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Status of Selected Properties of Soils under Crop-Livestock Farming System in Eastern Ethiopia

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Authors' contributions

This work was carried out in collaboration between all authors. Author LW designed the study, wrote the protocol, wrote the first draft of the manuscript and managed the literature searches and all laboratory analyses. Author KK involved in site selection, edited the data, reviewed and edited the manuscript. Authors JJM and FBRR reviewed and edited the protocol and the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Information on soil properties and fertility status of soils at farm levels under particular farming system is essential for boosting farm productivity and for sufficient food production. This study was conducted to investigate status and properties of soils under crop-livestock farming system, where crop grains are produced for food security and residues for animal feed and domestic fuel consumption. For the study, two farms under similar farming system were selected from two districts in eastern part of Ethiopia: Adele farm from Haramaya and Bala Langey farm from Kersa districts. Soil samples were collected from crop fields of each farm and analyzed following standard methods for soil physical and chemical analyses. The results indicate that soil textural class is sandy clay loam at both farms. The mean bulk density values were 1.43 and 1.39g cm^{-3} for Adele and Bala Langey farms, respectively. The soil reaction for Adele farm was neutral (pH=7.23) whereas soils of Bala Langey farm had slightly acidic reaction (pH=6.57). Organic carbon contents of soils of both farms were low, less than 1.5%. Nitrogen was low for Adele farm soils (<0.15%) and in the moderate range for Bala Langey farm soils (0.15-0.25%). Available soil P was very low at

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both farms (<10mgkg^{-1}). Extractable soil sulfur was also low for both farms (<5 mgkg^{1}). CEC of the soils of Adele farm was very high (>50Cmol (+)kg^{-1}) and it was high (>40 Cmol(+)kg^{-1}) for Bala Langey farm soils. Exchangeable base contents and EDTA extractable micronutrients were in the sufficiency ranges for soils of both farms. This study indicated that very low available phosphorus, low organic carbon and nitrogen followed by sulfur are the most productivity limiting factors associated with soil fertility as a result of crop residues removal for animal feed and domestic fuel consumption. Intervention management should focus on the enhancement of organic carbon, phosphorus, nitrogen and sulfur.

Keywords: Crop residue; farm; farm productivity; soil fertility; soil properties.

1. INTRODUCTION

Crop-livestock farming system is a traditional and main agricultural practice in the eastern part of Ethiopia, where crop grains are produced for food security and residues for animal feed and domestic fuel consumption. Sorghum stover is also used for construction by farmers who do not have adequate trees. Stover is mixed with wood for constructing houses and fences. Thus the contribution of crop residues in supporting the livelihood of small-scale farmers is significantly high in the farming system of the region. However, productivity of such farming system is being challenged by several constraints. Land degradation due to soil erosion, low soil organic carbon and nutrient depletion are among the main challenges contributing to low farm productivity [1-3]. Low farm productivity is common to the country in general and to the eastern part in particular.

Continuous mono-cropping with unbalanced nutrient application and nutrient mining have been reported as the causes for soil fertility depletion [4,5] in the farming system of Ethiopia. As a result, farm productivity is limited to the minimum capacity and has failed to satisfy the demand for food in terms of quality and quantity [6,7]. Maize and sorghum are the dominant food crops grown by the farmers in the eastern part of the country for subsistence consumption. However, productivity of these crops remains generally low due mainly to soil fertility depletion.

The extent of soil fertility degradation and nutrients which are highly depleted and require immediate attention is not adequately known under the crop- livestock farming system of the region. The generalized soil fertility depletion context might not be applicable to all nutrients and farming systems. For instance, soil fertility depletion under agro-pastoral, agro-forestry and crop-livestock farming systems could not be the same. In view of this, assessment of the status of the nutrients is deemed necessary for designing interventions for alleviating soil fertility depletion problems under specific farming system.

Soil fertility depletion may also be aggravated due to mismanagement of crop residues and soil organic carbon (SOC). Hence, crops residues have been used for animal feed and domestic fuel instead of being incorporated into soils for enhancement of soil fertility. Crop residues are an important constituent in nutrient cycling in biogeochemical systems [8] if not removed from the crop fields.

The significant impacts of crop residues return on soil organic carbon and nutrients have been reported by several investigators [9-12]. Nonetheless, the impact of crop residues removal on soil fertility and farm productivity is not well investigated for the crop-livestock farming system of the eastern part of Ethiopia, where farmers practice the overall crop residue removal management for animal feed and domestic fuel consumption.

