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Assessment and Mapping of Some Soil Micronutrients Status in Agricultural Land of Alicho-Woriro Woreda, Siltie Zone, Southern Ethiopia

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ABSTRACT
Even though the role of micronutrients in the balanced plant nutrition is vital, information regarding their status in the most Ethiopian soils is insufficient. As result, fertilizer recommendation for crops in the country is mainly for macronutrients yet. But, continuous application of only macronutrients may cause for rapid depletion of other nutrients such as micronutrients. In view of this, a study was conducted at Alicho-Woriro Woreda in Siltie Zone, Southern Ethiopia to assess and map status of some micronutrients (Manganes-Mn, Iron-Fe, Copper-Cu, Zinc-Zn and Boron-B). These 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). Particle size distribution was analyzed by laser diffraction. Soil reaction was determined by pH meter and OC was predicted from Mid Infra Red spectra. Concentration of assessed micronutrients ranged from Mn (10-161 mg kg^{-1}), Fe (101-225 mg kg^{-1}), Zn (1.53-10 mg kg^{-1}), Cu (0.92-3.9 mg kg^{-1}) and B (0.01-0.73 mg kg^{-1}). Based on these analytical results, status of Mn and Fe were excess, Zn and Cu were optimum and B varied from very low to low based on soil nutrients critical values of Mehlich-III.

Key words: Assessment, mapping, micronutrients, critical level

INTRODUCTION
Although micronutrients are required in trace quantities for plants, they are important as counterpart macronutrients (Fisseha, 1992). Most of micronutrients are associated with enzymatic activities of plants. Thus, micronutrient deficiency and/or toxicity can affect crops yield (Tisdale *et al.*, 1995). Applying deficient micronutrients towards soil in conjunction with common fertilizers promotes crops yield (Tisdale *et al.*, 1995).

Availability of micronutrient to plant growth is particularly sensitive to change in soil environmental factors such as soil pH, OC, liming and soil texture (Fisseha, 1992). As many findings showed that micronutrients status in the soil is mostly a positively correlated with clay and OC content but negatively correlated with soil pH (Dibabe *et al.*, 2007). In relation to soil texture, most sandy soils (coarse texture) are deficient in micronutrients whereas clay soils (fine texture) are not comparatively to be low in plant available micronutrients (Chhabra *et al.*, 1996).

Continuous application of macronutrients such as N and P fertilizers has significant contribution towards soil micronutrients depletion. For example, approximately two to six times more of the micronutrients are being removed annually from the soil than are applied to it in soils of India (Katyal and Randhawa, 1983). This can be significant particularly in Ethiopia where there is no micronutrient application towards soil in the form of chemical fertilizers or organic elements (Dibabe *et al*., 2007).

Currently, more attention is being given to fertilizing soil with micronutrients in many sub-Saharan countries including Ethiopia due to many reasons such as crops positive response towards micronutrients, long time cropping has removed large amounts of these nutrients, widespread use of animal manures has been decreased, top soil erosion has been removing certain micronutrients, spatial variability of micronutrients has been recognized and more concentration is being given to crop quality and nutritional value of crops (Fisseha, 1992).

Ethiopian Soil Information System (EthioSIS) of Agricultural Transformation Agency (ATA) and Ministry of Agriculture (MoA) is currently pursuing complete soil fertility assessment to come up with solid, evidence-based and targeted fertilizer recommendations and other management interventions for agricultural land soils of Ethiopia (ATA., 2013). Although there were many different studies in the country, those former soil fertility investigations were fragmented and had no fertilizer recommendation approach in country level.

