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Vol. 11(44), pp. 4504-4516, 3 November, 2016
DOI: 10.5897/AJAR2016.11494
Article Number: C2000C461481
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Soil micronutrients status assessment, mapping and spatial distribution of Damboya, Kedida Gamela and Kecha Bira Districts, Kambata Tambaro zone, Southern Ethiopia

Alemu Lelago Bulta[1]*, Tekalign Mamo Assefa[2], Wassie Haile Woldeyohannes[1] and Hailu Shiferaw Desta[3]

[1]School of Plant and Horticulture Science, Hawassa University, Ethiopia.
[2]Ethiopia Agricultural Transformation Agency (ATA), Ethiopia.
[3]International Food Policy Research Institute (IFPRI), Addis Ababa, Ethiopia.

Received 29 July, 2016; Accepted 25 August, 2016

Micronutrients are important for crop growth, production and their deficiency and toxicity affect crop yield. However, the up dated information about their status and spatial distribution in Ethiopian soils is scarce. Therefore, fertilizer recommendation for crops in the country has until recently focused on nitrogen and phosphorus macronutrients only. But many studies have revealed the deficiency of some micronutrients in soils of different parts of Ethiopia. To narrow this gap, this study was conducted in Kedida Gamela, Kecha Bira and Damboya districts of Kambata Tambaro (KT) Zone, Southern Ethiopia, through assessing and mapping the status and spatial distribution of micronutrients. The micronutrients were extracted by using Mehlich-III multi-nutrient extraction method and their concentrations were measured by using Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES). The fertility maps and predication were prepared by co-Kriging method using Arc map 10.0 tools and the status of Melich-III extractable iron (Fe), Zinc (Zn), boron (B), copper (Cu) and molybdenum (Mo) were indicated on the map. The extracted Fe ranged from 50.04 to 209.72 mg/kg, 60.08 to 240 mg/kg and 46.84 to 412.23 mg/kg in Kedida Gamela, Kecha Bira and Damboya districts soils, respectively. Zn ranged from 1.3 to 28 mg/kg, 0.9 to 47 mg/kg and 1.0 to 39 mg/kg for Kedida Gamela, Kecha Bira and Damboya districts, respectively. The calculated manganese activity index (MnAI) indicated that Mn is in excess and even toxic. B ranged from 0.02 to 1.83 mg/kg, 0.4 to 1.44 mg/kg and 0.06 to 2.03 mg/kg in soils of Kedida Gamela, Kecha Bira and Damboya woredas, respectively indicating that most of soils were deficient in B. Cu ranged from 0.6 to 2.9 mg/kg, 0.5-1.44 mg/kg and 0.8 to 3.4 mg/kg in Kedida Gamela, Kecha Bira and Damboya districts indicating its status fall between low and optimum category. Mo ranged from 2.21 to 18.71 mg/kg in the soils of the study area indicating that all soils were sufficient in Mo content. The means of all micronutrients except B showed significant differences among districts and showed moderate spatial dependences. The range of semivariogram for all studied micronutrients was greater than the average sampling distance indicating that it was adequate enough to catch spatial variability of them. In order to strengthen this result, plant sample analysis and calibration of micronutrients with plant response are recommended.

Key words: Boron, Copper, Iron, Kriging, Manganese, Mehlich-III, Molybdenum, Zinc and spatial dependency.

INTRODUCTION

Elements like Fe, Mn, Zn, Cu, B, Mo, Co and Cl are known to be essential for plant growth and are required in small quantities; hence, they are called micronutrients or tracer elements. In plants, they are important for protein and auxin production (Zn), as constituent of cytochrome oxidase (Cu), photosynthesis (Fe), carbon assimilation and nitrogen metabolism (Mn) (Arokiyaraje et al., 2011). They are all harmful when the available forms are present in the soil in large quantities and indiscriminate use of micronutrients is not advisable because of the small amounts needed and their interaction with other nutrients (Yadav and Meena, 2009). Maximizing agricultural production needs, among others, a balanced use of micronutrients (Patel and Singh, 2009). The deficiency or the excess presence of micronutrients such as Fe, Mn, Zn and Cu may produce synergetic and antagonistic effects in plants. As a result, either deficiency or excess (toxicity) of micronutrients results in abnormal growth, which sometimes cause complete crop failure. Thus, micronutrient deficiency and toxicity can reduce plant yield (Tisdale et al., 1995). Besides, grain and flower formation does not take place in severe deficiency (Nazif et al., 2006). Therefore, correcting micronutrient deficiencies through balanced fertilization promotes yield of crops (Wondwosen and Sheleme, 2011). In view of the above considerations, knowledge of the status and the spatial distribution of micronutrients become very important to revise the fertilizer package to boost crop productivity.

Due to misunderstanding or feelings that remarkable response doesn't occur from micronutrients application, until recently, it was concluded that micronutrients deficiency was not serious problem in Ethiopian soils (Desta Beyene, 1982). However, most recent studies confirmed that certain soil micronutrients were deficient in soils of Ethiopia which limit crop productivity. The deficiencies of Mo, Cu, and Zn are mainly reported on Ethiopian Nitisols (Teklu et al., 2003). Also, Yifru Abebe and Mesifn Kebede (2013) reported the deficiency of Fe and Zn in the majority of soil samples collected from the Vertisols of central Ethiopia.

Many studies revealed that judicious use of nitrogenous and phosphatic fertilizers in the intensive cropping system may cause the quick depletion of micronutrients in soils (Katyal and Randhawal, 1983). In addition to this, the availability of micronutrient to plant growth is highly dependent on some soil factors such as organic matter content, adsorptive surface, soil pH, lime content, soil texture, topography and nutrient interactions in the soil (Nazif et al., 2006; Eyob Tilahun et al., 2015). Thus, mapping the status and spatial variability of soil micronutrients in agricultural soils and adjusting their availability to plants through balanced fertilization is expected to increase crop productivity. Ethiopian Soil Information System (EthioSIS) being implemented by the Agricultural Transformation Agency (ATA) and Ministry of Agriculture and Natural Resources (MoANR) is currently pursuing complete soil fertility assessment by applying GIS and geostatisticcal tools with recent methods and models to come up with solid, evidence-based and targeted balanced fertilizer recommendations and other management interventions for agricultural land soils of Ethiopia. Currently, the fertility mapping and fertilizer recommendation work for the majority of the country's agricultural land has been completed. The project also gave attention for micronutrients by noting that crop production cannot be boosted by application of only DAP and urea that have been distributed to farmers until 2013 (EthioSIS, 2014, 2015).

Thus attention should be given to access to up-to-date data about status and spatial variation of micronutrients to ensure sustainable agricultural productivity. However, in Southern Nations, Nationalities and Peoples Regional State (SNNPRS) of Ethiopia information on micronutrient status at district level is scarce. Therefore, in this study, an attempt has been made to assess the status of Fe, Mn, Zn, B and Cu in the agricultural soils of Kedida Gamela, Kecha Bira and Damboya districts of KT zone of SNNPRS Ethiopia to map their status and spatial distribution and verify which areas require micronutrient fertilizer(s).