Information on soil properties and fertility status is essential for boosting farm productivity and for sufficient food production. However, detailed information on soil properties and fertility status of soils at farm levels under particular farming system are scarce in general and in the eastern part of the country in particular. Furthermore, as reported by [2] the recently available data on soil properties and fertility status of Ethiopian soils are mostly from on-station research and experimental plots. Because of these, detailed studies of major soil properties and fertility status in relation to organic carbon and nutrient contents at farm level are the top priority issues of soil fertility management programs of Ethiopian agriculture. Ethiopia is launching soil test based fertilizer recommendations under the package of soil health and fertility management program (Ethiopian Agricultural Transformation Agency), with the target of site specific soil fertility management.

Detailed studies of soil properties and fertility status under specific farming system are thus vital so as to understand farm productivity limiting factors from the soil fertility perspective. The objectives of this study were to investigate selected soil properties under crop-livestock farming system and to identify farm productivity limiting factors associated with soil fertility status.

2. MATERIALS AND METHODS

2.1 Description of the Study Farms

The study farms are in eastern part of Ethiopia at Haramaya and Kersa districts in Oromia Regional State. The two districts were selected based on the farming system of the region. One farm was selected from each district. Adele farmers' village from Haramaya and Bala Langey from Kersa districts were selected. The farms were selected from a group of interested farmers who permitted the study to be conducted in their farms.

The geographical location of Adele farm at Haramaya district is between 09°24`26``N, 041°58`00``E and 09°24`34`` N, 041°58`04``E with an average altitude of 2075 m.a.s.l. Bala Langey farm at Kersa lies between 09°25`41``N, 041°47` 48``E and 09°25`46``N, 041°47`56``E with an average altitude of 2005 m.a.s.l. Information obtained from Haramaya University Meteorological station indicates that the mean annual rainfall and mean maximum and minimum temperatures of Haramaya district are 784mm and, 24.36 and 9.61°C, respectively for the last 7 years (2007-2013) as presented by Fig. 1. Data on rainfall and temperature were not available for Kersa district.

The components of both farming systems are crop-livestock production. The cropping systems are maize and sorghum intercropped with legumes. Haricot bean is the dominant legume intercropped with main crops in the cropping system of the region. Khat (*Cath edulis*) is the main cash crop for the whole farming systems of the region. Vegetables are grown during rainy seasons but, more so in the dry seasons where underground water is available for irrigating the crops.

The components of the livestock system are cattle, donkey, sheep, goats and poultry at both farms. There are no goats in Bala Langey farm. Livestock are used as sources of food (meat, milk and milk products) and as saving asset while manure is used for soil fertility management to some extent.

2.2 Soil Sampling Site Selection, Sampling and Analysis

Soil sampling sites were selected from the crop fields of 2.5ha at Adele and 2 ha at Bala Langey farms along the diagonal lines from one end to the other opposite end. Disturbed soil samples were collected with an auger from 16 representative sites, 8 along one diagonal line and 8 along the other diagonal line at a depth of 0-30cm. Four composite subsamples were made from the 16 samples, 2 from samples collected along each diagonal line.

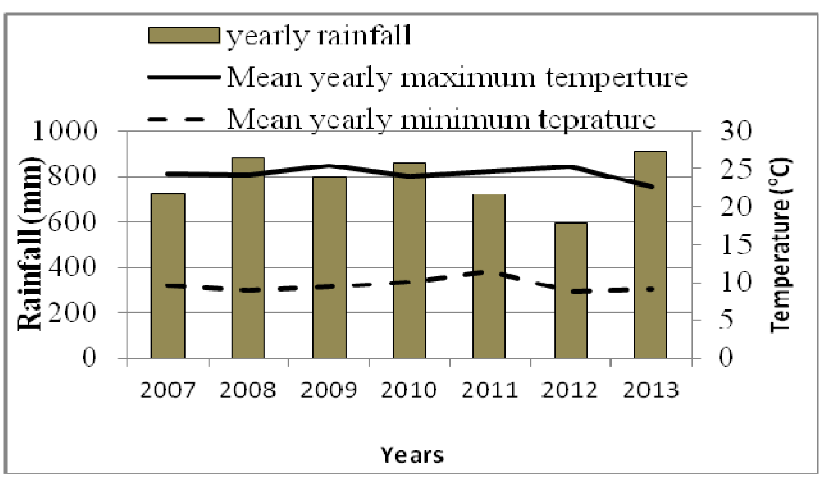

Fig. 1. Yearly rainfall and mean maximum and minimum temperature of Haramaya district (2007 - 2013)

The samples were air-dried and crushed to pass through 2mm sieve. Subsamples were ground to pass through 0.25mm sieve for nitrogen and organic carbon analysis. Four undisturbed soil samples were also collected, 2 along each diagonal line using 2.50 cm radius and 5.50cm height core sampler for the determination of dry soil bulk density to the depth of 0 – 30cm.