Most recent studies confirmed that certain soil micronutrients were deficient in soils of Ethiopia which limit crop productivity. Due to misunderstanding or seeming of not remarkable response towards micronutrients application, some of researchers concluded that micronutrients deficiency was not serious problem in Ethiopian soils (Beyene, 1982). According to diagnosis results of some micronutrients status by Haque *et al*. (2000), Beyene (1982) and Dibabe *et al*. (2007) in Ethiopian soils showed that Fe and Mn were above the critical level whereas status of Cu and Zn was variable throughout their study areas. Tena and Beyene (2011) also reported that Mn, Fe, Zn and Cu were above the critical level while extractable B was highly deficient and potentially crop production limiting nutrient and its status in the soil was less than three times that of critical value in Delbo-Atwaro watershed in Southern Ethiopia.

Generally, in most of the soil nutrient studies in Ethiopia, more emphasis was given to macronutrients; but studies in the micronutrients status of Ethiopian soils are scarce. Considering those problems, this study was conducted in Alicho-Woriro district in Southern Ethiopia to assess and indicate their (Mn, Fe, Cu, B and Zn) status from map.

MATERIALS AND METHODS

Characteristics of study area

Location: The study was conducted at Alicho-Woriro district in Northern Siltie Zone, Southern Ethiopia. Geographically, this area is situated between 7.850-8.009 N latitude and 38.079-38.281 E longitudes, which is about 217 km away from Addis Ababa (Fig. 1). The elevation of the study area ranges from 2350-3290 m above sea level (masl).

Climate: The study area is characterized by uni-modal rainfall pattern. Very high intensity of rainfall is observed in the months of July and August (Fig. 2). Recent 10 year (2004-2013) climatic data obtained from Ethiopian National Meteorology Authority (Addis Ababa) indicates that the mean annual rainfall is about 1092 mm and varies between 543-1998 mm. The average annual