MATERIALS AND METHODS

Study areas

Location

This study was conducted in Kedida Gamela, Kechabira, and Damboya woredas of Kambata and Tembaro (KT) Zone in 2014. Kembata and Tembaro (KT) is one of the zones of the Southern Nations, Nationalities and Peoples Regional State (SNNPRS) in Ethiopia. Geographically, the study area is situated at 7.12 to 7.42° latitude and 37.44 to 38° longitudes (Figure 1) and is situated approximately 250 km south-west of Addis Ababa. The whole KT zone is situated between 1500 and 3500 m above sea level (masl), and the topography is characterized by steep slope at the foot of Anbericho, Dato and Ketta mountains and valley sides to Holagaba Zato peasant association. However, the study areas situated 1689 and 2637 m.a.s.l.

Land use and vegetation

Mixed crop-livestock system is the main land use system in the

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*Corresponding author. E-mail: lelagoalemu@gmail.com.

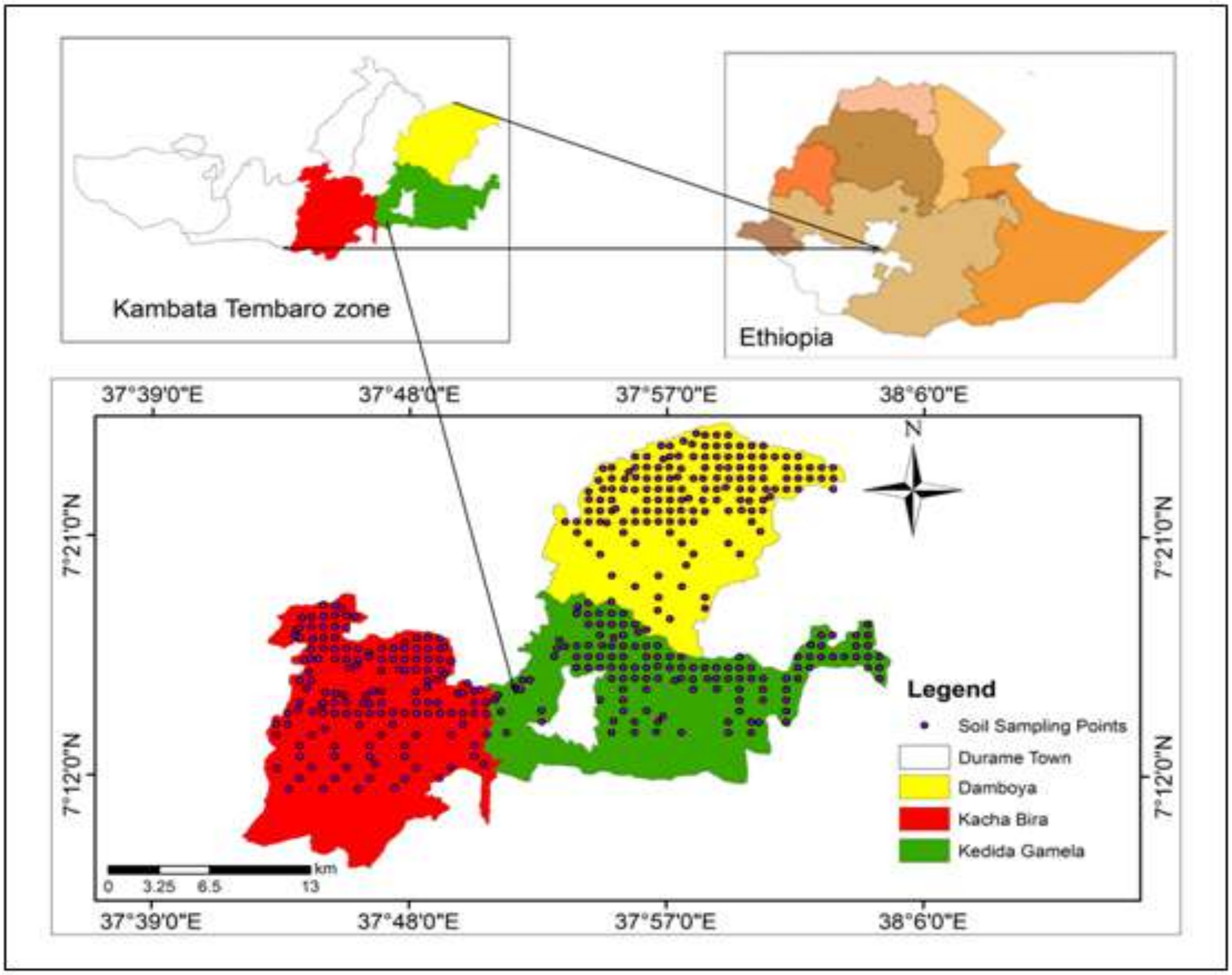

Figure 1. Map of the study area.

study Woredas. The major food crops grown in the study area are maize (*Zea mays* L, teff (*Eragrostic tef* Zucc. Trotter), wheat (*Triticum aestivum*), enset (*Ensete ventricosum*), Barley *Hordeum vulagare* L.) sorghum (*Sorghum biocolor* L., potato (*Salantum tuberosum*), faba beans, (*Vicia faba)*, field peas (*Pisum stivum)*, millet *(Elevsine coracana)* and other cereal crops and vegetables. Coffee (*coffee Arabic*) and chat (*Catha edulis Forsk*) are the dominant non-food cash crops in the study areas. Agriculture is entirely rainfed.

There are few types of natural vegetation such as *Juniperus procera, Olea africana and Hajenia abyssinica* in the grazing and arable land. However, in most of the study area eucalyptus trees are dominant trees and are replacing the natural forests. In addition, there are different grass species such as Elephant grasses covering the ground on the grazing lands especially in strongly sloping plain and hilly slope areas.

Soil sample collection

Surface soil samples were collected through gridded survey method over agricultural land of the study Woredas where sampling points were spaced 1 km from each other. Predefined sampling plots were identified and used to take samples following the field guideline. Samples were taken from locations having similar soil types, topography and similar land use history or land utilization type (LUT). Soil sampling was carried out by using GPS by navigating those Pre-defined points. Plot and center of the sub-plots were determined by letting the GPS which is fitted on Samsung tablet average position for at least 3 to 5 min.

Based on the topography and soil variability, in total, 156, 149 and 155 composite soil samples were collected from the agricultural soils of Kedida Gamela , Kecha Bira and Damboya woredas, respectively. The soil sampling depth was 0-20 cm for annual crops and 0-50 cm for perennial crops. For all soil types, 10 subsamples were collected within 15 m distance between and among each sub-sampling points in a circle method and composited. For each main sampling point, about 1 kg of representative composite soil sample was collected and logged into properly labeled plastic sample bag.

