Evaluations of Soil Fertility Status of Bulala and Harawa Farms of Bale Zone, Ethiopia

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Abstract
A study with the objective of identifying the fertility status of soils under crop production farming system was conducted. For this study, two farms were selected purposively from South Eastern Ethiopia: Bulala farm from Gololcha district and Harawa farm from Ginir district of Bale Zone of Oromia. The two farms were found under the same management conditions and were categorized in blocks prior to the start of the study. Based on this soil samples were collected randomly from blocks of the two farms. Then the collected samples were submitted to Ziway Soil laboratory and were analyzed based on the standard procedure and they fertility status were categorized. The result revealed that the texture of the farms ranged from clay to sandy loam. Soil pH ranged from moderately acidic to moderately alkaline while EC in the very low rate in both farms. Total N was categorized under low to medium range. Organic carbon ranged from low to high while available P ranged from very low to high range. Available K ranged is in the high category. The CEC was grouped under the moderate to the very high category. Regarding the Exchangeable bases, exchangeable Na is categorized as a very low rate while the rates for the K, Ca and Mg were under the high category. Hence, the addition of organic and inorganic fertilizers based on the soil test based results, improving cultural practice to improve CEC and the activity of soil organisms to have the optimum and sustainable productivity of farmlands is advisable
Keywords: *Organic Carbon, Soil Test, Fertilizer, Exchangeable Bases, Soil Fertility*

INTRODUCTION

The population of the planet is growing dramatically. In order to meet the increasing demand for food, the farming community has to produce more and more (Mishelia and Zirra, 2015). Agriculture is the basis for the economy of Ethiopia. It accounts for the employment of 90 percent of its population, over 50 percent of the country's gross domestic product (GDP) and over 90 percent of foreign exchange earnings (ECACC, 2002).

On top of this, Ethiopia has a considerable land resource for agriculture. About 73.6 million ha (66%) of the country's area is potentially suitable for agriculture (Fasil, 2002) and the Ethiopian agricultural sector has a proven potential to increase food supplies faster than the growth of the population. However, under present situations, where the land is a limiting factor, it is impossible to bring more area under cultivation (extensive farming), so the farming community should tackle this challenge of producing more and more food with the available land only (intensive farming) (Mishelia and Zirra, 2015). Regardless of this fact, the production system is dominated by small-scale subsistence farming system largely based on low-input and low-output rain-fed agriculture. As a result, farm output lags behind the food requirement of the fast-growing population. The high dependency on rain fed farming in the drylands of Ethiopia and the erratic rainfall require alternative ways of improving agricultural production.

In Ethiopia productivity of land, however, has been decreasing with the increasing intensification of agriculture due to land degradation. The major causes of land degradation are unsustainable agricultural practices: farming on steep slopes without sufficient use of soil and water conservation measures, mono cropping, excessive tillage, or declining use of fallow without appropriate replenishment of soil nutrients, burning of crop residues, conversion of forests, woodlands and bushlands to permanent agriculture, or their excessive exploitation through fuelwood and timber harvesting, overgrazing of rangelands, and lack of proper soil organic matter management. Land degradation occurs in different forms on various land use types: On cropland, soil erosion

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occurs through water and wind; chemical degradation– mainly fertility decline due to nutrient mining and salinity; physical soil degradation due to compaction, sealing and crusting; biological degradation due to insufficient vegetation cover, decline in soil organic matter; and water degradation mainly caused by increased surface runoff (polluting surface water) and declining water availability due to high evaporation.

Of the mentioned land degradation types, depleted soil nutrient status due to long term cultivation with little or no fertilizer additions is the prime cause of low yields in Ethiopia that leads to hunger and starvation (Amuri et al., 2010). Appropriate soil fertility management requires reliable soil information in terms of pedological characteristics. According to Sun et al. (2003), however, soil properties vary spatially and temporally from a field to a larger region scale, and are influenced by both intrinsic (soil formation factors, such as soil parent materials) and extrinsic factors (e.g., soil management practices, fertilization, and crop rotation). Hence, the heterogeneity and variation of soil properties should be monitored and quantified for a better understanding of the influence of such factors as management and pollution, and finally for leading to more efficient farming practices.