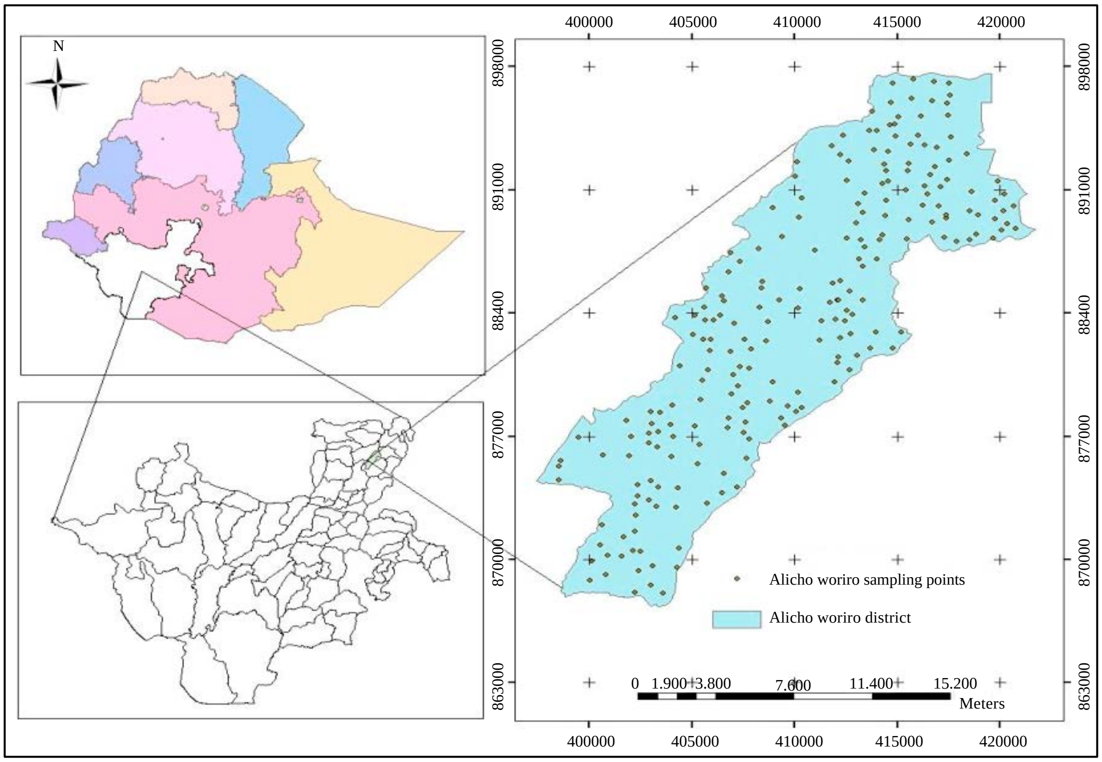

Fig. 1: Location map of the study Woreda with sampling points

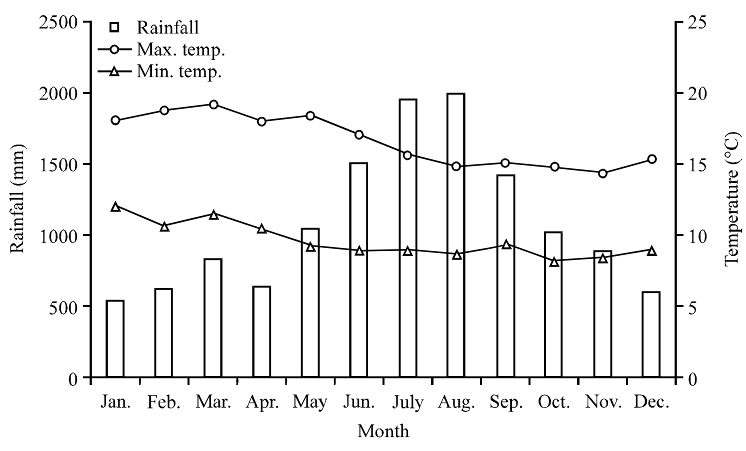

Fig. 2: Monthly average rainfall (mm) and mean maximum and minimum temperature (°C) data of the study area from January 2004 to December 2013

minimum and maximum temperatures of the area are 9.6 and 16.6°C. There is a frost hazard during autumn starting from October to the end of November causing severe crop losses when temperature varies in between 8.1-8.4°C.

Land use and vegetation: Mixed crop-livestock system occupies the main land use systems in the study area. Barley (*Hordeum vulgare*) is highly dominant crop grown in the study area over sorghum (*Sorghum* spp.), wheat (*Triticum aestivum*), chick pea (*Pisum sativum*), enset (*Enset ventricosum*), maize (*Zea mays*) and potato (*Salantum tuberosum*). Khat (*Catha edulis Forsk*) is other dominant non-food crop in the area. Agriculture is entirely rain-fed. There are few types of natural vegetation in the area in addition to different grass species covering the ground on the grazing lands.

Geology and soils: According to the Tefera *et al.* (1996), major geological occurrences that affected the study area were continued uplift of the Ethiopian plateaus at the end of the Mesozoic era and extreme heavy rainfall known as "Pluvial Rain" at quaternary period. In the Geological Map of Ethiopia, it was identified that Alicho-Woriro consists of deeply weathered acidic soils. Pellic and Chromic Vertisols were identified as major soil types in the study Woreda. Of these soil types, Pellic Vertisols are highly dominant soils in the study area which covers large area. Based on color, the dominant soils of the study area are black and red. Locally, the farmers call the red soils "kei afer" and the black soils "tikur afer". In terms of area coverage, the black soils are by far more dominant than the red soils in the Woreda.

Field soil survey and sampling techniques: Pre-defined sampling points were generated and randomly distributed over agricultural land of the district by following EthioSIS point generation and field guideline. Field data collection and soil sampling were carried out by using GPS by navigating those points. Plot and center of the sub-plots was determined by letting the GPS average position for at least 3-5 min. After center of sampling points were identified, 10-15 sub-samples were taken and composited based on the complexity of topography and heterogeneity of the soil type. A total, 223 composite soil samples were collected during the 2013 off season from the agricultural land of the district.