Soil samples were not taken from restricted areas such as animal dung accumulation places, poorly drained and any other places that cannot give representative soil samples. During soil sampling, data of spatial information (latitude and longitude), topography, slope, site, land use type, crop type, local soil name, sampling depth, soil

Table 1. Critical levels used for classifying soil fertility parameters analysis result (EthioSIS team analysis, 2014).

Soil parameter	Status	Critical level	Soil parameter	Status	Critical level
Fe (ppm)	Very low	-	Cu (ppm)	Very Low	<0.5
	Low	<25		Low	0.5-1
	Optimum	25-300		Optimum	0.9-20
	High	300-400		High	20-30
	Very high	>400		Very high	>30
Zn (ppm)	Very low	< 1	B(ppm)	Very low	<0.5
	Low	1-1.5		Low	0.5-0.8
	Optimum	1.5-10		Optimum	0.8-2
	High	10-20		High	2-4
	Very high	>20		Very high	>4
Mn(ppm)	Very low	<60	Mo(ppm)		
	Low	60-100		Low	< 0.05
	Optimum	100-300		Optimum	0.05-0.1
	High	300-500		High	>0.1
	Very high	>500			

Source: EthioSIS team analysis (2014).

color, crop residue management, rate of last year's fertilizer application and fertilizer type were recorded for each plot.

Sample preparation and soil laboratory analysis

The collected soil samples were air-dried, grounded and passed through 2 mm and 0.5 mm diameter sieves for analysis using wet chemistry conventional laboratory methods and spectral methods, respectively. Selected soil physical and chemical properties were analyzed at the National Soil Testing Center (NSTC) in Addis Ababa and the Mehlich-III extractable elements at Yara International Soil Laboratory in London.

Soil pH in H_2O (1:2) was determined by using digital pH meter with glass electrode (Miller and Kissel, 2010). Extractable micronutrients (Fe, Zn, Mn, Cu, B and Mo) of the soils were extracted by Mehlich-III multi-nutrient extraction method (Mehlich, 1984) and were measured with their respective wave length range by Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES). Particle size distribution was analyzed by laser diffraction in wet mode of analysis with HORIBA-Partica (LA-950V2). The analysis of soil samples was run in a wet mode using 1% sodium hexametaphosphate (Calgon) solution as dispersing agent (Agrawal et al., 1991).

Organic carbon was predicted from MIR spectra of soil samples. Soil organic matter (SOM) was estimated by multiplying the soil organic carbon by 1.72 (Nelson and Sommers, 1996; Baldock and Skjemstad, 1999). The different values for the various soil micronutrients were rated using the EthioSIS critical levels (EthioSIS, 2014) as shown in Table 1 that it prepared based on extensive literature review.

Data analysis

The micronutrients values of the soil samples were interpreted from analytical data according to EthioSIS critical levels (Table 1). Simple linear correlation analysis was carried out between micronutrients and some governing factors of micronutrients status by using SAS software 9.1 version. The descriptive statistics such as mean, mode, median, SD and range were carried out separately for Fe, Zn, Mn, Cu, B and Mo. Finally, the micronutrient status was reflected in the maps. Based on Karltun et al. (2013), determination of critical level for Mn depends on soil pH. The empirical formula used to calculate critical levels of manganese activity index (MnAI) was

$$MnAI=101.7+3.75*Mn -15.2*pH$$

Where MnAI is manganese activity index; pH is pH of soil in water and Mn is the Mehlich-III extracted manganese (Karltun et al., 2013).

Soil fertility mapping

Ordinary Kriging was used to predict unknown soil nutrients' values for non surveyed areas based on the nearby sampled data. Point data of selective soil attributes were interpolated. For every soil property, sample distribution and variability was evaluated using the experimental variogram. Among the Exponential, Spherical and Gaussian models, the best fitted model to these experimental variograms was chosen using the lowest sum square errors (SSE). Using the lowest SSE, the best model was chosen and predictions over the study area were carried out for each soil micronutrients by using Arc GIS software version 10 with output pixel size of 100 x 100 m. After kriging was carried out for selective soil parameters, very low, low, optimum, high and very high nutrients status classes were defined from the map based on the EthioSIS critical rating values (EthioSIS, 2014).

The spatial dependence between samples was also determined considering the relationship between the nugget effect (C_0) and sill ($C_0 + C_1$) expressed in percentage: 0-25% high, 25-75% medium and 75-100% low spatial dependence between samples, as proposed by Cambardella et al. (1994).

Table 2. Descriptive and geo statistics of some soil micronutrients in the study districts.

Woreda	Descriptive statistics	*Fe*	*Zn*	B	*Mn*	*Cu*	Mo
				(mg kg^{-1})			
Kedida Gamela (N=156)	Mean	129.29b	8.39^{b}	0.45	150.62^{a}	1.09b	10.85^{a}
	Std Dev	38.14	5.76	0.32	54.37	0.32	2.95
	Median	128.79	6.50	0.32	144.0	1.0	10.99
	Minimum	50.04	1.3	0.02	41.0	0.6	3.06
	Maximum	209.72	28	1.83	330.0	2.9	18.71
	CV (%)	29.50	68.61	71.11	36.1	28.85	36.79
Kecha Bira (N=147)	Mean	146.73a	14.45 a	0.38	145.12ab	1.19a	6.84^{c}
	Std Dev	32.25	9.05	0.23	51.76	0.39	1.81
	Median	147.70	12.80	0.34	142.0	1.1	6.69
	Minimum	60.08	0.90	0.04	26.0	0.5	2.21
	Maximum	240.52	47.8	1.44	295.0	1.44	10.56
	CV (%)	22.02	62.63	59.59	35.67	32.84	26.48
Damboya (N=155)	Mean	147.11a	4.78^{c}	0.36	133.7b	1.31a	9.62^{b}
	Std Dev	41.73	4.63	0.28	223.0	0.3	27.35
	Median	146.5	3.6	0.29	121.0	1.3	9.62
	Minimum	46.84	1.0	0.06	36.0	0.8	2.99
	Maximum	412.23	39	2.03	304.0	3.4	17.65
	CV (%)	28.37	96.86	77.78	39.02	22.90	28.24
Total (N=458)	Mean	141.06	9.11	0.40	143.24	1.2	9.15
	Std Dev	38.53	7.77	0.28	53.26	0.35	3.05
	Median	142.56	6.25	0.32	135	1.2	9.06
	Minimum	46.84	0.9	0.02	26.0	0.5	2.21
	Maximum	412.23	47.72	2.03	330.0	3.4	18.71
	CV (%)	27.31	85.22	70.63	37.18	28.98	33.37
	Model	Exponential	Exponential	Exponential	Spherical	Spherical	Spherical
	Range (m)	10125	6765.05	6291	1089	6883.71	19,144.70
	C_0/C_0+C_1	0.46	0.53	0.70	0.60	0.56	0.45
	Spatial dependence	moderate	moderate	Moderate	moderate	Moderate	Moderate
	F_{value}	9.14^{***}	40.66^{***}	2.32^{ns}	3.82^{*}	9.53^{**}	96.74***

Numbers in the brackets refer to sample size; *, **, *** significant at $p<0.05$ $p < 0.01$, 0.001, respectively.