In Ethiopia, the few existing soil resource inventories available are of small scale with the high level of generalization, which limits their use in soil fertility management in small scale farming systems. Therefore, smart agriculture is required for the sustainable use of soils that significantly determine the agricultural potential of an area. Thus, this study was initiated with the objective of identifying the fertility status of soils under a crop production farming system with implication to recommend management options.

MATERIALS AND METHODS

Description of Study Sites

Bulala and Harawa Farms are located in Golocha and Ginir districts of Bale Zone, Oromia region at distance of 522 km and 495 km, respectively from the Capital city, Addis Ababa, to south Eastern direction (Figure 1 and Figure 2). These districts are characterized by cereal – livestock based farming. Wheat, maize, teff, and barley are the dominant crops grown in the areas while animals like shallot, equines, and others are reared. The study area farms have an area of 1000 ha in size and belong to investors working in large scale farming of cereals, especially wheat.

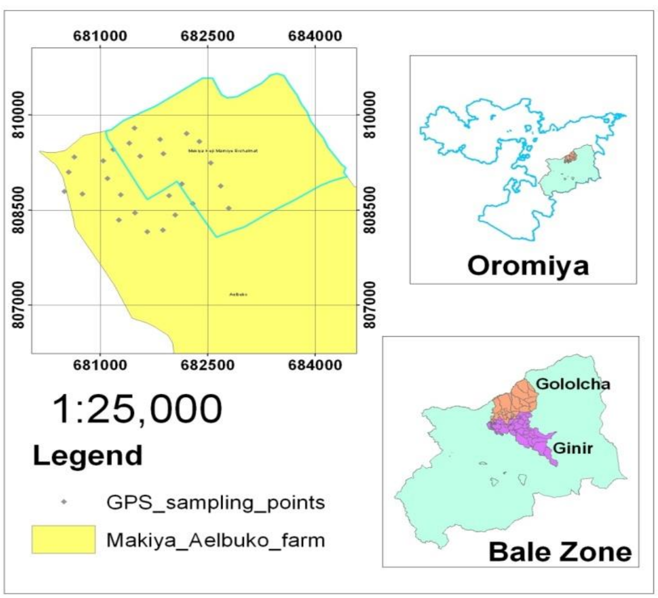

Figure 1: Study site and soil sampling points of Harawa Farms

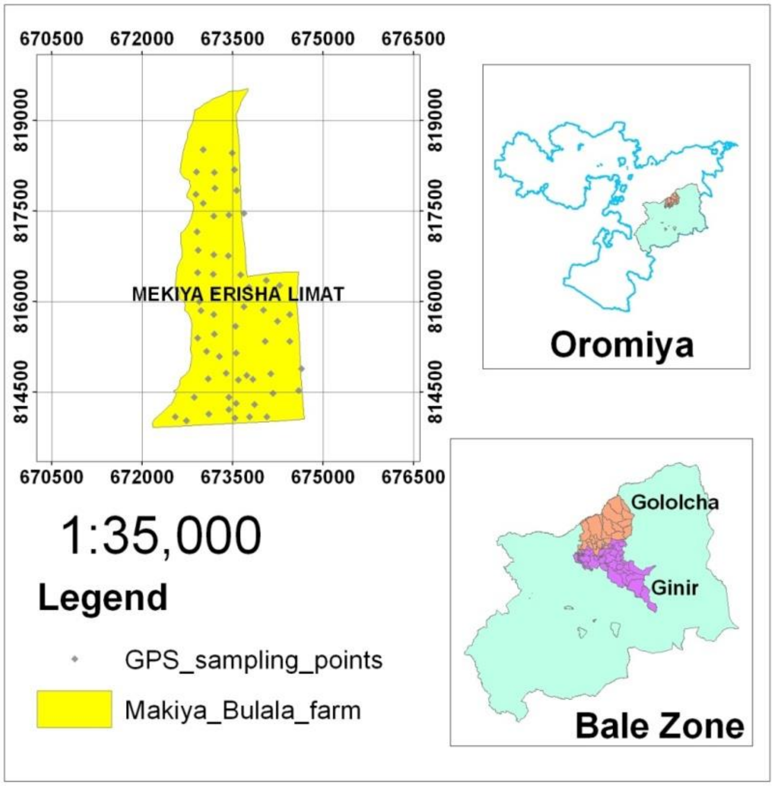

Figure 2: Study site and Soil sampling points of Bulala Farms.