The soil sampling depth was at top surface (0-20 cm) for annual crops and (0-50 cm) for perennial crops. For those landscapes having uniform topography and homogenous soil type up to 10 sub-samples were collected and composited within 10-50 m distance between and among each sub-sampling points in a zigzag method. But for undulating topography where slope varied in short distance and heterogeneous soil type, the number of sub-samples was extended up to 15 within relatively short distance that ranged between 10-20 m between and among each sub-samples. For each main sampling point, 1 kg of representative composite soil sample was collected and logged into properly labeled sample bag.

Soil samples were not taken from unusual areas like animal dung accumulation places, poorly drained and any other places that cannot give representative soil samples. During soil sampling, spatial information (latitude and longitude), topography, slope, elevation, land use type, crop type, local soil name, sampling depth, soil color, crop residue management, rate of last year fertilizer application and type were collected from each plot.

Soil laboratory analysis: The collected soil samples were air dried, crushed and passed through 2 mm diameter sieves. Extractable micronutrients (Fe, Cu, Mn, Zn and B) 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). Soil reaction or pH (1:2.5) was determined by pH meter using the procedure described by Van Reeuwijk (1993).

Organic carbon was predicted from MIR spectra of soil samples. After soil and control samples were loaded from the plate, the samples were subjected to spectral reading. Four readings were recorded in the form of graphic wave length for each soil sample. Graphic format MIR soil data was exported and then converted to excel format data after processing it by OPUS software. Finally, those four readings were averaged for each soil sample and taken as one sample value.

Particle size distribution was analyzed by laser diffraction 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. After soil samples were inserted into the equipment by spoon, consecutive four readings were recorded in the form of (.ngb) file format. The (ngb) file format data were converted to flat file using the file list utility and export package of the LA-950 software version 7.01. The flat file was then converted into sand, silt and clay% by using R-script program. Finally, fourth readings were taken for silt; clay and sand proportion from excel data to determine the textural class of each soil sample (Agrawal *et al*., 1991).

Mapping of soil micronutrients: Spatial prediction model was used to estimate the quantitative values of the response variable at unvisited locations. Universal kriging by using multivariate regression was used to predict unknown values of soil nutrients concentration for non-sampled areas based on the nearby surveyed data. Point data of selective soil attributes were interpolated across the study area using the geo-statistical model and their spatial prediction were evaluated. Mapping of predicted soil nutrients were carried out by using Arc GIS software version 10 with output pixel size of 100×100 m.

Non-agricultural lands in the study Woreda were clipped out from the study Woreda by using Google Earth before prediction of soil nutrients. After kriging was carried out for selective soil parameters, nutrients status classes were defined from the map based on the respective rating values.

Statistical data analysis: Simple linear correlation analysis was carried out between micronutrients and some governing factors of micronutrients status. Basically, quantitative analysis was carried out separately for micronutrients, texture, OC and pH. Finally, selected physical and chemical properties of soil parameters status were indicated from the maps.

RESULTS AND DISCUSSION

Soil pH, OC and particle size distributions which govern status of soil micronutrients: The soil reaction was ranged from 4.9-5.9 with a median value of 5.4 (Table 1) and rated as strongly acidic (<5.5) to moderately acidic (5.6-6.5) based on the rating suggested by Karltun *et al.* (2013). It has been established that some plant nutrients are not optimally available to plants within this pH range, plus this range of pH is not compatible to plant root growth

Table 1: Descriptive statistics of pH, OC and soil proportions of soil samples collected from study Woreda

Attributes	Range	Mean	SD	CV	Median
pH	4.85-5.89	5.4	0.3	1.4	5.40
OC (%)	1.50-3.01	2.5	0.5	2.0	2.48
Sand (%)	3.2-30.70	11.8	4.3	36.0	11.00
Silt (%)	5.8-50.00	30.0	9.2	31.0	29.40
Clay (%)	27.4-91.00	58.0	13.0	22.0	59.40