Soil particle size distribution was analyzed by the Bouyoucos hydrometer method as described in [13]. Soil dry bulk density was determined following the procedure described by Blake [14]. Soil pH was measured in 1:2.5 soil water ratios. Organic carbon and nitrogen were determined following the method described by [15] and Kjeldahl methods, as described by [16], respectively.

Exchangeable bases were extracted using ammonium acetate solution buffered at pH 7 [17]. Calcium and Mg were measured using Buck Scientific (AAS) model 210VGP atomic absorption spectrophotometer, in acetylene-air flame. Na and K were analyzed on Corning flame photometer. Cation exchange capacity (CEC) of the soils was estimated following the ammonium acetate procedure. The NH_4^+ ions were determined by ammonia (NH_3) distillation into sulfuric acid solution and then by back titration with dilute sulfuric acid.

Available phosphorus was determined by Olsen method [18]. Extractable sulfur was extracted with calcium tetrahydrogen phosphate [17]. Sulfur ($S\text{-}SO_4^{-2}$) content of the extract was measured by turbidmetric method [16] using UV/Vis spectrophotometer; model T80+, PG Instruments. The extractable micronutrients (zinc, iron, copper and manganese) were measured by atomic absorption spectrophotometer after extraction with EDTA [16]. Sub soil samples were digested with mixed acids, perchloric and nitric acids [19] to estimate total nutrient (P, K, Ca, Mg, S, Zn, Fe, Cu and Mn) contents of the soils. Percent exchangeable or extractable nutrients were calculated as: $P = a/b \times 100$

Where:

- P = Percent exchangeable or extractable nutrient
- a = Content of each exchangeable or extractable nutrient
- b = Total content of each exchangeable or extractable nutrient

3. RESULTS AND DISCUSSION

3.1 Soil Physical Properties

Soil texture and bulk density are the soil physical properties that were determined for the soils of the study farms**.** The results revealed that soil textural class was sandy clay loam at both farms with higher percentage of sand separates relative to clay and silt sized particles (Table 1). Soils textural class reveals that soils of both farms are expected to have good drainage and can possibly drain or leach ions. However, the values of percent base saturation (Table 4) depict that the soils are weakly leached. Furthermore, from the textural class perspective, the data indicate that soils of the two farms can be managed under similar management practices for crop production.

The mean bulk density values were 1.43 for Adele farms soils and 1.39 gcm^{-3} for Bala Langey farm soils (Table 1). As reported by [20], sandy clay loam soils with bulk density values above1.6 gcm^{-3} showed evidence of compaction which restricts root penetration and affects hydraulic conductivity and subsequently soil available water holding capacity. According to this concept, soils of the two farms under the current study do not have problems associated with soil bulk density.

Table 1. Selected physical properties of soils of Adele and Bala Langey farms

	Particle size distribution (%)			Textural class	Bulk density
Farms	**Sand**	**Silt**	**clay**	**name**	**(gcm^{-3})**
Adele	57.50	16.00	26.50	SCL	1.43
Bala Langey	56.25	14.25	29.50	SCL	1.39

**SCL=Sandy clay loam*

Soils of the study farms have same textural classes, sandy clay loam, but different bulk density values. From the soil properties point of views, soil texture and organic carbon are the soil constituents which can contribute to the variability in soil bulk density values. Differences in the bulk density values of soils of the two farms can be attributed to differences in the organic carbon contents of the soils. Data in Table 2 show that the two soils have different organic carbon content. The data also indicate that soil with relatively higher organic carbon content has lower bulk density value. Therefore, increasing soil organic carbon content through organic matter amendment is a mandatory management option for reducing higher bulk density values of soil for optimum crop production.

3.2 Soil Chemical Properties

3.2.1 Soil pH_w

Soil pH_w is the pH of the soil solution that plant roots and soil microbial are exposed to in the soil [20]. The mean pH_w values of the soils under the current study were 7.23 and 6.57 for the Adele and Bala Langey farms, respectively (Table 2). As per the pH ratings of [21], soils of the two farms had neutral reaction. However, the pH value for the Adele soil was very close to lower range of mildly alkaline reaction whereas value for soils of Bala Langey farm was also very close to upper range of slightly acidic reaction. In general, the pH values of the soils of both farms are in the range of pH values for most crops grown in the region. Furthermore, the pH, electrical conductivity (EC) and exchangeable sodium percentage (ESP) data (Tables 2 and 4) depict that the soils have no salinity or sodicity problems [22].