Soil Sampling and Analysis

Prior to the start of the study, information on past cropping history (i.e., cropping wheat year after year) was collected. After this, 88 composite soil samples were collected from 18 blocks of the two sites (Bulala and Harawa Farms). During composite soil samples collection, each block was grouped into a number of sub-blocks based on block size and one composite soil sample at depth 0 – 20 cm was collected for each sub-block. Hence, thirty soil samples at different sampling point from one sub-block were collected to constitute one composite soil sample. Consequently, a number of composite samples differ from block to block depending on the block size. The collected composite soil samples were taken and submitted to Ziway Soil Research Center for the analysis of soil physicochemical properties.

Depending upon the basic soil laboratory principle, the soil samples submitted to the laboratory were prepared (air dried, grind by pistil and mortar, sieved to pass through a 2 mm) and the less than 2 mm size were used for chemical analysis for further analysis of the required parameter including soil pH, EC, Texture, OC, Available P, Exchangeable bases, and CEC.

The soil pH and EC were determined by pH and EC meters in 1:2.5 soil-water suspensions (Jackson, 1973). Determination of particle size distribution (texture) was carried out using the hydrometer method (Day, 1965). Organic Carbon was determined by Walkley and Black method; Total Nitrogen was analyzed using the micro Kjeldhal method as described by Bremner and Mulvaney (1982). Available Phosphorus was determined using the Olsen ($NaHCO_3$) extraction method (Olsen and Sommer, 1982).

Cation Exchange Capacity (CEC) of the soil was determined from ammonium-saturated samples that were subsequently replaced by sodium (Na) from a percolating sodium chloride solution. The excess salt was removed by washing with alcohol, and the ammonium that was displaced by sodium was measured by the Kjeldahl method (Chapman, 1965). Exchangeable Cations (K, Ca, Mg and Na) were extracted using the ammonium acetate (1M NH_4OACpH_7) method from which exchangeable Ca and Mg were measured with the EDTA titration method. While the extract of K and Na was read on flame photometer (Chapman, 1965).

Statistical Data Analysis

The collected data on soil physicochemical properties were presented using descriptive statics. And results were reported in the form of Mean ± StDv and interpreted, organized and summarized into their respective blocks.

RESULTS AND DISCUSSIONS

Soil Particle Size Distribution

Soil texture is perhaps the most fundamental and most permanent soil property, not readily subject to change by normal soil management practices in the field (Brady and Weil, 2002). The texture is an important soil characteristic because it, in part, determines water intake rates, water storage in the soil, the ease of tilling the soil, the amount of aeration and influences soil fertility (Sharma. 2002; Gupta, 2000). It is also a guide to the value of land, and as a result, land use capability and soil management practices are largely affected by the texture (Gupta, 2000). Moreover, the rate of many important chemical reactions in soil is governed by soil texture because it determines the amount of surface area available for reaction.

The textural class of Bulala farm is sandy clay loam while that of Harawa farm is clay loam (Table 1). The dominant textural class of Bulala is sandy loam (BB13, BB14, BB45, BB59 and BB60) followed by clay (BB29, BB30, BB44 and BB58) then by loam (BB28 and BB43) (Table 2) while in Harawa farm, it is in the order of clay loam (HB2, HB3, and HB5), loam (HB4 and HB6) and clay (HB1) (Table 3).

Table 1: Soil particle size distribution in Bulala and Harawa Farms.