(Tisdale *et al.*, 2003). Amount of OC in the soils of the study Woreda ranged from 1.50-3.01% with median value of 2.48% (Table 1). Status of OC was totally optimum in all soil samples collected from the study district based on rating suggested by Tekalign *et al.* (1991). Accordingly, the sand content ranged between 3.2-30.7%, silt between 5.8-50% and clay 27.4-91% (Table 1). The median values for these separates were 11, 29.4 and 59.4%, respectively (Table 2). Among the agricultural soils of the study Woreda, clay soils cover 78% of it followed by silt and sand. Available Mn, Fe, Cu

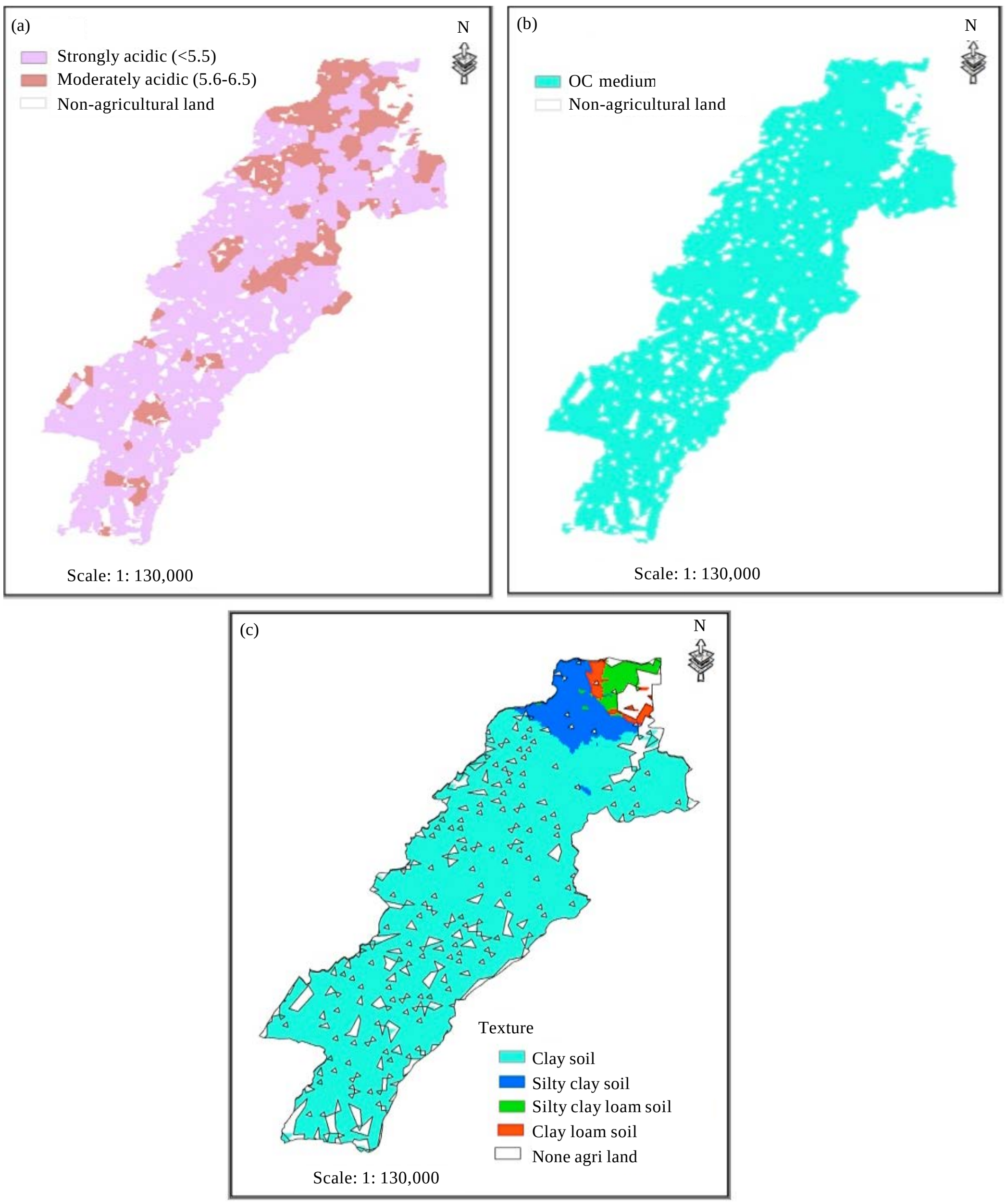

Fig. 3(a-c): Spatial variability of soil (a) pH, (b) OC and (c) Particle size distribution in the agricultural land soils of the study Woreda

Table 2: Correlation matrix (Pearson) of soil pH, OC and soil proportions versus micronutrients of the samples collected from study Woreda

Parameters	Fe	Mn	Cu	Zn	B
pH	-0.72**	-0.84*	0.27	0.30	0.24
OC	0.25	0.26	0.66**	0.64**	0.70**
Sand	-0.22*	0.28	-0.17	0.11	0.23
Silt	0.08	-0.26	0.25	-0.18	-0.27
Clay	0.58*	0.64*	0.42	0.32	0.32*

**,*Significant at $p = 0.01$ and 0.05, respectively

Table 3: Descriptive statistics of Mehlich-III extracted micronutrients (B, Cu, Zn, Fe and Mn) in the soil samples

Micronutrients (mg kg^{-1})	Range	Mean	SD	CV	Median	Status
Mn	10-161	85.00	44.00	21	81.00	Excess
Fe	101-225	154.00	22.50	15	156.00	Excess
Zn	1.53-10.0	4.00	1.34	15	3.90	Optimum
Cu	0.92-3.91	1.75	0.73	12	1.63	Optimum
B	0.01-0.73	0.42	0.30	22	0.50	Very low to low

and Zn were positively correlated with clay contents and OC whereas available Mn and Fe were negatively correlated with soil pH (Table 2, Fig. 3). This finding is in agreement with that of Dibabe *et al.* (2007).

