batu and Shashamane town. Geographically Negelle Arsi District is located between 7^0 10'00" to $7^0$40 '00" North and 38^0 25'00" to 38^0 55'00" East with total area coverage 67514.73 hectares. The Elevation ranges from 1590 to 2512 meters above sea level, whereas the average elevation is 1909 meters above sea level.

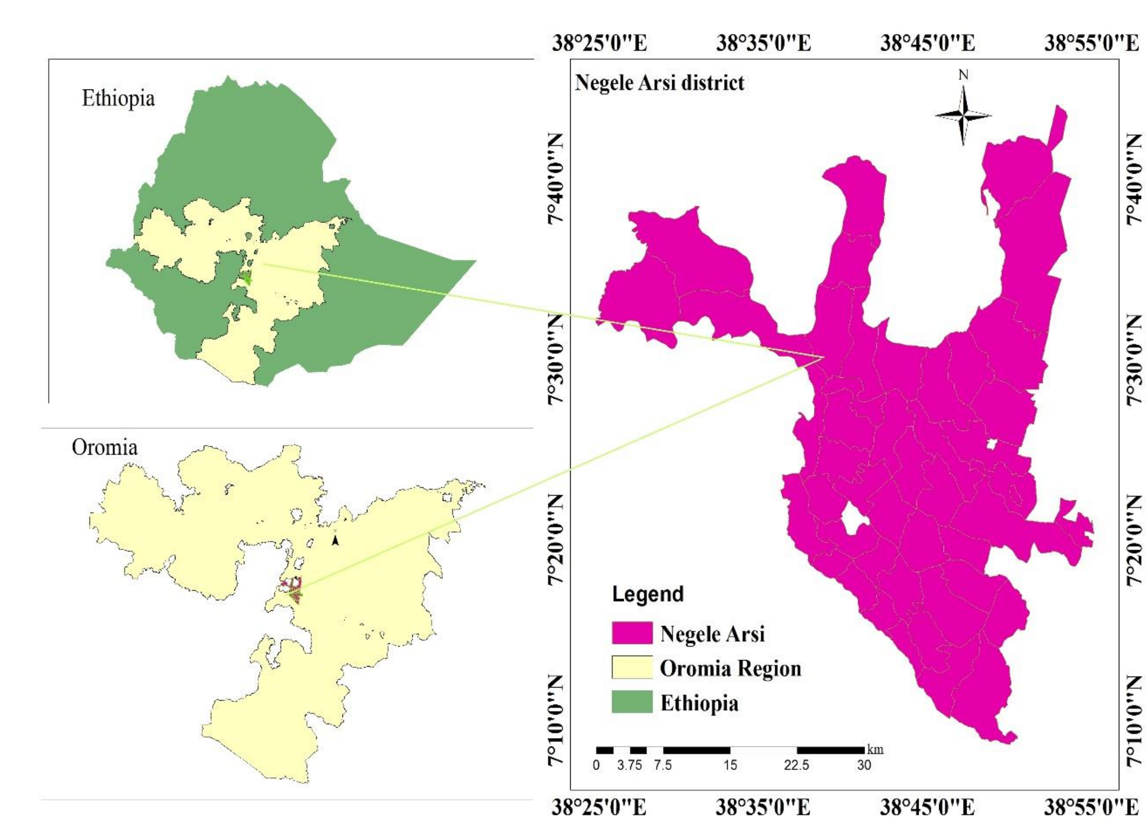

Figure 1:-Location map of the study area

The third selected area (Boset) district is found in East shewa zone, central rift valley of Ethiopia as representatives of Kolla ecological zone for our study. Geographically, Boset District is located between 8^0 20'00" to $9^0$00 '00" North and 39^0 20'00" to 39^0 50'00" East with total area coverage 67514.73 hectares. The Elevation ranges from 1200 to 1800 meters above sea level.

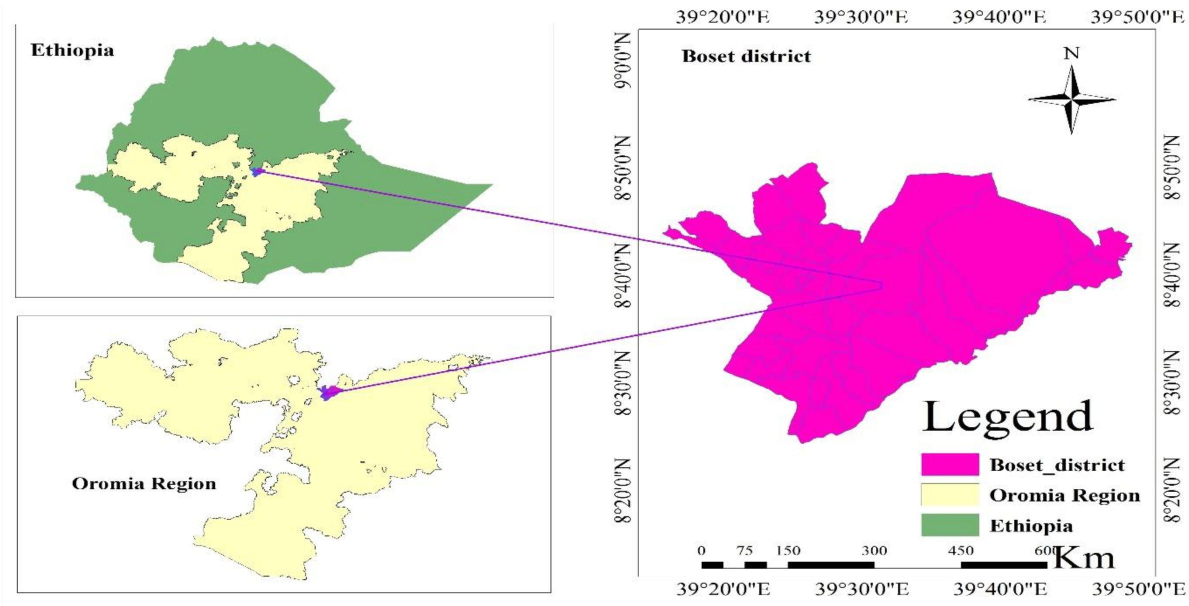

Figure 3:-Location map of the study area.

Land Use and Vegetation Cover

The main land use systems in the district are mixed (crop–livestock) agricultural system. The major crops produced are wheat (*Triticumaestivum*L.), maize (*Zea mays L*,), barley (Hordeumvulagare L.), potato (Salantumtuberosum), faba beans, (Viciafaba), field peas (Pisumstivum) and enset (*Enseteventricosum*). Besides, other cash crops (vegetables) are also produced widely. Agriculture is entirely rain fed. There are also different types of natural vegetation, grasses and waterlogged areas. *Land use land cover system of Neglle Arsi is similar to that of Kofele except availability of enset* also in Boset there is mixed agricultural system. The major crops produced are wheat (*Triticumaestivum*L.), Teff, maize (*Zea mays L*,), fruits and vegetables are common in the district

Data Collected:- Data were collected from both secondary and primary data such as **,** top sheet map, DEM, satellite image, soil map, geologic map, and administrative boundaries, auger soil samples, soil physical properties, texture, bulk density, soil chemical properties pH, CEC, EC, TN, Av.N, K, Av. P and OC.