Farms	Particle size distribution (%)			Textural Class
	Sand	Silt	Clay	
Bulala	49.35	25.08	25.57	Sandy clay loam
Harawa	31.79	35.40	32.81	Clay loam

Table 2: Soil particle size distribution in Farm Blocks of Bulala Farm (Mean + StDv)

	Soil particle size distribution			
Bulala Farm Blocks	Sand	**Silt**	**Clay**	Textural class
BB13	42.00 ±2.82	42.00 ± 1.41	16.00 ± 1.41	Sandy loam
BB14	54.90 ± 9.54	26.09 ± 6.02	19.00 ± 6.89	Sandy loam
BB28	44.66 ± 7.02	42.33 ± 3.05	13.00 ± 4.00	loam
BB29	28.33 ± 5.31	22.33 ± 5.60	49.33 ± 9.43	Clay
BB30	32.33 ± 7.02	23.00 ± 6.00	44.66 ± 7.02	Clay
BB43	45.66 ± 4.16	30.33 ± 3.05	24.00 ± 6.92	loam
BB44	31.00 ± 6.57	24.00 ± 3.50	44.66 ± 9.60	Clay
BB45	75.00 ± 3.74	14.20 ± 2.28	10.80 ± 1.78	Sandy loam

BB58	28.00 ± 6.71	30.00 ± 2.82	41.20 ± 7.69	Clay
BB59	58.84 ± 5.72	25.16 ± 4.30	16.00 ± 4.57	Sandy loam
BB60	75.4 ± 0.89	13.80 ± 1.09	10.80 ± 1.09	Sandy loam

Table 3: Soil particle distribution in Farm Blocks of Harawa Farm (Mean + StDv)

	Soil particle size distribution			
Harawa Farm Blocks	**Sand**	**Silt**	**Clay**	Textural class
HB1	27.00 ± 7.07	33.00 ± 4.24	40.00 ± 2.82	Clay
HB2	26.40 ± 2.96	35.20 ± 3.03	38.00 ± 3.28	Clay loam
HB3	29.00 ± 6.54	34.66 ± 4.67	36.33 ± 11.12	Clay loam
HB4	37.00 ± 2.58	48.00 ± 2.58	15 .00 ± 1.63	Loam
HB5	37.00 ± 12.82	23.33 ± 3.20	39.66 ±14.23	Clay loam
HB6	32.00 ± 2.30	43.60 ± 1.00	24.50 ± 1.91	Loam

Every textural class has its own characteristics including workability, soil nutrient, and water management. For example, loam soils have got good agricultural workability, and because of equal particle size distribution, it retains more nutrient and moisture than the others. On the other hand, heavy clay soils are bad in agricultural workability and also are characterized by the waterlogging problem, thus exercising water management (to drain soil from the field) is become prerequisites. While the sandy loam soils are easy for plowing but comparatively less in water and nutrient holding capacity than clay soil.

Soil pH and EC

The pH is a measure of soil acidity or alkalinity that gives an indication of the activity of the hydrogen ion (H+) and hydroxyl ion (OH–) in a water solution (Hazelton and Murphy, 2007). It is a very important property of soil as it determines the availability of nutrients, microbial activity and physical condition of the soil (Gupta, 2000) whereas the electrical conductivity (EC) measurement identifies soils which are potentially saline (Okalebo et al., 2002).

The soil pH of the Bulala farm is in the range 6.29 to 7.6 (Table 5). This range of soil pH is considered agriculturally as good soil reaction range (Jackson, 1973). The relatively higher pH values (neutral to slightly alkali soils) observed in the soils of the study area are due to the low rainfall amount as well as its erratic distribution which is insufficient to leach the basic cations appreciably to depths below the surface soil layers. On the other hand, soil pH of Harawa farm ranges from 5.57 – 6.81 (Table 6) indicating the existence of high rainfall comparatively. This ranges soil pH is agriculturally considered as moderately acidic to the neutral range which needs special consideration in using urea fertilizers.

Similarly, soil EC values ranged from 0.13 – 0.21dS/m at Bulala farm and from 0.09 – 0.2 dS/m at Harawa farm (Table 5 and 6). Thus, the EC values measured throughout the 0 – 20 cm depths of the soils in the study area indicated the concentration of soluble salts below the levels (i.e. <4 dS/m) at which growth and productivity of most agricultural crops are affected due to soil salinity (Landon, 1991; Jackson, 1973).

Total N and Organic C

Total N measures the total amount of nitrogen present in the soil, much of which is held in OM and is not immediately available to plants (Hazelton and Murphy, 2007). The values of total N ranged from 0.11 to 0.28 % and from 0.11 to 0.15 % at Bulala and Harawa farms respectively. According to the rating of Landon (1991), this rate is predominately categorized under low to medium range. Such values indicate that the need for application of organic or inorganic fertilizer to optimize the soil productivity.