Mehlich-III extractable micronutrients (B, Zn, Cu, Fe and Mn): The values of B in the soil samples ranged from 0.01-0.73 mg kg^{-1} with median value of 0.5 mg kg^{-1} (Table 3). Based on the critical level of 0.8 mg kg^{-1} for B suggested by Karltun *et al.* (2013), all soil samples collected from the study district were deficient in B. This finding is in agreement with that of Tena and Beyene (2011) who reported deficiency of extractable B in similar agro-ecology with the study Woreda. According to this, it could be concluded that available B was highly deficient and probably one of the limiting nutrients in the study Woreda (Fig. 4).

Zinc (Zn) values ranged from 1.53-10 mg kg^{-1} with median value of 3.9 mg kg^{-1} (Table 3). Comparison of extractable Zn content with the critical level of 1.5 mg kg^{-1} suggested by Karltun *et al.* (2013), all soil samples showed optimum amount Zn. Cu varied from 0.92-3.91 mg kg^{-1} with median value of 1.63 mg kg^{-1} (Table 3). Referring the critical value of 0.9 mg kg^{-1} suggested by Karltun *et al.* (2013), all soil samples showed optimum amount of Cu. This finding for Zn and Cu is in agreement with that of Tena and Beyene (2011) in the similar agro-ecology with present study area.

The values of Fe ranged from 101 to 225 mg kg^{-1} with median value of 156 mg kg^{-1} (Table 3). Mehlich-III extracted Fe was three times higher than DTPA extracted Fe and different authors reported 4.8 mg kg^{-1} as critical value of DTPA extracted Fe. According to this relationship, almost 14.4 mg kg^{-1} can be considered as critical value for Mehlich-III extracted Fe. As result, amount of Fe in the soil samples collected in this study Woreda were approximately 7-16 times greater than its critical level.