RESULTS AND DISCUSSION

The descriptive and geo statistics of soil micronutrients of soil samples collected from Kadida Gamela, Kachabria and Damboya districts are shown in Table 2.

Iron status

The Melich III extractable Fe varied from 50.04 to 209.72 mg kg^{-1} with a mean value of 129.29 mg kg^{-1}, 60.08 to 240.52 mg kg^{-1} with a mean value of 146.3 mg kg^{-1} and 46.84 to 233.32mg kg-^{1} with a mean value of 145.39 mg kg^{-1} in agricultural soils of Kedida Gamela, Kecha Bira and Damboya districts, respectively as shown in Table 2. Statistically significant difference ($p<0.0001$) was observed in mean values among the districts and moderate variability (CV= 27.31%) existed among Fe data. The highest and lowest mean values 147.11 and 129.29 mg kg^{-1}, respectively of extractable Fe content were recorded in Damboya and Kedida Gamela distrcts.

According to the critical level adopted by EthioSIS (2014), almost all of agricultural soil of Kedida Gamela, Kecha Bira and Damboya districts, were found to be optimum in Fe status.

Also, Figure 2 shows the Fe status that was predicted from measured sites by using co-Kringing. Exponential model was found to be the best fit for Fe data and range value for Fe was 10125 m. The nugget to sill ratio was 0.46 confirming the existence of moderate spatial

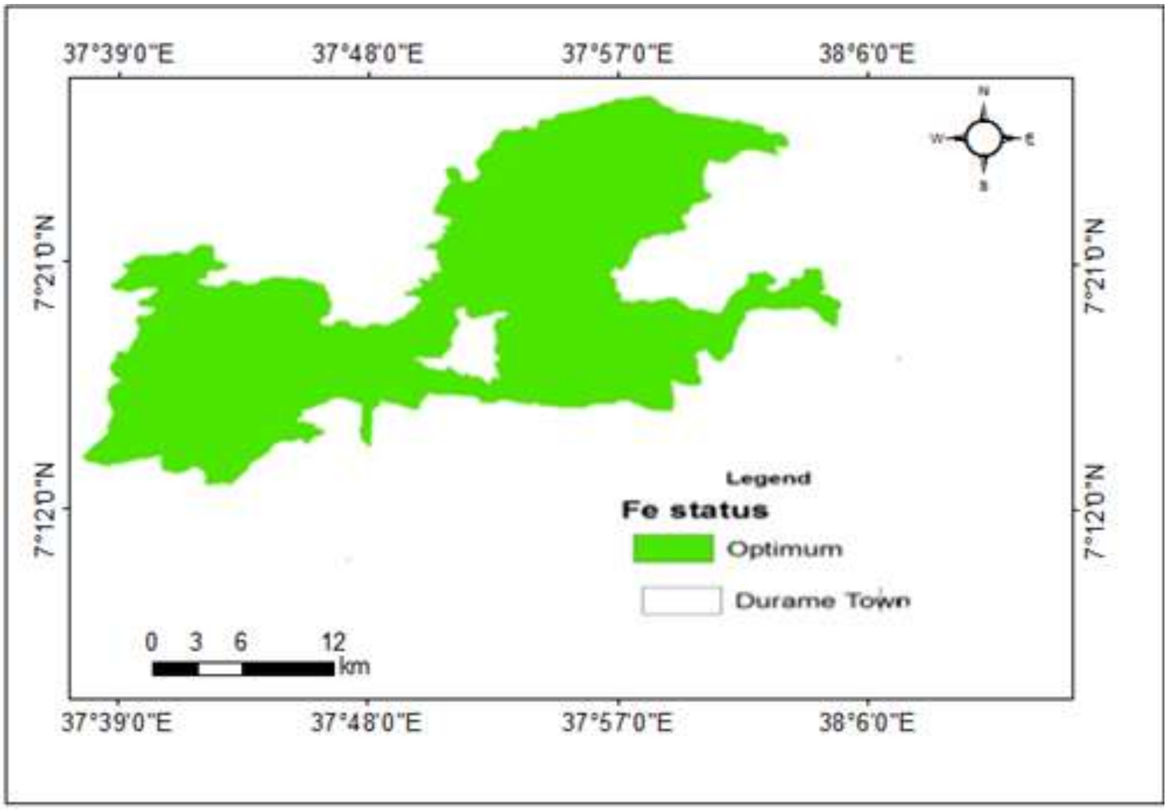

Figure 2. Soil extractable Fe map of the study area.

dependence between Fe dataset. It was observed that in terms of area coverage, all of the agricultural lands were found to be optimum in extractable Fe status. This finding is in agreement with the results of Haque et al. (2000), Abayneh (2005), Eyob et al. (2015) and Hilette et al. (2015) who reported that Fe was adequate in the soil samples collected from different regions of the country. On the other hand, Teklu et al. (2007) reported that 20 % of Vitric Andisols collected from Rift Valley of Ethiopia were deficient in Fe. Similarly, Yifru Abera and Mesifn Kebede (2013) reported Fe deficiency in 96% of soil samples collected from central highlands of Ethiopia. Also, EthioSIS fertility mapping project reported that Fe was deficiency in some Tigray agricultural soils (EthioSIS, 2014).

The existence of adequate Fe content in the soils may be due to the parent material that contains minerals like Feldspar, Magnetite, Hematite and Limonite which together constitute the bulk of trap rock in these soils (Vijaya Kumar et al., 2013). Also, soil reaction (pH) of the study area may contribute to the high amount of extractable Fe since the pH of the majority of soils in the study area is less than 7 that can enhance the solubility of Fe. Diatta (2014) and Diatta et al. (2014) reported that soil reaction (pH) is of prime importance in controlling towards the availability of micronutrients, since it affects directly their solubility as well as activity in the soil environment.

Zinc status

As shown in Table 2, extractable Zn widely ranged from 0.3 to 28 (mean = 8.39), 0.9 to 47.8 (mean= 14.45), and 1 to 39.2 (mean = 4.78) mg kg^{-1}, for agricultural soils of Kedida Gamela, Kecha Bira and Damboya Woredas, respectively. The mean separation showed that means were significantly different among districts (P<0.001).The highest mean value for extractable Zn content (14.45 mgkg^{-1}) was recorded in Kecha Brira district whereas the lowest mean value (8.39 mgkg^{-1}) was recorded in Kedida Gamela districts.