Methods of Data Collection

Site selection and Soil Sampling

The whole study areas were considered and its agro-climatic zones, parent material/soil types/, topography (slope), land use, were analyzed separately and classified into different categories. These layers were collectively analyzed to identify the representatives of major classes of every factor. First of all, agro-climatic zone classes were fixed, and then soil types, then finally topography, and land use of the representative sites were fixed. In order to assess the physic chemical status of the soils in each agro ecological zone of each district, ten to fifty subsamples soils (at 0-20 cm depth) were collected from each land-mapping unit to form one composite soil samples based on quarter method

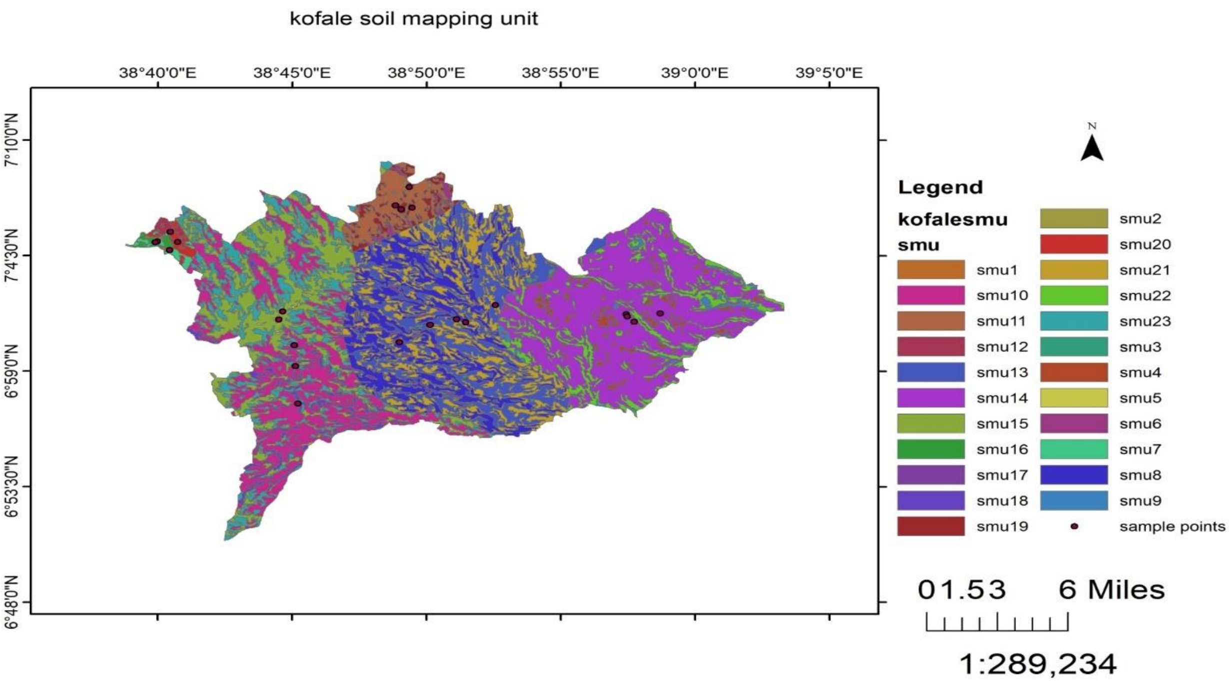

Table 1:-Important attributes of land units in Kofole district sampling point.

Smu	slope %	Land use	Soil type	Land units
06	2-8	Cultivated	Chromic luvisols	Wheat
12	16-32	Cultivated	Orthic luvisols	Wheat
13	16-32	Cultivated	Orthic luvisols	Wheat
14	16-32	Cultivated	Orthic luvisols	Wheat
46	16-32	Cultivated	Orthic luvisols	Wheat
58	16-32	Cultivated	Orthic luvisols	Wheat
115	2-8	Cultivated	Eutric Nitosols/pellic vertisols	Wheat
146	2-8	Cultivated	Eutric Nitosols/pellic vertisols	Maize
148	2-8	Cultivated	Eutric Nitosols/ pellic vertisols	Maize
149	2-8	Cultivated	Eutric Nitosols/ pellic vertisols	Wheat
107	2-8	Cultivated	Eutric Nitosols/chromic Nitosols	Wheat
189	2-8	Cultivated	Pellic vertisols /Lithosols	Wheat
169	2-8	Cultivated	Pellic vertisols /Lithosols	Wheat
208	2-8	Cultivated	Pellic vertisols /Lithosols	Wheat
160	16-32	Cultivated	Orthic Luvisols	Wheat

Note: smu=*Soil mapping units*

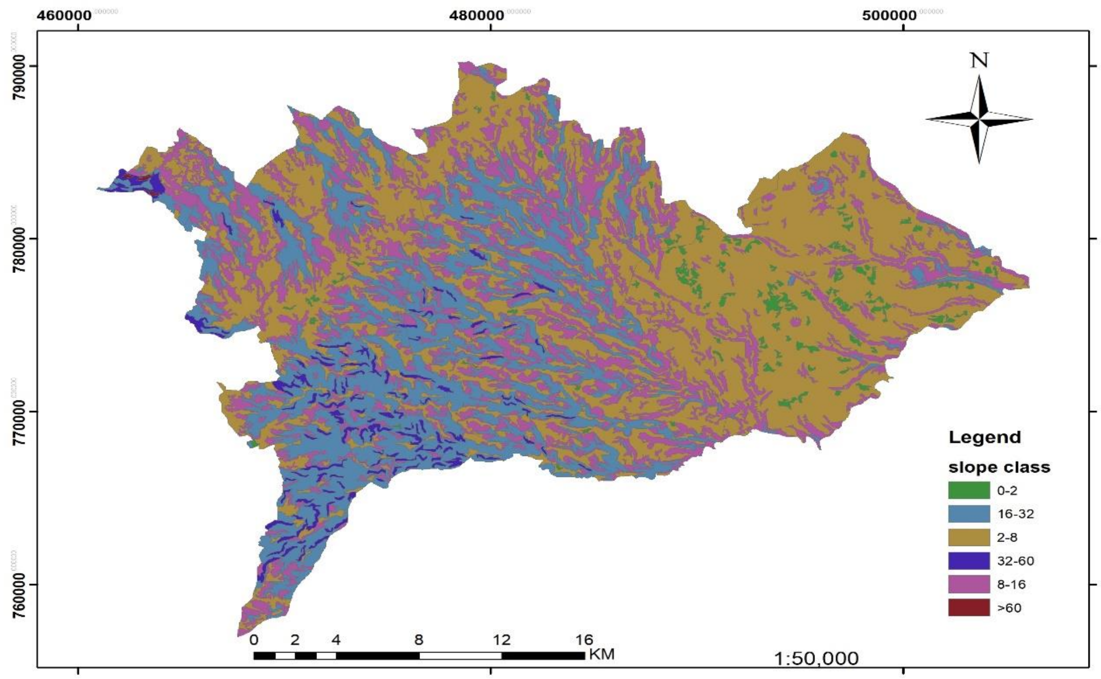

Figure 5:-Slope classes of kofole district

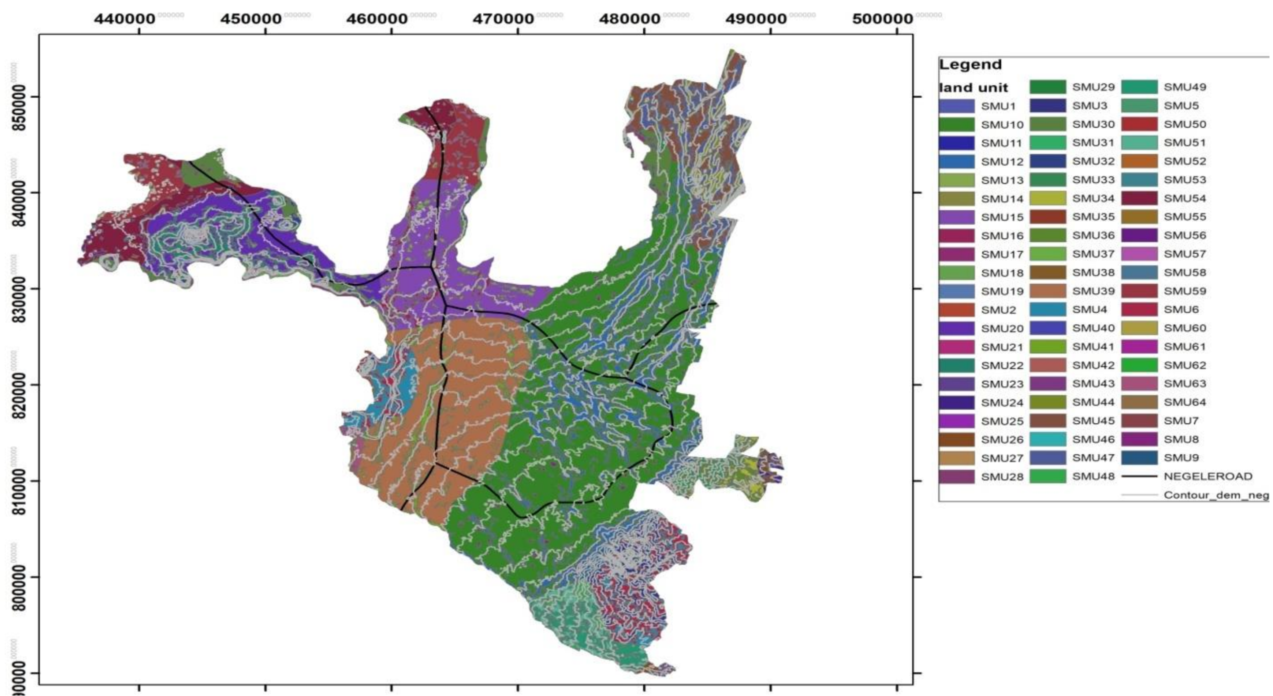

Figure 6: Negele Arsi soil mapping units

Table 2:-Important attributes of land units in Negelle Arsi district sampling point.