The values of soil organic carbon ranged from 2.78 – 10.56 % in Bulala farm while it ranges from 5.7 – 9.3 % in Harawa farm (Table 5 and 6). The C/N ratios of both farms are > 25, which indicates incomplete decomposition of organic matter (Brady and Weil, 2002). In addition to the analysis result of total N, this high C/N ratio gear out for supplementary nitrogen fertilizer to get planned crop yield and even to hasten the existing organic matter decomposition, which in turn increase the release of N from OM.

Table 4: Soil pH, EC, Total N and Organic C in Bulala and Harawa Farms (Mean +StDv)

Farms	pH	EC(ds/m)	TN (%)	OC (%)
Bulala	6.9 ± 0.52	0.17 ± 0.04	0.17 ± 0.06	5.43 ± 2.62
Harawa	5.93 ± 0.51	0.11 ± 0.05	0.12 ± 0.02	7.30 ± 2.33

Table 5: Soil pH, EC, Total Nitrogen and Organic Carbon in Bulala Farm Blocks (Mean +StDv)

	Soil Variables			
Bulala Farm Blocks	pH	EC (ds/m)	OC (%)	TN (%)
BB13	6.39 ± 0.82	0.14 ± 0.07	5.36 ± 1.10	0.13 ± 0.02
BB14	6.37 ± 0.32	0.13 ± 0.03	7.82 ± 1.82	0.23 ± 0.05
BB28	6.42 ± 0.78	0.13 ± 0.06	5.75 ± 0.51	0.15 ± 0.01
BB29	7.05 ± 0.56	0.18 ± 0.03	5.85 ± 1.02	0.20 ± 0.03
BB30	7.18 ± 0.28	0.17 ± 0.03	3.86 ± 0.56	0.13 ± 0.06
BB43	6.63 ± 0.85	0.18 ± 0.07	10.66 ± 3.42	0.28 ± 0.05
BB44	6.99 ± 0.37	0.18 ±0.07	6.30 ± 1.74	0.21 ± 0.03
BB45	7.60 ± 0.14	0.19 ± 0.01	2.79 ± 1.35	0.11 ± 0.02
BB58	6.83 ± 0.27	0.20 ± 0.03	4.68 ± 3.44	0.12 ± 0.02
BB59	7.02 ± 0.23	0.20 ±0.03	3.73 ± 1.72	0.14 ± 0.03
BB60	7.38 ± 0.26	0.17 ± 0.02	3.76 ± 1.14	0.15 ± 0.04

Table 6: Soil pH, EC, Total Nitrogen and Organic Carbon in Harawa Farm Blocks (Mean + StDv)

	Soil Variables			
Harawa Farm Blocks	pH	EC	OC (%)	TN (%)
HB1	6.81 ± 0.22	0.20 ± 0.02	9.07 ± 1.79	0.11 ± 0.01
HB2	5.97 ± 0.17	0.09 ± 0.01	9.13 ± 2.14	0.11 ± 0.01
HB3	6.22 ± 0.63	0.15 ± 0.09	7.16 ± 3.21	0.14 ± 0.03
HB4	5.60 ± 0.10	0.07 ± 0.01	5.70 ± 0.68	0.15 ± 0.01
HB5	5.77 ± 0.39	0.09 ± 0.02	6.98 ± 1.70	0.11 ± 0.01
HB6	5.56 ± 0.49	0.09 ± 0.02	6.43 ± 2.28	0.15 ±0.03

Available P

The values of available P in these soils ranged from 4.44 ppm – 31.27 ppm in Bulala and from 5.92 ppm – 16.5 ppm and Harawa farm. According to the rating by Hazelton and Murphy (2007), these values indicate that available P of the study area are categorized under very low (B28), low (B13, HB4, and HB6), medium (BB29, BB3, BB45, HB1, HB2, HB3 & HB5) and high (BB14A, BB43, BB44, BB59 & BB60) ranges (Table 8 and 9). Generally, available phosphorus of both farms ranges from very low to high range. Therefore, depending on initial soil available P; addition P fertilizer (organic or inorganic fertilizer) should be applied to soils of the farm for the optimum and sustainable productivity of soils.