From the frequency distribution (Fig. 3A), and referring to the critical level adopted by EthioSIS, (2014) (Table 1), the majority (66.03% of Kedida Gamela, 37.41% of Kehca Bira and 84.52% of Dambya woredas') agricultural soils were optimum in Zn status. The remaining 26.8% of Kedida Gamela, 30.61% of Kech Bira and 6.45% of Damiboya districts agricultural soils were found to be high in extractable Zn status. Also, 26.28% of Kedida Gamela, 30.61% of Kecha Bira and 1.94% of Dmboya woredas agricultural soils were found to be very high in Zn status.

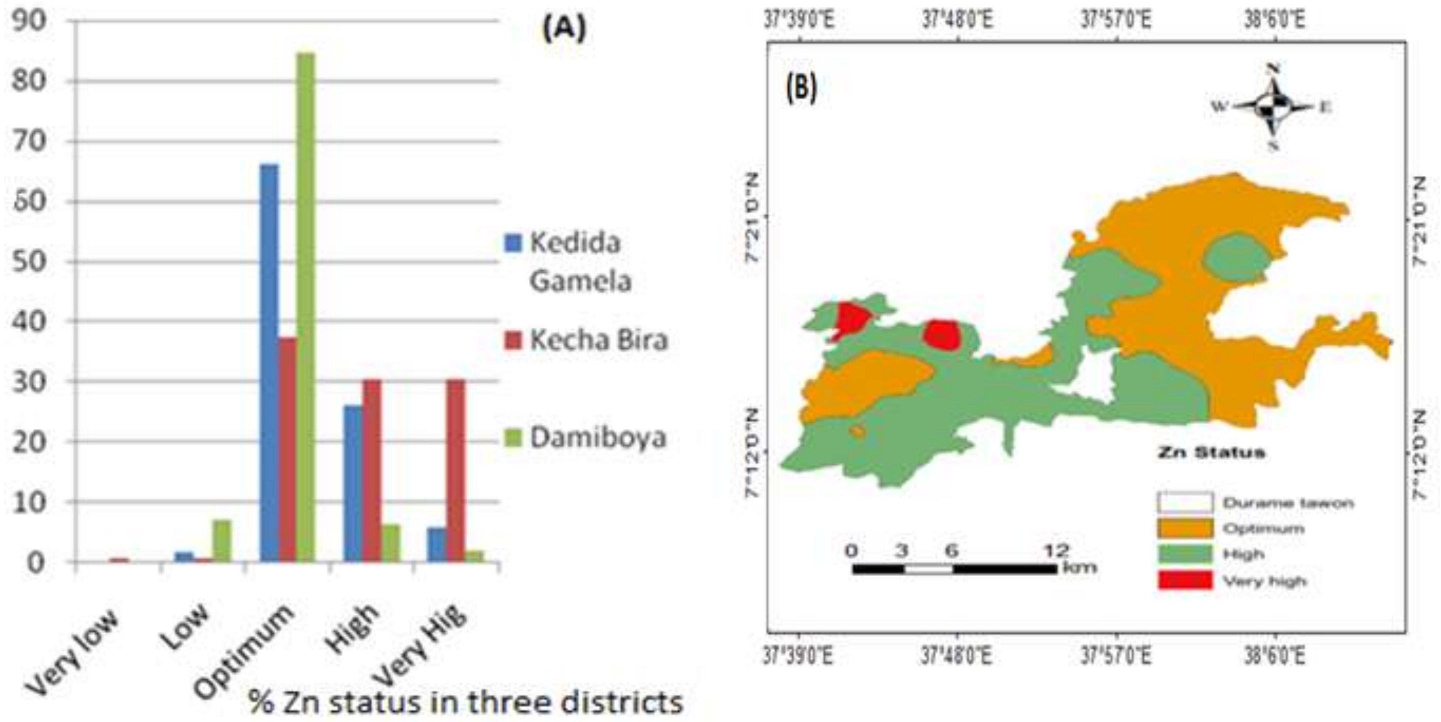

Figure 3. (A) Status of Zn (B) Soil extractable Zn map of the study areas.

Moreover, little proportion (1.92% of Kedida Gamela, 1.36% of Kacha Bira and 7.1% of Damboya woredas') agricultural soils were found to be below optimum level in extractable Zn status. Also, out of 147 samples of KechaBira district, only two soil samples (one each) were very low and low in Zn status.

Zinc status of unmeasured fields was predicted by interpolation using ordinary krining method. Exponential method was found to be the best fit on semivariogram of Zn. The range and sill to nugget ratio were found to be 6765.05 m and 0.53, respectively indicating moderate spatial dependent between Zn data. Figure 3B shows that in terms of area coverage, 61896.49, 65217.81 and 1690.569 ha were found to be optimum, high and very high in Zn status. The result of this study shows that Zn was in sufficient range in soils of all the study districts. This may be due to the soil conditions such as low pH and parent materials of soil that are high in Zn content. Certain soil conditions reduce the availability of Zn, notably high pH (Jones, and Eck, 1973). Thus, a high incidence of Zn deficiency often occurs on calcareous or limed soils. The present study soils were neither limed nor calcareous and the pH values in the majority of the soils were not too high to precipitate available Zn.

Manganese status

As shown Table 2, the Melich III extractable Mn ranged from 41 to 330 mg kg^{-1} for Kadida Gamela, 26 to 295 mg kg^{-1} for Keca Bira and 16 to 300 mg kg^{-1} for Damboya districts agricultural soils. Its concentration has reached at level of toxicity to affect most of the crop species (Jones, 2003). Statistically significant difference ($P<0.05$) was observed in mean values among the districts and moderate variability (CV= 28.98%) existed among Mn data. The highest and lowest mean values 150.62 and 133.7 mg kg^{-1}, respectively of extractable Mn content were recorded in Kedida Gamela and Damboya districts. The range and sill to nugget ratio were found 1089 m and 060, respectively indicating moderate spatial dependent between Mn data.

The calculated manganese activity indexes (MnAI) of soil samples ranged from 141-1252 for Kadida Gamela, 123-1130 for Keca Bira and 159-1142 for Damboya districts. According to Karltun et al*. (*2013), critical level for MnAI is 25. When the MnAI status of the soils of the study area was compared with the critical level, it was 5 to 50 times more than the critical level. This indicated that Mn toxicity is one of the factors that contribute to the low crop production and productivity in the study woredas. The result of this study is in line with the finding of Eyob Tilahun et al.(2015) and Wondwosen Tena and Sheleme Beyene (2011) who reported that amount of extractable Mn are generally high in the tropical soils and Mn toxicity is even more common than deficiency. Liming can be used to reduce Mn extractability and availability of Mn.