3.2.2 Organic carbon and total nitrogen

The soil organic carbon contents for both farms were less than 1.5%, which is the upper limit of low range for agricultural soils [23]. Nitrogen was in the range of low (0.05-0.15%) for Adele farm soils and moderate (0.15-0.25%) but very close to lower limit for Bala Langey farm soils [20]. Thus, organic carbon and total nitrogen contents of the soils of the farms were low (Table 2).

These low organic carbon and total nitrogen content of the soils can be attributed to non incorporation of the biomass into the soils. Since, all the above ground biomass and crop residues are removed for animal feed and domestic fuel consumption. Furthermore, application of animal manure is also minimum or non to the cop fields.

Farmers are aware of the benefits of manure for the enhancement of soil fertility. Nevertheless, the quantity of manure from their farmyard is not sufficient for the replenishment of organic carbon and nitrogen taken away with the crop residues. These all together resulted in low organic carbon and nitrogen contents of soils of the two farms.

3.2.3 Available phosphorus

Olsen`s available phosphorus content of soils of both farms (Table 3) was less and below the lower limit of low range ($10mgkg^{-1}$) of the P content of cultivated soils [24] for crop production. Nevertheless, total P content of the soils was very high 27.25g Pkg^{-1} soil (116.90 ton Pha^{-1} to 0-30 cm depth) for the Adele farm and 19.40g Pkg^{-1} soil (80.90ton Pha^{-1} to 0-30cm depth) for the Bala Langey farm (Table 3). Percentage extractable P from the total P of the soils was 0.007 and 0.04 for Adele and Bala Langey farm soils, respectively. These results indicate that P is the least extractable nutrient for Adele farm soils and the second least extractable for Bala Langey farm soils (Table 3).

The data in Table 3 reveal that soils with low available P have high total P in unavailable form to the plant roots. This calls for characterization of the soils in terms of their phosphorus adsorption capacity and a particular management option for the conversion of the unavailable phosphorus to be accessible to the plant roots. Organic amendment could be the best, because soils of Bala Langey farm with relatively higher organic carbon content had higher available and lower total phosphorus compared to Adele farm soils.

3.2.4 Sulfur

Sulfur is one of the macronutrient that plant demands in large quantity for optimum biomass production and for the synthesis of sulfur containing amino acids and proteins. Plant obtains sulfur from soils which exists in the available form (SO_4^{2-}). Extractable soil sulfur was less than 5mg kg^{-1} for soils of both farms (Table 3), which is the upper range of very low phosphate extractable soil sulfur [25]. Therefore, sulfur fertility management is not optional for these soils for sustainable crop production. On the other hand, total sulfur content of the soils was 66.06g Skg^{-1} (28.34 ton Sha^{-1} to 0-30 cm depth) for the Adele farm and 38.89g Skg^{-1} (16.22 ton Sha^{-1} to 0-30 cm depth) for the Bala Langey farm. Similar to total phosphorus, soil with low extractable sulfur had high total sulfur content. Higher total sulfur content which is not extractable may be from the sulfide minerals in soils which are hardly soluble in water. These minerals can be solublised through chemical or biological oxidation which is governed by the soil conditions.

Table 2. pH, electrical conductivity (EC), organic carbon (OC) and total nitrogen (TN) contents of soils of Adele and Bala Langey farms (mean ± Standard deviation)

Farms	pH	EC	OC (%)	TN (%)
Adele	7.23 ± 0.08	0.103 ± 0.01	1.16 ± 0.09	0.15 ± 0.01
Bala Langey	6.57 ± 0.09	0.02 ± 0.003	1.41 ± 0.20	0.16 ± 0.01

Table 3. Available, total, percent (%) extractable phosphorus and extractable, total and % extractable sulfur of soils of Adele and Bala Langey farms (mean ± standard deviation)

Farms	Phosphorus			Sulfur		
	Available ($mgkg^{-1}$)	Total (gkg^{-1})	% Extractable	Extractable ($mgkg^{-1}$)	Total (gkg-1)	% Extractable
Adele	1.88 ± 0.86	27.25 ± 1.43	0.007 ± 0.003	2.36 ± 3.78	66.06 ± 8.90	0.004 ± 0.006
Bala Langey	8.21 ± 1.72	19.40 ± 2.11	0.04 ± 0.005	2.53 ± 3.35	39.11 ± 2.60	0.007 ± 0.009