The results of Mn varied from 10.0-161 mg kg^{-1} with median value of 81 mg kg^{-1} (Table 3). Calculated manganese activity indexes of soil samples ranged from 53 to 625. With reference to Manganese Activity Index suggested by Karltun *et al.* (2013) which is 25 as critical level, amount of Mn was 2 to 25 times more of its critical level. As result, Mn toxicity could be expected that is one

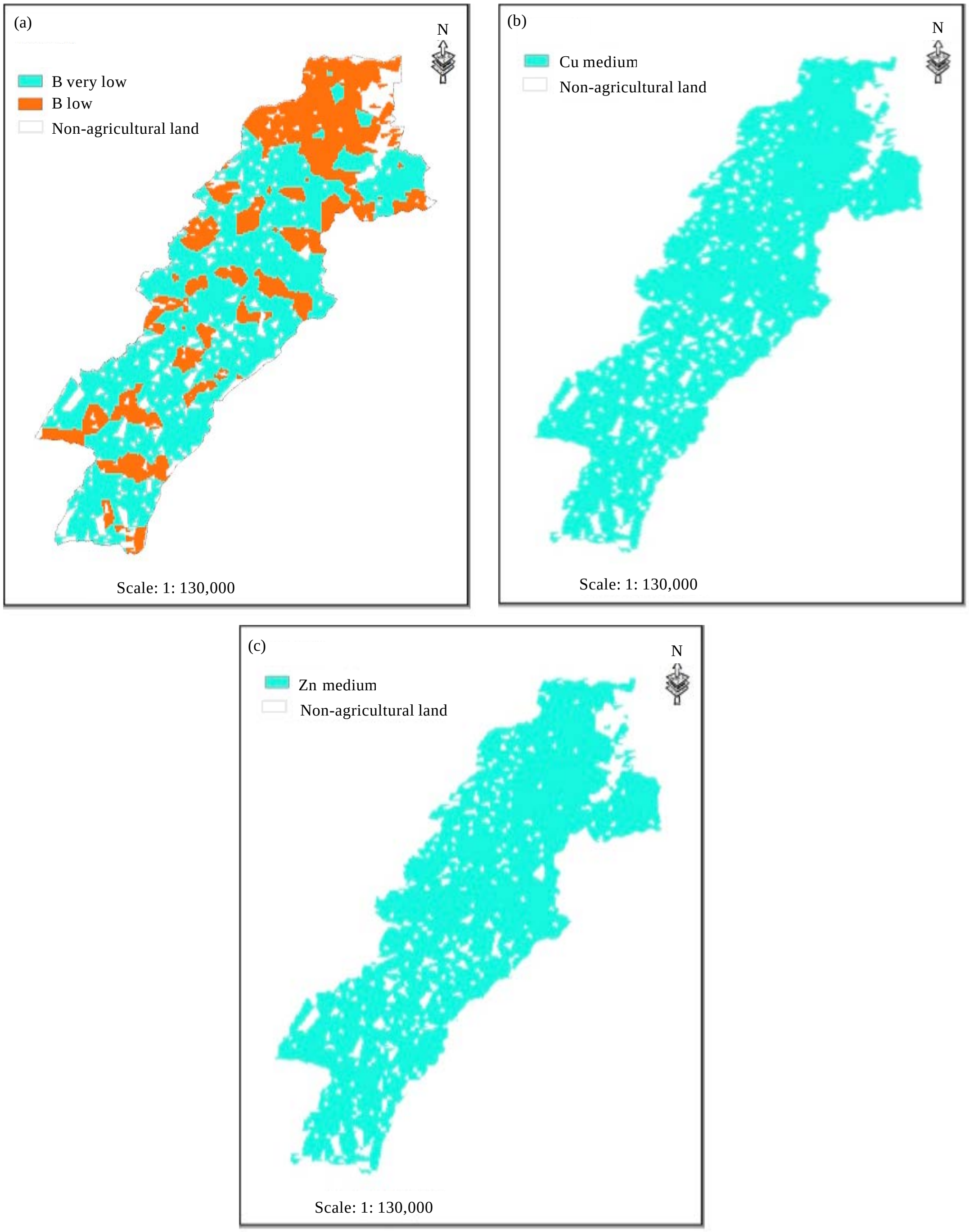

Fig. 4(a-c): Spatial variability of extractable, (a) Boron (B), (b) Copper (Cu) and (c) Zinc (Zn) in the in the agricultural land soils of the study Woreda