The existence of higher amount of Mn in soils of the

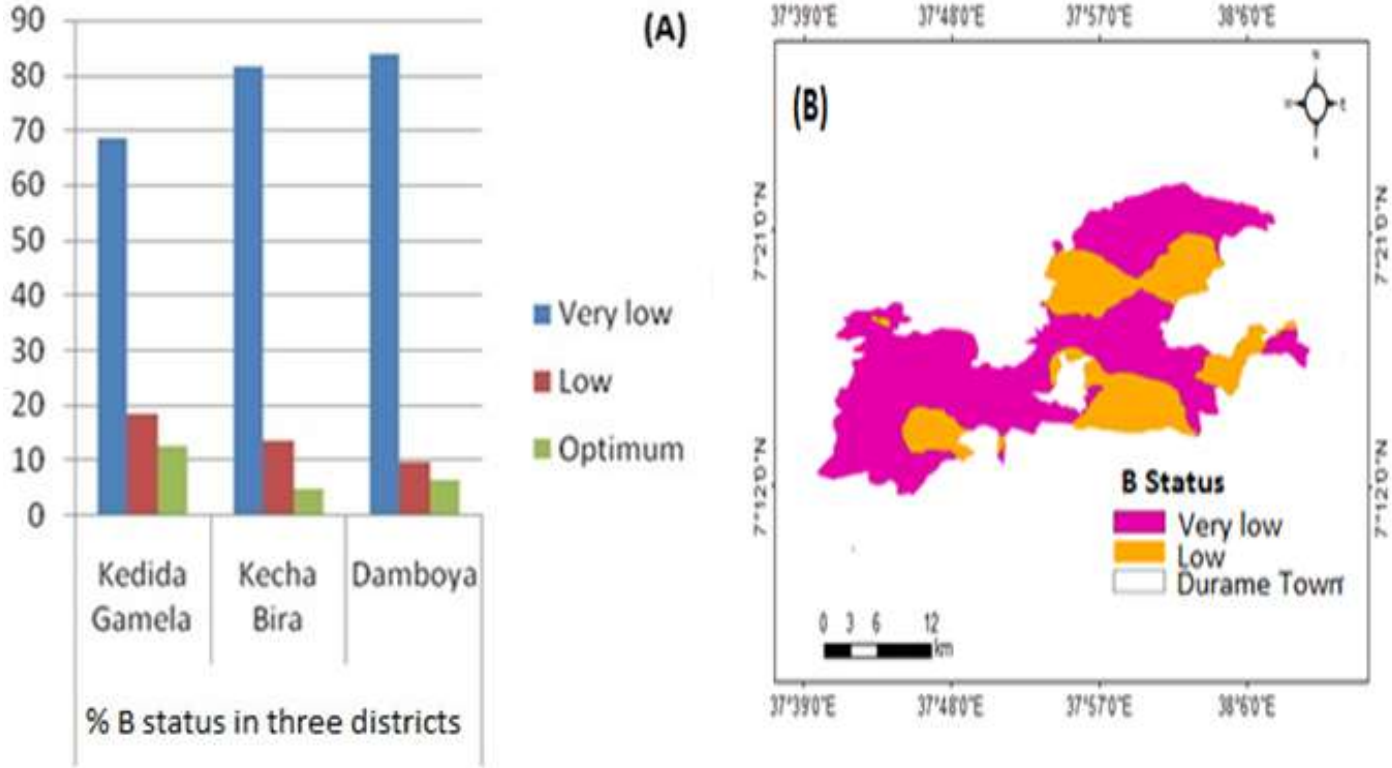

Figure 4. (A) Frequency distribution of B status of the three woredas (B) B status map.

study area may be due the weathering of primary Mn-containing ferromagnesium minerals that form secondary minerals such as pyrolusite (MnO_2). According to Jones (2003), Mn is also found in soils as Mn oxides, in part adsorbed at the surfaces of clay minerals.

Boron status

Melich III extractable B varied from 0.02 to 1.83 mg kg^{-1}, 0.4 to 1.44 mg kg^{-1} and 0.06 to 2.00 mg kg^{-} in agricultural soils of Kedida Gamela, kecha Bira and Damboya districts, respectively (Table 2).The mean B value was found to be 0.45 ppm for Kedida Gamela, and 0.38 ppm for both Kacha bira and Damboya districts and means are not significantly different (p>0.05). The larger CV (>50%) indicates that there was higher variability between B data, mainly due to variation in landscape positions, management practices, land use types, soil type and inherent properties like soil texture and pH. Also, random sampling of large number of samples from vast areas could result in moderate to high soil variability.

As shown in the frequency distribution (Figure 4A) , the majority of soils (68.59% of Kedida Gammela, 81.63% of Kacha bira and 83.87% of Damboya districts were found to be very low in Melich III extractable B status. The other 18.59, 13.61 and 9.68% of Kedida Gamela, Kecha Bira and Damboya districts' agricultural soils were respectively, found to be low in B status. A few proportion (12.82% of Kedida Gamela, 4.76% of Kecha Bira and 6.45% of Damboya districts') agricultural soils were found to be optimum. The exponential model was found to be the best fit for B data. The range value 7290.08 m and nugget to sill ratio 0.71 indicates that the spatial structure for B data is moderate.

Area coverage in different status of B was calculated after prediction of all areas by using co-kiring method by spherical model as shown in Figure 4B. Accordingly, in terms of area coverage, 90880.78 ha (70.56%), 37864.09 ha (29.39%), 60.0 ha (0.001%) of the agricultural soils in the study districts were very low, low and optimum, respectively. This revealed that nearly all agricultural soils of the study areas were below critical level in B status and it is one of the crop yield limiting nutrient in the study areas. The result of this study is in line with that of Wondwosen Tena and Sheleme Beyene (2011) and Eyob Tilahun et al. (2015) who reported that B was deficient in some soils of western and southern Ethiopia.

The possible reasons for B deficiency in the study area may be due to loss of B through leaching in acidic soil, low B absorbing capacity of soils, low OM, continuous cultivation of soils, low B containing parent materials, lower application rate of manure and use of non B containing fertilizer (Oyinlola and Chude, 2010; Chesworth,