Available K

The average available K content of the surface 0 – 20 cm depth of soils of the study area varied from 431 to 680 ppm for Bulala farm Blocks and 654 to 900 ppm for Harawa farm Blocks. The range in both farms is in the high range of rating and is suitable for major agricultural crops (Landon, 1991).

CEC and Exchangeable Bases

CEC of these soils ranged from 26.09 – 62.44 (cmol(+)Kg^{-1}soil and 13.09 – 63.6 (cmol(+)Kg^{-1}soil in Bulala and Harawa farms respectively. Such values are grouped as moderate to very high categories (Hazelton and Murphy, 2007). Whereas out of exchangeable bases (Na, K, Ca and Mg), the value of exchangeable Na is categorized as a very low rate while the rates for the K, Ca and Mg were under the high category.

In considering CEC, it has been suggested that the proportions of the various cations of the effective CEC are more relevant to plant performance than the actual levels. For optimal plant growth the proportion of exchangeable bases should be in the range 65 – 80 for Ca, 10 – 15 for Mg, 1 – 5 for K and Na 0 – 5, Hence, Exchangeable Na and K was at the rate which is the desired proportions of CEC of cations for many plants while Ca and Mg very a much lower rate for optimal plant growth.

Table 7: Av. Phosphorus, Av. Potassium, Exchangeable Bases and Cation Exchange Capacity in Bulala and Harawa Farms

			Exchangeable bases (cmol(+)kg^{-1})				
Farms	**P (ppm)**	**K (ppm)**	**Ca**	**Mg**	**Na**	**K**	**CEC(cmol(+)Kg^{-1}**
Bulala	19.00	549.00	19.44	4.06	0.001	2.18	40.98
Harawa	10.67	791.77	16.81	6.34	0.00	3.30	28.26

Table 8: Available P, Available K, Exchangeable Bases and CEC in Bulala Farm Blocks (Mean +StDv)

			Exchangeable bases (cmol(+)kg^{-1})				
Bulala Farm Blocks	**P (ppm)**	**K (ppm)**	**Ca**	**Mg**	**Na**	**K**	**CEC(cmol(+) Kg^{-1}**
BB13	5.64	543.75	28.60	7.80	0.00	2.02	31.08
BB14	20.40	504.77	18.21	2.90	0.00	1.73	39.72
BB28	4.44	481.00	29.73	8.80	0.00	1.87	26.08
BB29	13.80	431.50	16.06	3.73	0.00	1.95	39.56
BB30	14.01	545.50	19.20	3.46	0.00	1.9	42.00
BB43	31.26	493.00	16.00	4.00	0.00	1.85	45.00
BB44	23.4	521.41	18.00	3.20	0.01	2.61	40.93
BB45	16.22	501.80	21.76	2.88	0.00	1.38	45.05
BB58	4.68	620.00	17.00	6.16	0.00	2.47	52.44
BB59	25.02	680.00	19.10	4.33	0.00	3.08	40.47
BB60	20.04	560.10	20.96	2.56	0.00	1.88	41.13

Table 9: Available P, Available K, Exchangeable Bases and CEC in Harawa Farm Blocks (Mean +StDv)

			Exchangeable bases (cmol(+)kg^{-1})				
Harawa Farm Blocks	**P (ppm)**	**K(ppm)**	**Ca**	**Mg**	**Na**	**K**	**CEC(cmol(+)Kg^{1}**
HB1	16.50	714.50	21.40	3.60	0.00	2.84	63.60
HB2	9.12	654.70	12.32	2.96	0.00	2.40	49.24
HB3	8.49	731.00	23.86	7.60	0.00	2.93	27.32
HB4	7.34	900.00	14.50	6.00	0.00	3.80	18.16
HB5	15.66	887.00	15.86	7.40	0.00	3.99	16.80
HB6	5.91	840.25	13.30	8.80	0.00	3.70	13.09

CONCLUSION AND RECOMMENDATION

Soil test based fertility management is an effective tool for increasing productivity of agricultural soils that have a high degree of spatial variability resulting from the combined effects of physical, chemical or biological processes. The results revealed that the pH of Bulala is in the range which is considered agriculturally suitable while the pH of Harawa is in the moderately acidic to the neutral range which needs special consideration in using Urea fertilizer. EC of both farms indicates the concentration of soluble salts below the levels (i.e., <4 dS/m). Total N contents of both farms ranged from low to medium, indicating the need for the addition of nitrogen fertilizer (organic and inorganic) to build nitrogen for plant requirement and to enhance organic matter decomposition. The level of available phosphorus is ranged from very low to medium in most cases. Therefore, there is also a high need for application of phosphorus fertilizer to correct the limiting element P.