of directly or indirectly affecting factors of crop productivity and production. This finding is in agreement with Haque *et al.* (2000), Beyene (1982), Dibabe *et al.* (2007) and Tena and Beyene (2011) who reported that amount of extractable Mn and Fe are generally high in the tropical soils and Mn toxicity is even more common than deficiency (Fig. 4, 5).

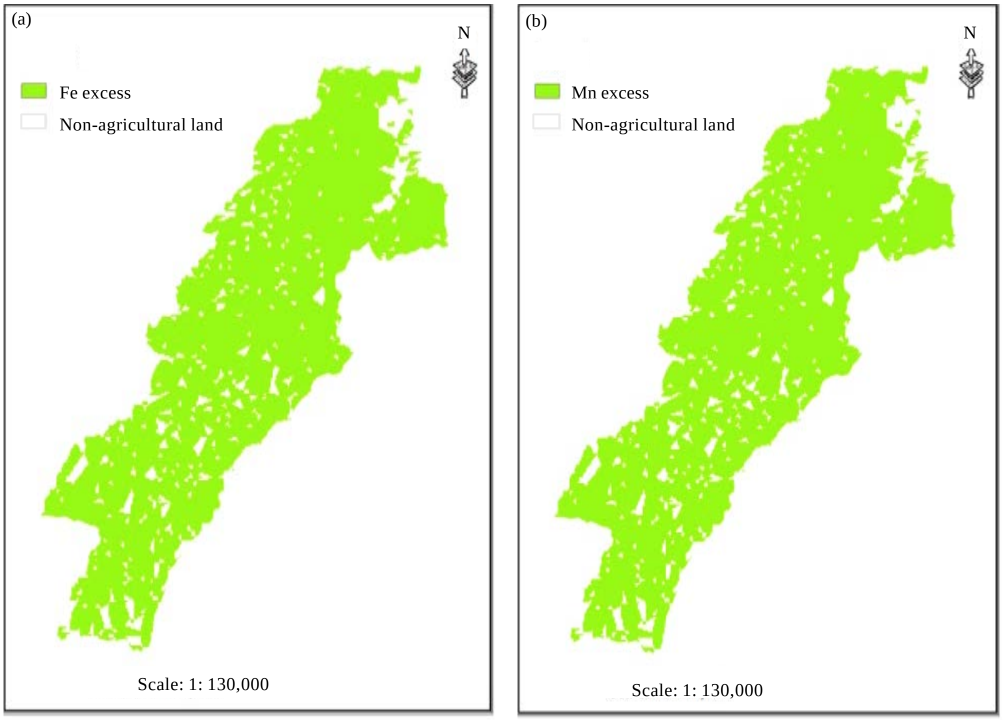

Fig. 5(a-b): Spatial variability of extractable, (a) Iron (Fe) and (b) Manganese (Mn) in the agricultural land soils of the study Woreda

CONCLUSION

It is evidence that from this study, extractable Mn and Fe were excess, Cu and Zn were optimum. Conversely, extractable B was below the critical level throughout the study area. As result, periodic check up of toxic elements such as Mn and B is recommended. The soil reaction was varied from strongly acidic to moderately acidic. Status of OC was totally optimum in all soil samples collected.

As future research direction remark, locally tailored critical values for all micronutrients need to be developed in order to make sure that these findings are well done. Furthermore, periodic assessment of soil nutrients is recommended to obtain targeted and optimum yield.

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