Smu	slope %	Land use	Soil type	Land units
03	2-8	Cultivated	Chromic vertisols/Eutric Nitosols	Wheat
04	2-8	Cultivated	Chromic vertisols/Eutric Nitosols	Wheat
06	2-8	Cultivated	Mollic Andosols	Wheat
09	2-8	Cultivated	Chromic vertisols/Eutric Nitosols	Wheat
10	2-8	Cultivated	Chromic vertisols/Eutric Nitosols	Wheat
15	2-8	Cultivated	Vitric Andosols	Wheat
18	2-8	Cultivated	Chromic vertisols/Eutric Nitosols	Wheat
20	2-8	Cultivated	Chromic vertisols/Eutric Nitosols	Wheat
16	2-8	Cultivated	Mollic Andosols	Maize
22	2-8	Cultivated	Eutric Cambisols	Maize
38	2-8	Cultivated	Mollic Andosols	Maize
39	2-8	Cultivated	Chromic Vertisols /Eutric Nitsols	Maize
49	8-16	Cultivated	Chromic Vertisols /Eutric Nitsols	Maize
59	8-16	Cultivated	Mollic Andosols/Eutric Cambisols	Maize

Note: smu=*Soil mapping units*

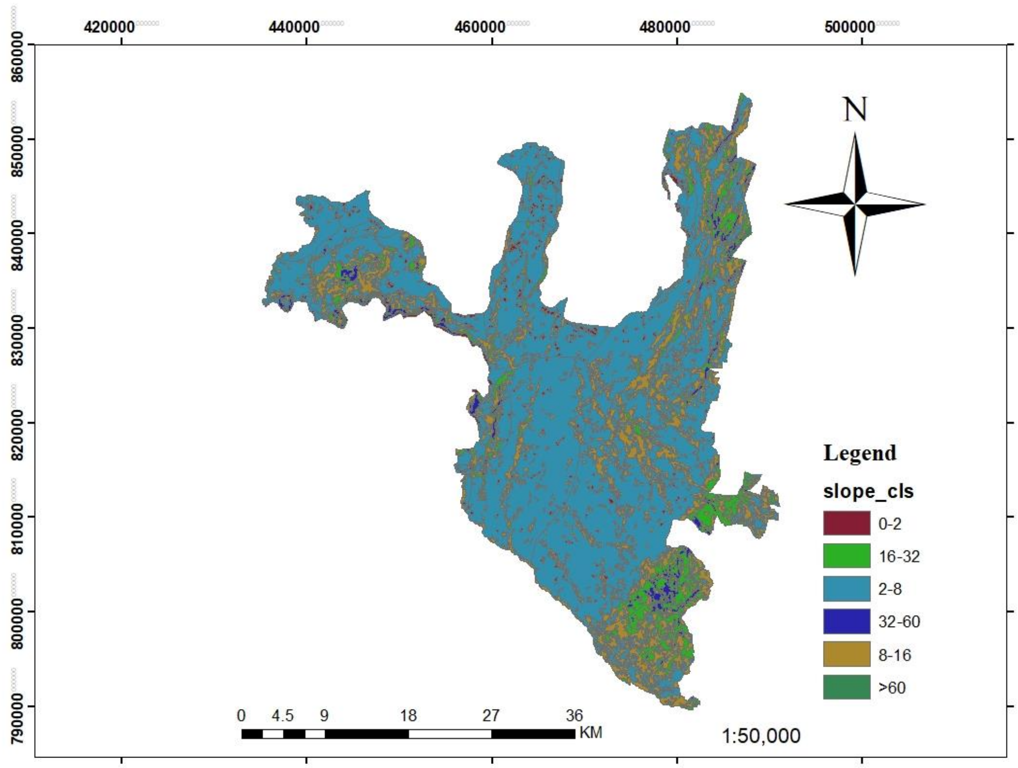

Figure 7:-slope classes of Negele Arsi

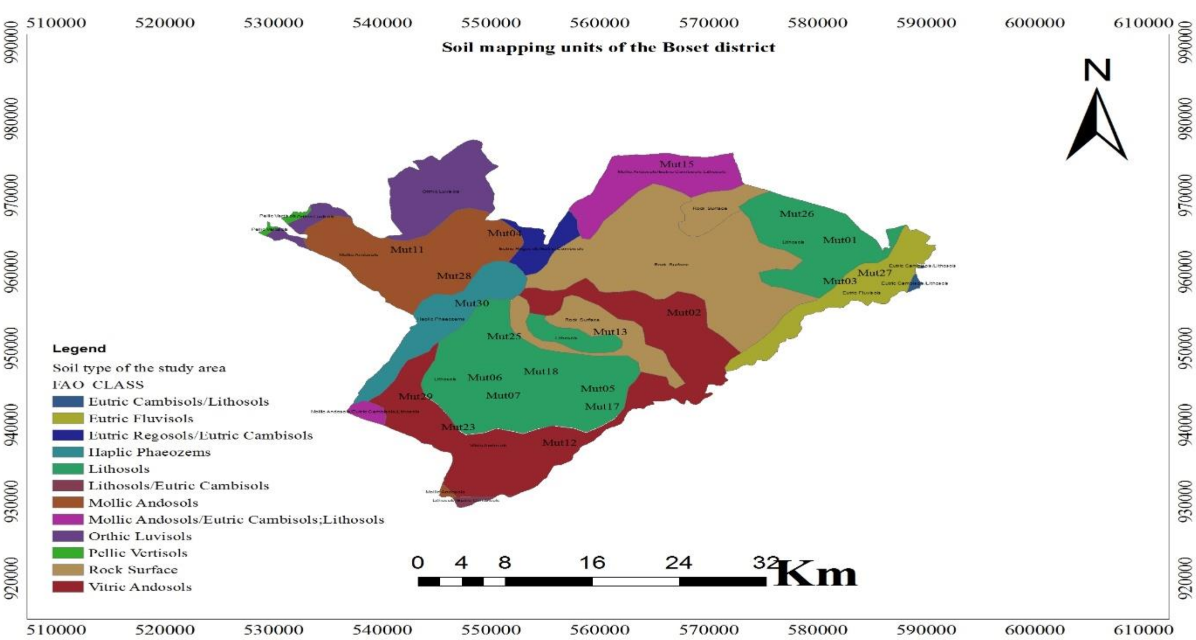

Figure 8:-Soil mapping units of Boset

Table 4:-Important attributes of land units in Boset district sampling point.

Smu	slope %	Land use	Soil type	Land units
01	2-8	Cultivated	Lithosols	Wheat
02	2-8	Cultivated	Vitric Andosols	Teff
03	2-8	Cultivated	Eutric Fluvisols	Wheat
04	2-8	Cultivated	Mollic Andosols	Wheat
05	2-8	Cultivated	Lithosols	Wheat
06	2-8	Cultivated	Lithosols	Wheat
07	2-8	Cultivated	Litho sols	Wheat
11	2-8	Cultivated	Mollic Andosols	Wheat
12	2-8	Cultivated	Vitric Andosols	Maize
13	2-8	Cultivated	Eutric Cambisols	Maize
15	2-8	Cultivated	Mollic Andosols /Eutric Cambisols	Maize
17	2-8	Cultivated	Lithosols	Maize
18	8-16	Cultivated	Lithosols	Teff
23	8-16	Cultivated	Vitric Andosols	Teff
25	2-8	Cultivated	Lithosols	Teff
26	8-16	Cultivated	Lithosols	Wheat
27	2-8	Cultivated	Eutric Fluvisols	Teff
28	2-8	Cultivated	Mollic Andosols	Teff
29	8-16	Cultivated	Vitric Andosols	Wheat
30	2-8	Cultivated	Haplic Phaezoms	Wheat