Hence, the addition of organic and inorganic fertilizers based on the soil test based results, improving cultural practice to improve CEC and the activity of soil organisms to have the optimum and sustainable productivity of farmlands is advisable.

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REFERENCES

i. *Amuri N, Semu E, Msanya BM, Mhoro L & Anthony JM. 2010. Evaluation of the soil fertility status in relation to crop nutritive quality in the selected physiographic units of Mbeya Region, Tanzania. Research Application Summary. Second RUFORUM Biennial Meeting 20 – 24 September 2010, Entebbe, Uganda.*

ii. *Brady N.C., and R.R.Weil.., 2002. Nature and Properties of Soils. 13th ed. New York, USA.*

iii. *Brady NC & Weil RR. 2002. The nature and properties of soil, 13th Ed. Preason Education, Asia.*

iv. *Bremner JM & Mulvaney CS. 1982. Methods of soil analysis: in Chemical and microbiological properties, ASA Monograph number 9. . pp. 595-624*

v. *Chapman HD. 1965. Cation exchange capacity. In: C.A. Black, L.E. Ensminger and F.E Clark (eds). Methods of soil analysis. American society of Agronomy. 9: 891-901*

vi. *Day PR. 1965. Particle fractions and particle size analysis. In: C A. Black (Ed). pp. 546-566 .*

vii. *ECACC. 2002. A Report on Preliminary Results of Area, Production and Yield of Temporary Crops (Meher Season Private Peasant Holding), Part II, on Ethiopian Agricultural Sample Enumeration, Addis Ababa, Ethiopia.*

viii. *Fasil K. 2002. Analysis of Yield Gap for Wheat Cultivation in the Highlands of North Ethiopia. Ph.D. Thesis, Gent University, Belgium.*

ix. *Gupta P.K. 2000. Soil plant water and fertilizer analyses. Agrobis India. 438p.*

x. *Hazelton P. & Murphy B. 2007. Interpreting Soil Test Results: What Do All The Numbers Mean? NSW Department of Natural Resources, CSIRO Publishing, Australia.*

xi. *Jackson ML. 1973. Soil Chemical Analysis. 2nd Edition. Prentice Hall of India Private Limited, New Delhi, India.*

xii. *Landon JR. 1991. Booker Tropical Soil Manual: A handbook for soil survey and agricultural land evaluation in the tropics and sub tropics. Longman Inc., New York.*

xiii. *Mishelia A. & Zirra EM. 2015. Application of Geographic Information System (G.I.S.) In Evaluating Suitable Areas for Wheat Cultivation in Adamawa State Nigeria. International Journal of Scientific Knowledge 6(1): 14 – 22.*

xiv. *Okalebo JR, Gathua KW & Womer PL. 2002. Laboratory methods of soil and plant analyses: a working manual, 2nd Ed. TSBF – CIAT and SACRED Africa, Nairobi, Kenya.*

xv. *Olsen SR, Cole CV, Watanabe FS & Dean LA. 1954. Estimation of Phosphorus in soils by extraction with sodium bicarbonate. USDA, Circular 939.*

xvi. *Sharma A.K. 2002. Handbook of organic farming. Agrobios, India.*

xvii. *Sun B, Zhou S, & Zhao Q. 2003. Evaluation Of Spatial And Temporal Changes Of Soil Quality Based On Geostatistical Analysis In The Hill Region Of Subtropical China. Geoderma 115: 85–99*

xviii. *Von Reeuwijk LP. 1992. Procedures for soil analysis. International soil reference and information center (ISRIC) Wageningen, The Netherlands. 23p*