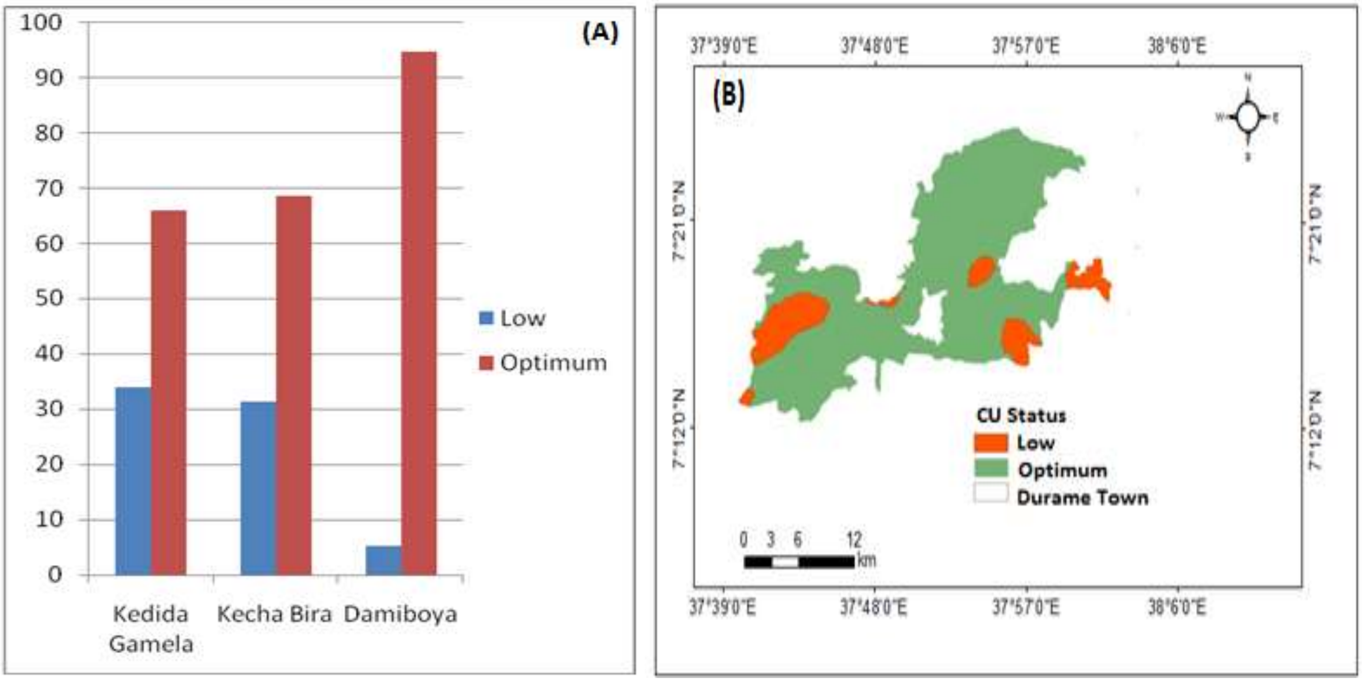

Figure 5. (A) Frequency distribution of Cu status of the three districts (B) Cu status map.

2007). Generally, this finding revealed that B is deficient and it may be one of yield limiting elements in all soils of the three woredas since its deficiency affects the growing points of roots, shoots and young leaves and retard the uptake of calcium (Tandon, 1997). Therefore, it is strongly recommended that B should be included in blended or compound fertilizer to boost the crop yield in the study area.

Copper status

As shown in Table 2, extractable Cu ranged from 0.6 to 2.9, 0.5 to 1.44 and 0.8 to 3.4 mg kg^{-1} in agricultural soils of Kedida Gamela, Kecha Bira and Damiboya districts, respectively. The mean Cu values were found to be 1.09, 1.119 and 1.31 mg kg^{-1} for Kedida Gamela, Kecha Bira and Damboya districts, respectively.

As shown in the frequency distribution (Figure 5A) and referring the Cu critical levels, adopted by EthioSIS (2014), the majority of agricultural soils of the study areas (66.03% of Kedida Gamela, 68.71% of Kecha Bira and 94.84% of Damboya districts) were found to be optimum in Melich III extractable Cu status. The remaining 33.70% of Kedida Gamela, 31.29% of Kecha Bira and 5.16% of Damboya woredas were found in low category of Cu status.

Exponential model provided the best fit for the semivariogram of Cu. The range for Cu on semivariogram was 6884.71 m (Table 2). The nugget to sill ratio 0.56 indicates that the spatial dependence of extractable Cu was moderate. The prediction map (Figure 5B) indicates that in terms of area coverage, 11 and 89% of soils were found to be low and optimum, respectively in Cu status as per of critical level adopted by EthioSIS (2014).

The finding of this study revealed that 11% of agricultural soils in the study woradas were deficient in Cu. This may be due to low soil OM, intensive cropping systems and non use of Cu containing fertilizer which could result in high Cu mining from the soils. Soils derived from coarse-grained sediments (sands and sandstones) as well as acid igneous rocks are usually low in Cu. According to Harmsen.and Vlek (1985), factors affecting the soils ability to provide Cu to plants include pH, humus content and proportion of sand to clay (Harmsen and Vlek, 1985). The findings of this study revealed that 11% of agricultural soils should be supplemented Cu containing fertilizers in order to improve crop yields since most plants are sensitive to Cu deficiency. Cereals (oats, wheat, barley, maize) and vegetables are particularly sensitive (Murphy and Walsh, 1972).

Molybdenum status

The Melich III extractable Mo varied from 3.06 to 18.71 mg kg $^{-1}$(mean 10.85 mg kg^{-1}), 2.21 to 10.52 mg kg^{-1} (mean 6.84 mg kg^{-1}) and 2.99 to 17.56 mg kg-^{1} (mean 6.92 mg kg^{-1}) in agricultural soil of Kedida Gamela, Kecha Bira and Damboya districts, respectively as shown in