Note: Smu=*Soil mapping units*

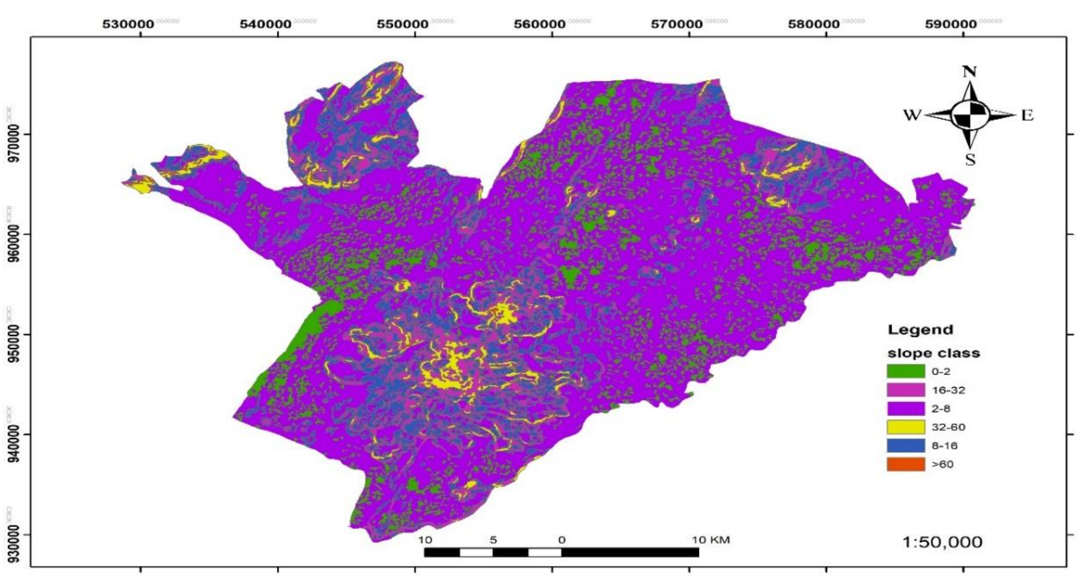

Figure 9: slope classes of Boset district

Season of Soil Sample Collection

- ✓ The time of sampling was started from the onset of rainfall season and at dry season.

Soil Sample Preparation

The sampled soils were carefully bagged, labeled, packed and transported to the Batu soil Research soil laboratory for analysis. The disturbed soil samples collected from each land units were grinded using mortar and pestle and made to pass through 2 mm sieve in the laboratory for all the selected soil parameters except for soil OC and total N prior to analysis. For the analysis of OC and total N, the soil samples were further passed through 0.5 mm sieve. Finally, the soil samples were analyzed for selected Physico-chemical properties following the standard analytical procedures.

Soil Laboratory Analysis

Analysis of Soil Physical and Chemical properties

Particle size distribution was analyzed on field by feel method and in the laboratory by the Bouyoucos hydrometer method using sodium hexametaphosphate as a 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 was determined using electrical conductivity meter as described by Sahlemedhin and Taye (2000). Organic carbon (OC) was determined using Walkley black method. Total nitrogen contents in soil were 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 soil samples with ammonium acetate. Amounts of Ca^{2+} and Mg^{2+} in the leachate were measured by titration using the EDTA method and K^{+} and Na^{+} were analyzed by flame photometry. Cation exchange capacity (CEC) was determined after saturating the samples with 1N ammonium acetate (pH =7) as described in (Okalebo *et al.,* 2002).

Results and Discussion

Selected soil physical properties at wet and dry Season of Kofele District

Soil texture

The mean data revealed that, three soil textural classes were observed in the study area for wet and dry season of Kofele District at different soil types, slope classes and land units. Soil textural classes of all soil-mapping units of the study area were loam, sandy loam and sandy clay loam throughout in the district for both seasons (Table 4).

Accordingly, the lowest mean sand content at wet (43.5%) and at dry (47.8%) was recorded on soil mapping unit 146 on Eutric nitosols/pellic vertisols on and 6 on chromic luvisols moderately sloping respectively; while the highest mean sand content at wet and dry season the same (67.5%) and was observed on soil mapping unit 46 and 14 on the same soil type (Orthic Luvisols) on steep slopes (16-32 % Figure 5). On the other hand, the lowest mean silt value (11.5%) and (13%) were recorded on smu 14 and 115 at wet and dry season of the study area respectively whereas the lowest mean value of clay (14%) content are recorded on smu160 ,while the highest mean value of clay were recorded on smu169 (Table 1).

Generally, sand size fraction followed by clay fraction dominates the study area. The textural classes recorded in soils of almost all the land units imply that, under natural conditions, the soils have good drainage. On the other hand, the high sand proportion may suggest relatively poor water retention capacity, which may make successful rain-fed agriculture difficult particularly under conditions of erratic rainfall. The slight difference in sand, silt and clay content among the land units could be related to variations in topography, slope, land use and management practices. Similarly, Thangasamy *et al*. (2005) reported that variation in soil texture may be caused by variation in parent material, topography, in situ weathering and translocation of clay.

Table 5:-Mean of Selected soil physical properties of different soil mapping units in kofele District at dry and wet season of 2011/2012 years.

SMU	Particle size distribution (%) (wet season)			Textural class	Particle size distribution (%) (dry season)			Textural class
				Class				Class
	Sand % Mean	silty% Mean	clay% Mean		Sand% Mean	Silty% Mean	Clay % Mean	
146	54	21	25	Sandy clay loam	56	21	23	Sandy clay loam
46	55.5	18	26.5	Sandy loam	55.8	26.2	18	Sandy loam
148	49.5	34.5	16	Loam	50	31	19	Loam
6	58	26.5	22.5	Sandy loam	47.8	32.2	20	Sandyloam
14	63.5	12.5	24	Sandy clay loam	67.5	10.5	22	Sandy clay loam
107	59.5	14.5	26	Sandy clay loam	60	25	15	Sandy clay loam
13	59.5	24.5	16	Sandy loam	60	23	17	Sandy loam
160	59.5	26.5	14	Sandy loam	59	27	14	Sandy loam
58	49.5	30.5	20	loam	50	31	19	Loam
189	55.5	22.5	22	Sandy clay loam	51	21	28	Sandy clay loam
115	55.5	22.5	22	Sandy clay loam	60	13	27	Sandy clay loam
208	59.5	18.5	22	Sandy clay loam	59	15	26	Sandy clay loam
149	56.5	13	30.5	Sandy clay loam	56	31	13	Sandy clay loam
12	59.5	18.5	22	Sandy clay loam	59.5	8.5	32	Sandy clay loam
169	59.5	11.5	30	Sandy clay loam	51	16	33	Sandy loam

Soil Chemical Properties

Soil reaction (pH)

Soil pH is a measure of the acidity or alkalinity of the soil. It plays an important role in the availability of nutrients essential for plant growth. Inherent factors that affect soil pH include climate, mineral content, and soil texture. Natural soil pH reflects the combined effects of the soil-forming factors (parent material, time, relief or topography, climate, and organisms. The soil pH values were varied among the slope, soil types and land units at both seasons. The highest pH mean values were recorded 5.9 % at dry season at SMU 13 on steep slopes (figure 5) and Orthics luvisols soil types (Table 1) whereas the lowest mean value were recorded 4.42% at wet season at SMU 149 (Table. 6) at moderately sloping (2-8%) figure 5 on Eutric Nitosols/Pellic vertisols. The variation in pH values among land units might be due to differences in parent material, topographic position, land use type, removal of basic cations by crop harvests, and prevailing weather conditions. In addition, previous studies have reported that factors associated with the variations in soil pH differ with locations and scales (Zheng Z., Wang, 2017).

Soil organic carbon

Organic Carbon: The level of soil organic carbon determines the multiplication of microorganisms and makes the system more dynamic. The results showed that the highest mean vale of OC was recorded 3.51% at dry season(Table 6) on SMU146 at moderately sloping area (figure 5) on Eutric Nitosols /Pellic vertisols whereas the minim mean values were recorded 0.37% at wet season (Table 6) at steep slopes on Orthic luvisols

The most probable source of variation in OC contents among soil mapping units might be variation in altitude, intensity of cultivation, cropping system and soil management practices. The highest OC contents of soil mapping units might be due to the contribution of vegetation cover and lower OM decomposition rates. On the other hand, the low levels of OC in the soil of mapping units might be attributed to continuous cultivation with complete removal of crop residue and limited application of farmyard manure**.** 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 lands. 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). Generally, the SOC of the study area was between low and high (Tekalign, 1991) who rated the values of OC as extremely very low (< 0.5%), low (0.5 - 1.5%), medium (1.5 - 3%) and high (> 3%).