Biological oxidation is carried out by microorganisms in the soil system. Presence of microorganisms in soil again depends on quantity and quality of soil organic carbon. However, organic carbon contents of soils of the two farms were low (Table 2) to support the biological oxidation of hardly soluble sulfur. This suggests that bioavailability of sulfur is affected by low soil organic carbon. Therefore, increasing soil organic carbon in terms of quantity and quality is essential for increasing bioavailability of sulfur.

3.2.5 Cation exchange capacity and exchangeable bases

Cation exchange capacity and exchangeable bases are soil quality indicators related to soil fertility status. The cation exchange capacity (CEC) of the soils of Adele farm was very high (Table 4), greater than 50 cmol (+) kg^{-1}. The very high CEC value is due to pH of the soil which is > 7.00 where presence of $CaCO_3$ expected. For soils of Bala Langey farm CEC was high greater than 40cmol (+) kg^{-1} according to the rating by [26].

The exchangeable Ca was very high for soils of Adele farm and high for soils of Bala Langey farm (Table 4). Exchangeable Mg was very high for soils of both farms. Exchangeable K was in the range of [0.7 - 2.0Cmol (+)kg^{-1}] which is high range for potassium [20]. Thus, the exchangeable bases are sufficient for crop production.

The Ca to CEC ratio was in the range of (0.65-0.80) for soils of Adele farm, which is a normal range for many plants [21] but below the range for soils of Bala Langey farm (Table 4). The Mg to CEC ratio for soils of both farms was above the range suggested by [21]. Ratios for K to CEC were in the normal range (0.01- 0.05) for soils of the two farms. These ratios reveal that there are no soil fertility problems associated with CEC and exchangeable bases.

Magnesium is the dominant exchangeable base of the total basic cation analyzed for the soils of the two farms, followed by calcium then potassium. Sixty and 42% of Mg is exchangeable from the total Mg content of soils of Bala Langey and Adele farms, respectively, (Table 4). At both farms, the order of percentage exchangeable bases of the total is Mg > Ca > K, but the order of exchangeable bases from the soil exchange sites is Ca > Mg > K > Na (Table 4).

Percent base saturation (PBS) was very high for soils of Adele farm (> 80%) and high for soils of Bala Langey farm (> 60%) as per the rating by [21]. This suggests that the exchange sites of the soils are mostly occupied by basic cations and are weakly leached.

Exchangeable base contents of the soils of both farms are in the ranges of high and very high which indicate sufficiency of these nutrient for crop production. But organic carbon, phosphorus, nitrogen and sulfur are in lower or close to lower ranges for agricultural soils. This indicates productivity of the farms is definitely affected by soil fertility associated with organic carbon, phosphorus, nitrogen and sulfur.

Table 4. Cation exchange capacity, Exchangeable, total, percent (%) exchangeable bases and percent base saturation of soils of Adele and Bala Langey farms (mean ± standard deviation)

Exchangeable properties	Adele farm	Bala Langey farm
CEC (cmol(+)kg^{-1}	50.72 ± 1.64	46.87 ± 2.57
Exchangeable bases (cmol(+)kg^{-1}		
Ca	35.89 ± 2.19	20.05 ± 3.84
Mg	9.07 ± 0.12	13.03 ± 0.39
K	0.79 ± 0.02	0.76 ± 0.03
Na	0.32 ± 0.02	0.28 ± 0.02
Total bases (cmol(+)kg^{-1}		
Ca	176.08 ± 6.25	115.11 ± 5.37
Mg	21.25 ± 1.93	21.43 ± 0.86
K	14.81 ± 0.13	14.50 ± 0.50
PBS	92.81 ± 3.23	72.65 ± 4.82
ESP	0.63 ± 0.001	0.60 ± 0.001
Percent exchangeable bases		
Ca	20.38 ± 0.57	17.42 ± 3.33
Mg	42.68 ± 4.06	60.80 ± 2.92
K	5.33 ± 0.14	5.24 ± 0.09
Ratios		
Ca/CEC	0.71 ± 0.03	0.43 ± 0.07
Mg/CEC	0.18 ± 0.13	0.28 ± 0.04
K/CEC	0.02 ± 0.001	0.02 ± 0.003
Ca/Mg	3.96 ± 0.25	1.54 ± 0.34

Therefore, enhancement of soil organic carbon through crop residue incorporation or manure application is important for the intervention of soil organic carbon depletion. Phosphorus, nitrogen and sulfur fertilizers application rates should be studied at the field and in glass house. Fertilizers should be applied based on the study results.