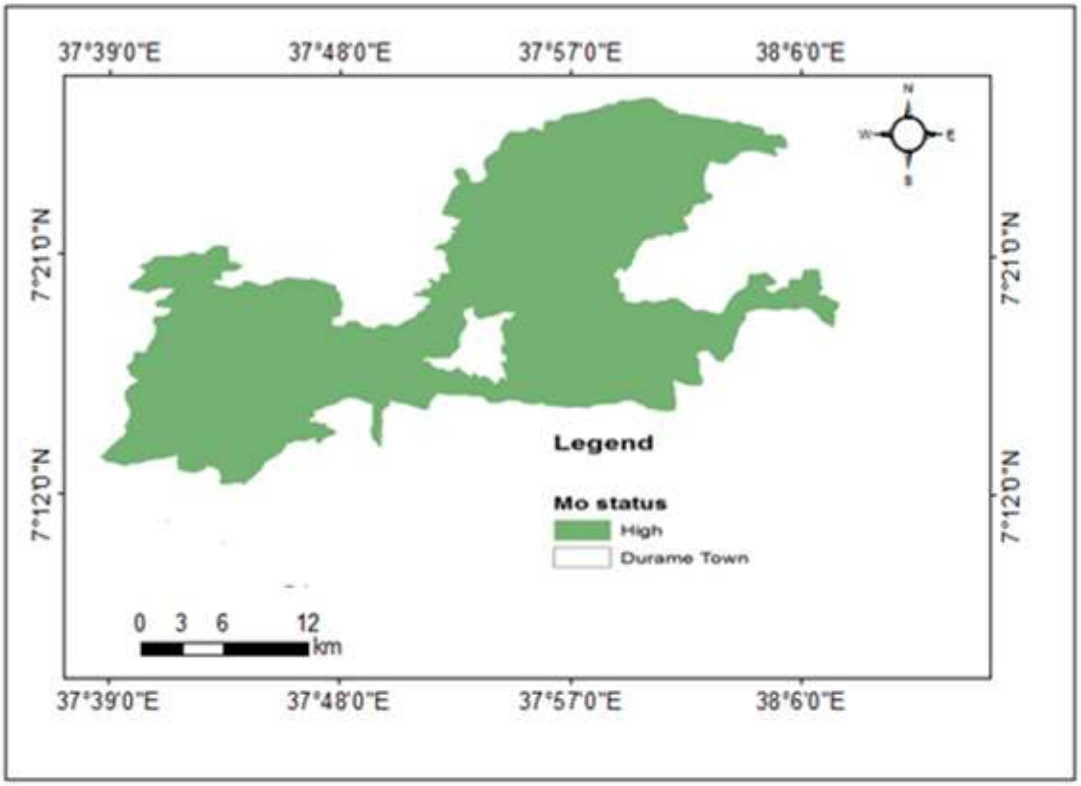

Figure 6. Soil extractable Mo map of the study area

Table 2. Statistically significantdifference (p<0.0001) was observed in mean values among the woredas and moderate variability (CV= 33.71%) existed among Mo data. This indicates that soil characteristics in the woredas differ greatly and such manifestation of differences in extractable Mo content in the soils might be ascribed to the larger variation in soil characteristics such as pH, calcium carbonate and soil texture, which greatly influence the amount of extractable Mo in soils, and its eventual availability to growing plants (Gupta and Dabas, 1994; Adhikari et al., 1997; Sharma et al., 2003).

According to the critical level adopted by EthioSIS (2014), almost all of agricultural soils of Kedida Gamela, Kecha Bira and Damboya districts were found to be high in Mo status. This might be linked with the stage of weathering of soils. Availability of Mo in young volcanic soils is generally high (Mengel and Kirkby, 2001). Figure 6 shows the Mo status predicted from measured site. Spherical model was found to be the best fit for Mo data and range value for Mo was 19,144.7 m. The nugget to sill ratio 0.45 indicates that the spatial dependence of extractable Cu was moderate.

Regardless of high status of extractable Mo in the soils of study area, for future application of balanced fertilizers together with high-yielding varieties would lead to Mo deficiency. For instance, in India introduction of high-yielding varieties and higher use of nitrogen, phosphorus and potassium, increased crop production many folds and led to Mo deficiency in 11% of Indian soils (Singh, 2001). Similarly, Gupta and Lipsett (1994) reported that applying S has been found to decrease uptake of Mo by plants. Therefore, in order to judge the status of Mo in the study area soils, further study is recommend after harvesting high crop yields in the near future since Mo is one of the important micronutrients which helps in biological N fixation in legumes and legumes are given special consideration in the study region.

Relationship between available micronutrients and some soil properties

The micronutrient content of soils is influenced by several factors among which soil organic matter content, soil reaction and clay content are the major ones (Fisseha, 1992). Therefore, an attempt was made to examine the relationship between copper, zinc, boron and molybdenum and some soil properties (pH, organic matter and particle size) by simple correlation analysis (Table 3), to identify the soil factors involved in regulation of amounts of extractable Cu, Zn, B and Mo in soils. Significant and positive (p<0.001) relationship of extractable Fe, Zn, B and Cu with organic matter (r = 0.21, 0.43, 0.12 and 0.13), respectively was observed

Table 3. Correlation between some soil properties and extractable micronutrients in soils of study areas.

Extractable micronutrients	Soil properties				
	pH	OM	Clay	Silt	Sand
Fe	-0.43**	0.212**	-0.3	0.13*	-0.11*
Zn	-0.07	0.43**	-0.056	0.061	0.098*
Mn	-0.1*	0.009	-0.87	0.079	0.062
B	0.32**	0.123**	-0.168**	0.11*	0.172**
Cu	0.22**	0.129**	-0.09*	0.16**	-0.037
Mo	0.18**	-0.05	-0.55***	0.62***	0.25***

(Table 3). The results were in close agreement with findings of Yadav (2011); Khalifa et al. (1996), Eyob Tilahun et al. (2015) and Kumar et al. (2013). The reason for this might be the ability of SOM to form natural chelates that can maintain micronutrients in an available form. Also, organic matter controls the affinity, attraction strength of micronutrients with most functional groups (Jean et al., 2014).

The negative correlation of extractable Fe, Zn and Mn with soil pH was observed. This indicates that there is precipitation of extractable micronutrients into insoluble products when pH rises. The activity of Mn, Fe, and Zn decreases 100-fold for each unit increase in soil pH (Lindsay, 1978). Various correlation studies by Rajagopal et al. (1977) and Haldar and Mandal (1979) have confirmed that decline in extractable Zn associated with the rise in pH. Many researches revealed that soil pH is negatively correlated with Fe content (Wang et al., 2009; Sharma et al., 2004; Najafi-Ghiri et al., 2013). According to Katyal et al. (1982), Zn deficiency was generally observed in crops growing on alkaline soils. Ismunadji et al. (1982) reported that Fe chlorosis was severe in several crops growing on high pH calcareous upland soils of Indonesia. The availability of micronutrients Fe, Zn and Mn decreases as the soil pH increases due to the hydrolysis reactions (through the splitting of water molecules in their hydration shells) (Sinskey, 2009). Boron and Mo were positively and significantly related with pH, silt and sand but negatively correlated with clay. Chavan et al. (1980) also noticed an increase in water-soluble B with fineness of texture. While Le Mare (1970) stated that B deficiency occurs on light textured soils. Goldberg (1993) stated that sorption of B to Fe and Al oxides was pH dependent and was highest at pH 6 to 9 and bioavailability of B was highest between pH 5.5 to 7.5, decreasing below 8.5. According to Singh (1970), high B and Mo contents were noticed in saline alkaline soils.

CONCLUSION AND RECOMMENDATION

This study showed that the Melich III extractable Fe, Zn and Mo status in most of agricultural soils of the study woredas was found to be sufficient. The calculated MnAI was greater than the critical value that indicates the Mn toxicity is common in the soils of study areas. Extractable B is below optimum level in most of soil samples analyzed and it might be one of the yield limiting nutrients in the study areas. Majority of soil samples analyzed were optimum in Cu status but about 11% of soil samples analyzed were low in Cu status.

Further, the contents of micronutrients (Fe, Zn, Mn, Cu and B) increased with increase in organic matter content this might be due to organic matter content may supply chelating agents. In order to boost crop yield, fertilizers that contain B for all soils of study the areas and Cu for 11% of the study area soils should be recommended. Moreover, the geo-referenced sampling sites can be revisited after a few years with the help of GPS, which helps in monitoring the changes in the status of nutrients over a period of time, which otherwise is not possible by traditional methods of sampling .The study can be strengthened by further analysis of plant tissue samples taken from field grown crops in the study areas.

Conflict of Interests

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors would like to thank the Ethiopian Soil Information System (EthioSIS) of the Agricultural Transformation Agency (ATA) and Ministry of Education (MoE), for financial support and scholarship, respectively. Also, our thanks is extended to farmers in Kedida Gamela, Kecha Bira and Damboya districts for their assistance and sharing of knowledge and experiences to us during the field study.

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