Table 6: - Mean value of soil pH, Available P and Organic Carbon at wet and dry season for Kofele district 2011/2012 years

SMU	pH:H2O	pH:H20	Av.p (ppm)	Av.p(ppm)	OC (%)	OC (%)
	Mean	Mean	Mean	Mean	Mean	Mean
	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
146	5.77	5.74	6.16	9.68	2.35	3.51
46	5.84	4.96	6.77	11.96	3.33	2.21
148	5.54	4.56	7.88	11.68	2.45	2.16
6	4.81	5.45	7.00	10.92	2.06	2.54
14	4.62	4.84	12.96	10.6	2.55	2.65
107	4.26	5.49	15.08	10.2	2.35	1.51
13	5.62	5.9	18.07	19.09	2.65	1.14
160	5.33	4.88	9.98	10.2	2.53	1.12
58	5.6	5.51	7.84	11.24	0.64	0.84
189	5.43	4.57	9.5	10.52	2.59	2.00
115	4.62	5.2	12.06	14.2	0.84	2.20
208	4.72	4.64	9.94	10.32	0.64	1.63
149	4.42	5.3	8.46	11.28	0.62	1.19
12	4.81	5.67	5.36	9.36	0.37	1.44
169	4.62	5.4	10.32	12.3	2.73	1.04

Available Phosphorus

Soil available phosphorus values were varied among soil mapping units, slope and soil type at both season. The highest mean value of available phosphorus recorded were 19.09 mg kg-1 at dry season (Table 6) on SMU 13 at steep slope range (16-32%) on Orthic Luvisols whereas the lowest mean value of available phosphorus were recorded 5.36 mg kg-1at wet season (Table 6) on SMU 12 at the same soil type and slope that of SMU13 (Table 4).

The results showed that during dry season with less or no rain, there is no leaching of nutrients from the soil, which results in the accumulation of high nutrients. Less amount of available Phosphorus occurs in rainy season because of leaching due to rain and soil erosion. Ashraf *et al*., (2012) reported that soils with maximum leaching are known to contain low amount of phosphorus as compared to the soil with minimum leaching. Semwal *et al*., (2009) reported in their study that the available phosphorus was found maximum in winter season and that the reason was because more accumulation of minerals takes place in dry season.

Generally, according to (Jones, 2003), the Av. P contents of the soils in the study area ranged from low to high .According to this author, the Av. P extracted by Olsen method is rated for Av. P < 3 mg kg^{-1} as very low, 4-7 mg kg^{-1} as low, 8-11 mg kg^{-1} as medium, and > 12 mg kg^{-1} as high. Awdenegest *et al*. (2013) also argued that the higher Av. P in the topsoil layer of farmland might be related to the application of animal manure, compost, household wastes like ashes and fertilizer for soil fertility management. This finding is also in line with Girma and Endalkachew (2013) who pointed out that the relatively higher phosphorus in topsoil might be attributed to external phosphorus supply, and phosphorus carries over from fertilization.

Cation exchange capacity at wet and dry season at the District

Cation exchange capacity values were varied among soil mapping units, slope and soil type at both season. The highest mean value of CEC recorded were 14.0 (cmol $^{(+)}$ kg^{-1}) soils at SMU 146 (Table 7) at moderately sloping area (Figure 5) on Eutric luvisols/Pellic vertisols at dry season. The Lowest mean value recorded were 9.0(cmol $^{(+)}$ kg^{-1}) at SMU 6 on Chromic luvisols moderately sloping area at wet season. The CEC of the study area ranged from 9.0 to 11.56 (cmol $^{(+)}$ kg^{-1} for wet season where as it ranges from 12 to 14 (cmol $^{(+)}$ kg^{-1} for dry season (Table 7). As per CEC, rating indicated in Hazelton and Murphy (2007) the CEC of soils under the different soil-mapping units varied from low to moderate at the study area.

Low mean value of CEC was recorded at wet in soil of mapping units 6,160 14 and 149 on chromic luvisols Eutric Nitosols and Orthic Luvisols at different slope classes respectively. At dry season moderate range mean value CEC were recorded in all soil-mapping units at different slope classes, soil types and land units. The little or no rainfall at these periods might be due to the accumulation of the respective cation at the top soil. At these periods, there was little or no leaching of these cations and variation in CEC values of the studied soils might be the result of observed differences in OM and amount of clay, 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. In line with Alemayehu (2007) and, Fentaw and Yimer (2011) reported that depletion of OM as a result of intensive cultivation contributed to lower CEC of the soils. The lowest CEC in some soil mapping unit was in similar with the relatively low clay content under. This is in agreement with the finding of Teshome *et al.* (2013) in soils of Abobo area, Western Ethiopia, while high-recorded CEC in some soil-mapping unit were relatively due to high content of clay and Oc respectively than other land units. This is also in consent with findings of Yihenew *et al*. (2015) who revealed that high clay and organic matter contents contributed to high CEC . Based on mean values soil CEC at dry season soil sampling is a better time for sample collection.

Table 7.Mean vale of CEC and exchangeable cations at wet and dry season for kofele district 2011/12 Years

	Cmol(+)/kg soil									
SMU	CEC		Na		K		Ca2+		Mg2+	
	Mean		Mean		Mean		Mean		Mean	
	Wet season	dry season	Wet season	dry season	Wet season	dry season	Wet season	dry season	wet season	dry season
146	12	14	0.31	0.37	0.54	0.66	6	7	2.8	2.86
46	13.33	13.60	0.21	0.35	0.38	0.58	6.9	6.43	2.24	2.55
148	12.45	12.68	0.27	0.35	0.28	0.49	6.9	7.33	2.0	2.24
6	13.06	14.00	0.33	0.40	0.34	0.48	3.9	5.14	2.0	2.16
14	11.55	12.22	0.20	0.25	0.28	0.33	2.2	2.95	2.9	2.95
107	12.35	13.60	0.25	0.34	0.29	0.39	3.4	3.9	2.0	2.94
13	12.65	12.20	0.21	0.23	0.24	0.58	5.4	6.82	1.9	2.88
160	11.88	12.10	0.33	0.50	0.46	0.56	4.8	5.72	1.03	2.50
58	12.78	13.00	0.30	0.57	0.49	0.58	5.0	5.43	2.9	2.55
189	12.80	13.40	0.56	0.61	0.47	0.69	8.5	12.33	1.7	1.85
115	12.2	12.40	0.48	0.68	0.24	0.57	5.8	9.88	1.9	2.33
208	12.29	12.72	0.13	0.55	0.08	0.56	4.8	5.13	2.7	2.9
149	11.56	12.53	0.28	0.28	0.12	0.55	2.12	2.16	1.9	2.8
12	9	12.40	0.24	0.27	0.22	0.49	2.9	5.43	2.9	2.55
169	12.59	12.68	0.26	0.43	0.26	0.9	2.10	5.24	2.68	2.97

Note: *SMU=soil mapping unit*

Exchangeable basic cations

The mean value of Exchangeable bases in soils of different land units in the district also exhibited spatial variations **(**Table 7**).**The highest mean value of exchangeable Ca^{2+} recorded were 9.88 Cmol(+)/kg at SMU (115) at moderate sloping area on Eutric Nitosols/pellic vertisols (Table 1) at dry season. The lowest mean value of exchangeable Ca^{2+} were recorded 2.10 Cmol (+)/kg at (SMU 169)steep slopes (16-32%) on Orthic luvisols at wet season (Table 1).Generally exchangeable Ca^{2+} were higher at dry season at all soil type ,slope and land units than wet season. The highest mean value of exchangeable Mg^{2+} recorded were 2.97 Cmol (+)/kg at (SMU169) Table 7 at moderately sloping area on Eutric Nitosols/pellic vertisols at dry season (Table 1) whereas, the lowest mean value recorded were 1.03 Cmol (+)/kg at (SMU160) at steep slopes on Orthic luvisols.This also show that exchangeable Mg^{2+}were higher at dry season than wet season. The little or no rainfall at these periods might be due to the accumulation of the respective cation at the upper depth. At these periods, there was little or no leaching of this cations. The mean values Exchangeable K^+ and Na^+ also show the same trend higher at dry season. However, exchange complex was predominantly occupied by exchangeable Ca^{2+} followed by Mg^{2+}, K^+, and Na^+ (Table 7), which could be considered as essential for plant growth except Na^+.These basic cations in productive agricultural soils are present in the order $Ca^{2+} > Mg^{2+} > K^{+} > Na^{+}$ and deviations from this order can create ion-imbalance problems for plants (Bohn, 2001).