3.2.6 Micronutrients

Micronutrients are essential elements for plant growth but required at the micro level by the plants. The concentrations of EDTA extractable micronutrients were much lower than the total contents in the soils of both farms under the current study (Table 5).

Single EDTA extractable micronutrients for soils of both farms follow the order Mn > Fe > Cu > Zn. [27] reported similar order for EDTA extractable micronutrients for some Ethiopian soils. On the other hand, the total soil micronutrient content follows the order Fe > Mn > Cu > Zn for the Adele farm. For the Bala Langey farm the order is Fe > Mn >Zn > Cu, which is the order for the abundance of these elements in the earth crust. This is also similar with the [28] report for total acid digested micronutrient concentration for Argentina soils. Difference in order of total Zn and Cu content of the soils may be because of the difference in chemical properties of the soils.

Table 5. EDTA extractable, total and percent (%) extractable micronutrients of soils of Adele and Bala Langey farms (mean ± standard deviation)

Micronutrients	Farms	
	Adele	Bala Langey
Extractable (mgkg^{-1})		
Cu	8.40 ± 0.49	8.54 ± 0.44
Fe	70.66 ± 5.42	91.39 ± 4.74
Mn	203.56 ± 3.80	210.78 ± 6.76
Zn	2.26 ± 0.62	2.51 ± 0.62
Total		
Cu (mgkg^{-1})	138.84 ± 4.62	64.35 ± 0.64
Fe (gkg^{-1})	67.78 ± 5.40	64.35 ± 3.59
Mn (gkg^{-1})	3.62 ± 0.16	3.52 ± 0.38
Zn (mgkg^{-1})	68.85 ± 7.08	66.07 ± 3.12
Percent Extractable		
Cu	6.05 ± 0.49	12.49 ± 0.81
Fe	0.12 ± 0.013	0.14 ± 0.02
Mn	5.62 ± 0.36	5.98 ± 0.58
Zn	3.28 ± 1.01	3.80 ± 0.88

Percentage extractable follows the order of Cu > Mn > Zn >Fe indicating that more Cu but less Fe was extracted by single EDTA extraction compared to the total content in the soils. EDTA extractable micronutrient contents of Bala Langey farm soils were slightly greater than that of Adele farm soils. This can be attributed to the relatively lower soils pH value and higher organic carbon content. Similar to phosphorus and sulfur, total micronutrient contents of Adele farm soils were higher than that of Bala Langey farm soils. Therefore, soil properties and conditions are playing significant role in restraining the bioavailability of the nutrients.

The extractable micronutrients concentration of soils of the two farms are above the critical values established by [29] and used by [30] and [31] for the assessment of micronutrient status of some Ethiopian soils**.** In general, the micronutrient contents of soils of both farms are in the sufficiency range [26] except Zn which is in the medium range. Therefore, even though EDTA extracts more micronutrients, fertility enhancement of these nutrients is not as serious as organic carbon phosphorus, nitrogen and sulfur for soils of both farms. Thus, management should focus on sustainable utilization and monitoring of the micronutrients in relation to the crops grown seasonally on the soils.

4. CONCLUSION

The textural class of soils of both farms is sandy clay loam. At both forms the soils do not have problems associate with bulk densities. pH of the soils is in the range for most crops grown in the region. There are no salinity or sodicity problems at both farms.

Organic carbon, nitrogen, phosphorus and sulfur are low at both farms. Except nitrogen which was moderate for soils of Bala Langey farm. Cation exchange capacity and exchangeable bases are very high for Adele farm soils and high for Bala Langey soils and are sufficient for crop production. Micronutrient contents of the soils are also sufficient.

In general, soils of the studied farms do not have fertility problems associated with pH, CEC, exchangeable bases and micronutrients. However, available phosphorus, organic carbon and nitrogen followed by sulfur are the most limiting soil fertility factors contributing to the lowest productivity of the farms. Therefore, intervention management should focus toward the enhancement of soil organic carbon, phosphorus, nitrogen and sulfur.

Soil organic carbon can be enhanced through crop residue incorporation or animal manure application. Phosphorus, nitrogen and sulfur fertilizers application rates should be studied at field and in glasshouse and applied based on the study results.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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