Selected Soil Physical Properties at Wet and Dry Season of Negelle Arsi District

Soil Texture

The physico-chemical properties of soil play an important role in the availability of nutrients and the microbial activity of soil. The mean data revealed that, two soil textural classes were observed in the study area at dry season and wet season of Negelle district at different soil types, slope classes and land units. The district was selected as woyina adega agro ecological zone. Soil textural classes of all soil-mapping units of the study area were sandy loam and Loam throughout in the district for both seasons (Table 8) . Accordingly, the lowest mean sand content (51 %) at SMU 04 at moderately sloping area on Chromic vertisols /Eutric Nitosols at wet season and similarly (51 %) was recorded on soil mapping unit 22 on Eutric cambisols on similary slope whereas the highest mean sand content at wet and dry season recorded were 69.5 % and 73% was observed on soil mapping unit 15 and 18 on Vitric Andosols and Chromic vertisols/Eutric cambisols at the same slopes (2-8) % Table 2). On the other hand, the lowest mean silt value (18 %) and (10.5%) were recorded on soil mapping units 49 and 18 at dry and wet season at same soil type (Chromic veritsols/Eutric nitosols) on different slope classes (Table 2) respectively whereas the lowest mean value of clay content(8%) were recorded at soil mapping unit 16 on mollic andosols (Table 2) at wet season also the highest mean value of clay 18% were recorded at sol mapping unit 3 (Table 8) on Chromic vertisols at wet season. Generally, sand size fraction followed by silt fraction dominates the study area. The textural classes recorded in soils of almost all the land units imply that, under natural conditions, the soils have good drainage

Table 8:- Mean of soil textural class at dry and wet season of Negele Arsi district 2011/2012

SMU	Particle size distribution %			Textural class	Particle size distribution %			Textural class
	at dry season				wet season			
	Sand% Mean	Silt% Mean	Clay% Mean		Sand% Mean	Silt% Mean	Clay% Mean	
3	59	32	9	Sandy loam	57.5	22.5	20	Sandy loam
4	52	31	17	Loam	51	31	18	Loam
6	59	28	13	Sandy loam	59.5	28.5	12	Sandy Loam
9	60	28	12	Sandy loam	63.5	24.5	12	Sandy loam
10	53	36	11	Sandy loam	61.5	26.5	12	Sandy loam
15	69	24	7	Sandy loam	69.5	16.5	14	Sandy loam
16	66	23	11	Sandy loam	59.5	32.5	8	Sandy loam
18	73	20	7	Sandy loam	69.5	10.5	20	Sandy loam
20	69	20	11	Sandy loam	59.5	25.5	15	Sandy oam
22	51	32	17	Loam	52	30	18	Loam
38	55	28	17	Sandy loam	51.5	30.5	18	Sandy loam
39	59	26	15	Sandy loam	53.5	32.5	14	Sandy loam
49	69	18	13	Sandy loam	53.5	28.5	18	Sandy loam
59	69	22	11	Sandy loam	55.5	22.5	22	Sandy loam

Note:SMU=soil-mapping units

Soil Chemical Properties

Soil pH

Soil pH is a measure of the acidity or alkalinity of the soil. It plays an important role in the availability of nutrients essential for plant growth. Inherent factors that affect soil pH include climate, mineral content, and soil texture. Natural soil pH reflects the combined effects of the soil-forming factors (parent material, time, relief or topography, climate, and organisms). The pH of newly formed soils is determined by the minerals in the parent material. Temperature and rainfall affect the intensity of leaching and the weathering of soil minerals. In warm, humid environments, soil pH decreases over time through acidification due to leaching from high amounts of rainfall. In dry environments where weathering and leaching are less intense, soil pH may be neutral or alkaline.

Soil pH values were varied among the land units at both seasons. The highest pH mean values were recorded 8.36 % at dry season at soil mapping unit 20 at moderately sloping area on chromic vertisols/ Eutric Nitosols. The lowest mean value 5.29 was recorded at soil mapping unit 15 (Table 9) at similarly slope on with smu 20 but the soil type was Vitric andosols at wet season (Table.2). The variation in pH values among land units might be due to differences in parent material, topographic position, land use type, removal of basic cations by crop harvests, and prevailing weather conditions. Generally, soil pH of the study area varied from 5.29 to 8.36, in accordance with the rating of (Jones, 2003) ranged as strongly acidic to moderately alkaline.

Table 9:- Mean of soil pH at dry and wet season of Negele Arsi district 2011/2012

Smu	3	4	6	9	10	15	16	18	20	22	38	39	49	59
Soil pH(Mean at dry season)	5.96	6.45	6.1	7.19	7.64	8.23	8.18	7.31	8.36	8.12	7.45	6.89	7.43	7.49
Soil pH (Mean) at wet season	5.64	6.25	5.93	6.9	5.94	5.29	6.72	7.46	7.45	7.59	6.82	6.79	6.69	6.52

Smu=soil mapping units

The result revealed that maximum pH was observed in dry season and the minimum was in wet (rainfall) season may be due to basic cations (e.g., Ca, Mg, and K) which are essential to living organisms are leached from top soil during rainy season.

Soil Organic Carbon

Organic Carbon: The level of soil organic carbon determines the multiplication of microorganisms and makes the system more dynamic. The results showed that the highest mean of organic carbon was recorded 0.88% (Table 10) at soil mapping unit 6 at moderately sloping on mollic andosols soil type at wet season (Table 2) whereas the lowest mean values were recorded 0.28 % at soil mapping unit 39 similarly at moderately sloping and on Chromic vertisols /Eutric Nitosols at dry season (Table 2). Soil organic carbon of study area varied from 0.28 to 0.88 in accordance with the rating of (Tekalign, 1991) ranged as very low to low. The result showed that declining trend during dry this may be due to high decomposition rate of organic matter. In consent with this findings (Hartel, 2005) reported that declining trend during the dry season may be because of organic carbon content decreases with increase in temperature and decomposition rates (microbial respiration) doubles with every 10^{o}C increase in the temperature

Table 10:-Mean of soil OM status for both dry and wet season at Negele Arsi district.

Smu	Mean of soil organic carbon at dry season (%)	Mean of soil organic carbon at wet season (%)
03	0.59	0.86
04	0.33	0.57
06	0.75	0.88
09	0.28	0.73
10	0.33	0.84
15	0.32	0.33
16	0.3	0.51
18	0.33	0.53
20	0.37	0.29
22	0.35	0.76
38	0.33	0.61
39	0.28	0.57
49	0.39	0.76
59	0.53	0.45

Available Phosphorous

Soil available phosphorus values were varied among soil mapping units at both season. The highest mean value of available phosphorus were recorded 18.28 mg kg^{-1} (Table 11) at soil mapping unit 6 at soil mapping unit 6 at moderately sloping on mollic andosols soil type at dry season (Table 2) .The lowest mean values recorded were 9.28 mg kg^{-1} at soil mapping unit 20 at moderate slope on Chromic vertisols/Eutric Nitosols. Generally, according to (Jones, 2003), the Av. P contents of the soils in the study area ranged from medium to high .According to this author, the Av. P extracted by Olsen method is rated for Av. P < 3 mg kg^{-1} as very low, 4-7 mg kg^{-1} as low, 8-11 mg kg^{-1} as medium, and > 12 mg kg^{-1} as high.

Table 11:-soil available phosphorus at dry and wet season at Negele Arsi district 2011/2012

(smu)	Mean of soil available phosphorus (mg kg-1) at dry season.	Mean soil available phosphorus (mg kg-1) at wet season
03	18.24	11.54
04	17.56	12.6
06	18.28	16.48
09	13.8	13.66
10	18.22	14.26
15	14.12	10.56
16	11.56	12.14
18	11.2	9.52
20	11.4	9.28
22	13.56	9.96
38	11.36	13.02
39	11.4	13.3
49	15.16	16.3
59	18.16	12.96

The results showed that during dry season with less or no rain, there is no leaching of nutrients from the soil, which results in the accumulation of high nutrients. Less amount of available Phosphorus occurs in rainy season because of leaching due to rain and soil erosion. Ashraf *et al*., (2012) reported that soils with maximum leaching are known to contain low amount of phosphorus as compared to the soil with minimum leaching. Semwal et al., (2009) reported in their study that the available phosphorus was found maximum in winter season and that the reason was because more accumulation of minerals takes place in dry season.

Exchangeable Bases (Ca, Mg, K, Na)

The mean value of Exchangeable bases in soils of different land units in the district also exhibited spatial variations **(**Table 12**).**The highest mean value of exchangeable Ca^{2+} recorded were 28 Cmol(+)/kg (Table 12) at soil mapping unit (22) at moderate sloping area on Eutric cambisols (Table 1) at dry season. The lowest mean value of exchangeable Ca^{2+} was recorded 7.10 Cmol (+)/kg (Table 12) at soil mapping unit (20) at (2-8%) slope on chromic vertisols/ Eutric Nitosols at wet season (Table 2).).Generally, exchangeable Ca^{2+} was higher at dry season at all soil type, slope and land units than wet season. The highest mean value of exchangeable Mg^{2+} recorded were 9 Cmol (+)/kg at sol mapping unit (38) Table 12 at moderately slope on mollic andosols at dry season (Table 2) whereas the lowest mean value recorded were 2.0 Cmol (+)/kg at soil mapping unit (18, 20) at moderate slopes on chromic vertisols .This also show that exchangeable Mg^{2+}were higher at dry season than wet season. The little or no rainfall at these periods might be resulted accumulation of the respective cation at the upper depth.

Table12:-Mean of Exchangeable bases and at dry and wet season 2011/2012

(Smu)	Exchangeable bases at dry and wet season in cmol(+)kg^{-1}							
	Mean of Exchangeable bases at dry season				Mean of Exchangeable bases at wet season			
	Ca	Mg	Na	K	Ca	Mg	Na	K
03	14	4	0.65	0.36	13.3	3.1	0.33	0.32
04	23	5	0.54	0.95	14.3	3.1	0.95	0.65
06	16	4	0.41	0.4	12.2	3.1	0.33	0.45
09	18	6	0.39	2.19	16.4	3.1	0.56	1.57
10	18	5	0.37	2.4	15.6	2	0.41	2.31
15	12	6	1.19	2.98	17.3	3.1	1.52	2.12
16	20	5	0.04	2.36	13.3	3.1	0.61	1.84
18	20	5	2.12	2.56	14.3	2	2.10	2.47
20	21	4	1.95	2.2	7.1	2	1.61	1.4
22	28	4	2.21	2.35	17.3	5.1	1.93	2.22
38	27	9	1.28	2.10	19.2	3.1	0.69	1.25
39	17	5	2.34	0.88	14.3	3.1	0.46	2.11
49	14.6	5	1.45	0.23	14.3	4.1	0.33	0.73
59	21	4	2.12	1.86	13.2	3.1	0.59	1.43

Cation Exchange Capacity

Soil cation exchange capacity values were varied among soil mapping units at both season. The highest mean cation exchange capacity values recorded were 41.cmol (+) kg^{-1} (Table 13) at soil mapping (38) at moderately sloping area on chromic vertisols/Eutric nitosols whereas lowest mean CEC value recorded were 23.36 cmol (+) kg^{-1}at soil mapping unit (03) on similar slope and soil type to soil mapping unit 38 at wet season. The highest mean cation exchange capacity at dry season recorded were 34 cmol(+) kg^{-1}at soil mapping (38) and the lowest mean recorded were 21.38 cmol(+) kg^{-1}(Table 13) at moderately sloping area on mollic andosols(Table 2). Generally, cation exchange capacity was higher at wet season at different, slope classes, soil type and land units type than dry season. The low values of cation exchange capacity (CEC) in the dry and beginning of rains in the study area might be due to the distribution of soil organic matter, as soil organic matter was found to have influenced the distribution of cations exchange capacity. Also, organic matter had been identified as a storehouse for cations (Schlecht *et al.,* 2006).

13:-Mean of Cation Exchange capacity at dry and wet season at Negele Arsi district 2011/2012

(smu)	CEC at dry season in cmol(+)kg^{-1}	CEC at wet season cmol(+)kg^{-1}
03	22.76	23.36
04	23.56	24.5
06	21.38	25.4
09	25.13	28.8
10	23.67	27.5
15	25.74	26.02
16	24.81	29.47
18	25.78	30.05
20	22.23	31.83
22	32.71	38
38	34.21	41
39	23.17	29.8
49	24.95	26.02
59	22.76	32

Selected Soil Physical Properties at Wet and Dry Season of Boset district

Soil texture

The mean data revealed that four soil textural classes were observed in the study area at dry season and wet season of Boset district at different soil types, slope classes and land units. The district was selected as Kolla agro ecological zone. Soil textural classes of all soil-mapping units of the study area were Loam, Loam sandy, Sandy loam and Sandy clay loam throughout in the district for both seasons (Table 14). Accordingly, the highest mean sand content (84 %) were recorded at soil mapping unit 25 (Table 14) at moderately sloping area on Litho sols(Table 4) at dry season where as the lowest mean value at dry season were 42% at similar slope but on vitric andosols. The highest mean value of sand content at wet season recorded were 83 % on at the same soil mapping unit, slope and soil type with dry season. Generally, sandy size fraction followed by silt fraction is the dominant soils around the study area. The textural classes of soils in almost all the land units are sandy loam, loamy sand followed by loam. The most probable reasons for the variation in the textural class in the study area might be differences in topography and parent material.

Table 14:- Mean of soil textural class at dry and wet season of Boset district 2012/2013

SMU	Particle size distribution %			Textural class	Particle size distribution %			Textural class
	at dry season				wet season			
	Sand% Mean	Silt% Mean	Clay% Mean		Sand% Mean	Silt% Mean	Clay %	
01	48	36	16	Loam	48	36	16	Loam
02	42	32	26	Loam	42	32	26	Loam
03	74	18	8	Sandy Loam	74	18	8	Sandy Loam
04	72	20	8	Sandy Loam	72	20	8	Sandy Loam
05	82	10	8	Loamy Sand	82	10	8	Loamy Sand
06	80	12	8	Loamy Sand	80	12	8	Loamy Sand
07	78	16	6	Loamy Sand	78	16	6	Loamy Sand
11	76	18	6	Sandy Loam	76	18	6	Sandy Loam
12	58	26	16	Sandy Loam	58	26	16	Sandy Loam
13	62	24	14	Sandy Loam	62	24	14	Sandy Loam
15	60	26	16	Sandy Loam	60	26	16	Sandy Loam
17	80	12	8	Loamy Sand	80	12	8	Loamy Sand
18	74	16	10	Sandy Loam	74	16	10	Sandy Loam
23	53	35	12	Sandy Loam	53	35	12	Sandy Loam
25	84	11	5	Loamy Sand	83	11	5	Loamy Sand
26	50	30	20	Loam	50	30	20	Loam
27	52	28	20	Loam	52	28	20	Loam
28	54	26	20	Sandy Clay Loam	54	26	20	Sandy Clay Loam
29	48	34	18	Loam	48	34	18	Loam
30	74	20	6	Sandy Loam	74	20	6	Sandy Loam

Soil pH of the Study Area

Soil pH values were varied among the soil type, slope and land units at both seasons. The highest pH mean values were recorded 7.88 at dry season at soil mapping unit 27 (Table 15) at moderately sloping area on Eutric Fluvisols (Table 4) whereas the lost mean value were recorded 7.25 at soil mapping unit 01 with similar slope to soil mapping unit 27 but on different soil type which is Litho sols. The variation in pH values among land units might be due to differences in parent material, topographic position, land use type, removal of basic cations by crop harvests, and prevailing weather conditions. Generally, soil pH of the study area varied from 7.25 to 7.88 in accordance with the rating of (Jones, 2003) ranged from Neutral to moderately alkaline. The highest pH might be might be attributed to the little rainfall and probably due to dry season.

Table 15: - Mean value of soil pH, Available P and Organic Carbon at wet and dry season for Boset district 2012/2013 years

SMU	pH:H2O	pH:H20	Av.p (ppm)	Av.p(ppm)	OC (%)	OC (%)
	Mean	Mean	Mean	Mean	Mean	Mean
	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
01	7.25	7.87	11.02	12.9	0.16	0.16
02	7.4	7.5	12.42	15.24	0.95	0.91
03	7.51	7.59	8.88	9.78	0.35	0.35
04	7.32	7.42	13.11	18.72	0.38	0.38
05	7.72	7.62	9.2	12.2	0.12	0.11
06	7.41	7.51	8.22	10.22	0.15	0.15
07	7.67	7.52	7.68	9.28	0.71	0.71
11	7.65	7.25	9.82	10.12	0.17	0.12
12	7.72	7.51	9.01	9.9	0.18	0.15
13	7.48	7.38	9.42	10.04	0.16	0.16
15	7.52	7.62	11.22	13.12	0.31	0.21
17	7.22	7.42	16.16	17.16	0.41	0.41
18	7.6	7.32	10.32	12.22	0.32	0.322
23	7.4	7.25	11.99	13.66	0.35	0.35
25	7.7	7.28	13.55	14.15	0.38	0.38
26	7.8	7.62	10.85	11.58	0.12	0.12
27	7.82	7.88	9.96	11.4	0.14	0.14
28	7.6	7.86	11.22	14.72	0.28	0.28
29	7.54	7.84	9.4	9.4	0.16	0.16
30	7.55	7.87	10.02	9.2	0.25	0.25
30	7.55	7.87	10.02	9.2	0.25	0.25

Note: smu=soil mapping unit

Soil Organic Carbon

The results showed that the highest mean of organic carbon was recorded 0.95% (Table 15) at soil mapping unit (02) at moderately sloping on vitric andosols soil type at wet season (Table 2) whereas the lowest mean values were recorded 0.11 % at soil mapping unit (05) at similar slope and on lithosols at dry season (Table 4).Soil organic carbon generally varied interms of slope, soil type and land units. Low of soil organic matter in the dry season might be due low rain and complete consumption. Soil organic carbon of study area varied from 0.11 to 0.95 in accordance with the rating of (Tekalign, 1991) ranged as very low to low. The result showed that declining trend during dry this may be due to high decomposition rate of organic matter.

Available Phosphorus

Soil available phosphorus values were varied among soil mapping units, slope and soil type at both season. The highest mean value of available phosphorus recorded were 18.72 mg kg-1 at dry season (Table 15) on soil mapping unit (04) at moderately sloping range (2-8%) on Mollic andosols whereas the lowest mean value of available phosphorus were recorded 8.8 mg kg-1at wet season (Table 6) at soil mapping (03) at the same slope on Eutric fluvisols (Table 4).

Generally, according to (Jones, 2003), the Av. P contents of the soils in the study area ranged from medium to high. According to this author, the Av. P extracted by Olsen method is rated for Av. P < 3 mg kg^{-1} as very low, 4-7 mg kg^{-1} as low, 8-11 mg kg^{-1} as medium, and > 12 mg kg^{-1} as high. The results showed that during dry season with less or no rain, there is no leaching of nutrients from the soil, which results in the accumulation of high nutrients. Less amount of available Phosphorus occurs in rainy season because of leaching due to rain and soil erosion.

Exchangeable Bases (Ca, Mg, K, Na)

The mean value of Exchangeable bases in soils of different land units in the district also exhibited spatial variations **(**Table 16**).**The highest mean value of exchangeable Ca^{2+} recorded were 40.3 Cmol(+)/kg (Table 16) at soil mapping unit (28) at moderate sloping area on Mollic andosols (Table 1) at dry season. The lowest mean value recorded was 20.5 Cmol (+)/kg (Table 16) at soil mapping unit (25) at (2-8%) range slope on Lithosols at wet season (Table 4).Generally, exchangeable Ca^{2+} was higher at dry season at all soil type, slope and land units than wet season.

According to (Tekalign, 1991) exchangeable Ca^{2+} of the study area found medium to very high range. The highest mean value of exchangeable Mg^{2+} recorded were 5.9 Cmol (+)/kg at soil mapping unit (28) (Table 16) at moderately slope on mollic andosols at dry season (Table 4) whereas the lowest mean value recorded were 3.1 Cmol (+)/kg at soil mapping unit (29) at steep slopes on vitric andosols. This also show that exchangeable Mg^{2+}were higher at dry season than wet season. Also exchangeable K^{+} and Na+ follow the same trend at given study area. The little or no rainfall at these periods might be resulted accumulation of the respective cation at the top soil.

Table12:-Mean of Exchangeable bases and at dry and wet season 2012/2013

(Smu)	Exchangeable bases at dry and wet season in cmol(+)kg^{-1}							
	Mean of Exchangeable bases at dry season				Mean of Exchangeable bases at wet season			
	Ca	Mg	K	Na	Ca	Mg	K	Na
01	30.7	4.8	3.34	2.37	25.7	5.6	2.5	2.3
02	34.6	4.8	5.57	2.54	24.6	6.6	4.8	2.4
03	6.7	3.8	1.2	2.15	22.7	4.8	2.2	2.11
04	15	3.25	2.52	2.75	22.9	5	2.52	2.52
05	8.6	4.8	2.18	2.21	23	4.8	2.18	2.61
06	9.1	4.35	2.12	1.96	24.1	5.35	2.78	2.96
07	10.6	4.8	0.36	2.13	21.3	5.3	2.36	2.78
11	13.6	4.22	2.12	2.16	24.6	8.22	2.32	2.9
12	14.1	3.32	2.25	2.35	22.1	6.32	2.9	2.96
13	31.7	4.8	2.76	2.37	25.7	5.34	3.15	2.73
15	17.6	4.55	2.12	2.34	20.6	5.55	2.98	2.67
17	17.3	5.6	2.61	2.3	22.3	5.8	3.61	2.87
18	18.1	4.2	2.12	2.12	22.91	4.2	2.68	2.55
23	29.8	4.8	5.99	2.76	24.8	4.8	4.99	2.96
25	20.5	4.2	2.26	2.2	20.5	4.2	3.26	2.86
26	36.5	4.8	2.82	2.56	28.5	4.8	3.22	2.94
27	24.2	3.8	1.9	2.11	24.2	3.8	2.9	2.44
28	40.3	5.8	3.21	3.71	28.3	5.8	3.21	3.66
29	16.1	3.3	3.1	3.25	32.1	3.1	3.19	3.74
30	12	3.2	2.6	3.1	22	5.6	3.6	3.79

Cation Exchange Capacity

Soil cation exchange capacity values were varied among soil mapping units at both season. The highest mean cation exchange capacity values recorded were 49.73cmol (+) kg^{-1} (Table 17) at soil mapping (28) at moderately sloping area on mollic andosols(Table 4) whereas lowest mean CEC value recorded were 25.5 cmol (+) kg^{-1}at soil mapping unit (29) at steep slope range on vitirc andosols.The highest mean cation exchange capacity at dry season recorded were 38cmol(+) kg^{-1}(Table17) at soil mapping (30) kg^{-1} at moderately sloping area on Haplic Phaezoms soil type (Table 4). Generally, cation exchange capacity was higher at wet season at different, slope classes, soil type and land units type than dry season.

Table 17:-Mean of Cation Exchange capacity at dry and wet season at Boset district 2012/2013

(smu)	CEC at dry season in cmol(+)kg^{-1}	CEC at wet season cmol(+)kg^{-1}
01	35.21	36.21
02	36.36	38.36
03	29.56	34.56
04	28.25	36.25
05	29.9	33
06	28.12	35.12
07	27.5	32.5
11	31.2	36.2
12	30.15	35.15
13	29.4	34.4
15	31.25	32.25
17	28.66	34.66
18	27.1	31.1
23	28.8	32.8
25	29.32	32.32
26	37.24	37.24
27	30.4	32.4
28	36.73	49.73
29	25.5	35.5
30	38.21	33.4

Conclusion and Recommendation

These study were conducted in three agro-ecological zones namely, Dega (Kofale district) and Woina dega (Negele Arsi district) and Kola(Boset district to determine threshold values for soil parameters of varying land use, topography, season, agro-climatic zones and soil type and to determine best season of soil samples collection in West Arsi and East shewa Zones of oromia regional state.Altitude, slope gradient, topography, land use type and soil management history were used for spatial and temporal variability soils of three agro ecology zones. Soils of Dega (Kofole) were sandy clay loam; sandy loam and loam, Soil of woyina adega (Negelle Arsi) were sandy loam and loam whereas, kollaa (Boset) soil were sandy loam, loamy sand followed by loam in textural classes for the three-agro ecology zones respectively. Generally, sand size fraction dominated the study area. Soil pH values were varied among the land units at both seasons for the three-agro ecology zones. However, highest pH mean values were recorded at dry season at agro ecological zone of studied area (Dega ,woyin adega and kolla).Laboratory result showed that highest mean value of OC were recorded at wet season at Dega agro ecological zone might be due to low microbial activities where as low mean value of OC were recorded at woyina adega and kolaa agro ecological zone at different slope classes, soil type and land units .The highest mean value of available phosphorus were recorded at dry season at all ecological zone selected area at all soil type ,slope classes and land units. High available phosphorus might be due to low leaching at dry season. Soil organic carbon and cation exchange capacity shows low mean value at all soil type, slope classes and land units at dry season in ecological zone of the studied area. All parameters show similar trend at dry season (high value were recorded at dry season than wet season Generally, based on all above results, dry season may be better for soil sample collection at any soil type ,slope classes and land units for all the of studied ecological zones

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