FERTILITY STATUS OF EUTRIC NITISOL AND FERTILIZER RECOMMENDATION USING NUMASS IN THE SELECTED AREAS OF JIMMA ZONE, SOUTHWESTERN ETHIOPIA

[SITUACIÓN DE LA FERTILIDAD DE UN NITISOL ÉUTRICO Y RECOMENDACIÓN DE FERTILIZACION, UTILIZANDO NUMASS EN ÁREAS SELECCIONADAS DE LA ZONA DE JIMMA, SUROESTE DE ETIOPÍA]

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SUMMARY

Nutrient management decision support system (NuMaSS) is a tool that diagnoses soil constraints and selects the appropriate management practices, based on agronomic, economic and environmental criteria, for location-specific conditions. However, its validation in different soil orders and agroecosystems should be tested. Thus, the present study was conducted to assess the fertility status of Eutric Nitisol and suggests the application of NuMaSS as a diagnostic tool to recommend supplementary N and P fertilizers for maize across different agroecology zones. Accordingly, fifty soil samples were collected from five locations and analyzed for the major soil physical and chemical properties. The soil pH-H_2O was below the critical level for all soil samples. Nitrogen, Cu and Zn were deficit in all soil samples. Deficiency of available phosphorous was also observed in 88% of the soil samples. High probabilities of nitrogen and phosphorous deficiency were also observed in the study areas using NuMaSS. Moreover, 24 kg/ha P and 73 kg/ha N for Dedo; 24kg/ha P and 82 kg/ha N for Agaro; 20 kg/ha P and 100 kg/ha N for Serbo; 27 kg/ha P and 94 kg/ha N for Dimtu; and 4.9kg/ha P and 97 kg/ha N for Asendabo were recommended for maize using NuMaSS.

Keywords: NuMaSS; Soil fertility; Critical level; maize.

RESUMEN

El sistema de apoyo la toma de decisiones de manejo de nutrientes (NuMaSS) es una herramienta que sirve para diagnosticar las limitaciones del suelo y para seleccionar las prácticas de manejo apropiadas, con base en criterios agronómicos, económicos y ambientales, por las condiciones específicas de cada lugar. Sin embargo, su validación debe ser probada en diferentes órdenes de suelo y agroesistemas. Por lo tanto, el presente estudio se realizó para evaluar el estado de fertilidad de Nitisol eútricos y sugiere la aplicación de NuMaSS como una herramienta de diagnóstico para recomendar fertilización complementariamente de N y P para el maíz en las zonas de la agroecologicas diferentes. En consecuencia, cincuenta muestras de suelo fueron tomadas de cinco lugares y se analizaron las principales propiedades físicas y químicas. Del suelo El pH del suelo-H_2O estaba por debajo del nivel crítico para todas las muestras del suelo. Nitrógeno, Cu y Zn presentaron niveles de déficit en todas las muestras de suelo. La deficiencia de fósforo disponible también se observó en el 88% de las muestras de suelo. Altas probabilidades de deficiencia de nitrógeno y fósforo, se observaron en las áreas de estudio con NuMaSS. Por otra parte, 24 kg / ha de P y 73 kg / ha de N para Dedo; 24kg/ha P y 82 kg / ha de N para Agaro, 20 kg / ha de P y 100 kg / ha de N para Serbo, 27 kg / ha de P y 94 kg / ha de N para Dimtu y P 4.9kg/ha y 97 kg / ha de N para Asendabo se recomienda para el maíz con NuMaSS.

Palabras clave: NuMaSS; fertilidad del suelo; nivel crítico; maíz.

INTRODUCTION

Declining of soil fertility is a fundamental impediment to crops production and a major reason for slow growth in food production in Sub-Saharan Africa (SSA) (Sánchez *et al.*, 1995; Quinones et al., 1998; Shapiro and Sanders, 1998). In Ethiopia, soil degradation and nutrient depletion have gradually increased in area and magnitude and have become serious threats to agricultural productivity (Hurni, 1988; Campbell et. al, 1996; Bojo and Cassels, 1995; Fasil and Charles, 2009). Nutrient balance calculations for countries by Stoorvogel and Smaling (1990) also showed that Ethiopia was among the countries with the highest rates of net nutrient losses. The annual nutrient deficit is estimated at -41 kg N, -6 kg P and -26 kg K by ha. Thus, there is an urgent need to improve soil fertility and nutrient management in the country.

Depletion of soil nutrient is a reversible constraint as long as soil test based fertilizer application is in place (Fasil and Charles, 2009). However, assessing soil fertility status is difficult because most soil chemical properties either change very slowly or have large seasonal fluctuations; in both cases, it requires long-term research commitment (Taye and Yifru, 2010). Moreover, the knowledge requirements to properly diagnose and prescribe best management alternatives for location-specific nutrient problems throughout the world exceed the capacity of any human expert. Scarcity and cost of experts; however, can be alleviated by adopting a new system called nutrient management decision support system (NuMaSS). NuMaSS is a tool that diagnoses soil constraints and selects the appropriate management practices, based on agronomic, economic and environmental criteria, for location-specific conditions.

In Jimma zone, Nitosols are the dominant soil types and they are much utilized for crop production. There are about 6827 km^2 of Nitisols in the zone covering about 35% of the district's landmass (BPEDORS, 2000). According to Weigel, (1986) and Elias (2002), Nitisols are inherently fertile, but large Ethiopian areas have now been depleted due to continuous cultivation, leaching and erosion. However, the fertility status of Eutric Nitisol that dominates the study area is not quantified. Furthermore, farmers usually apply blanket recommendation of fertilizer in the study area irrespective of soil orders and agroecosystems. Therefore the objective of the study is to evaluate the fertility status of Eutric Nitisol in Jimma zone and to determine the recommended amount of N and P fertilizer for maize across different agroecosystems using NuMaSS.

MATERIALS AND METHODS

Description of the Study Areas

The study was conducted in the Jimma Zone, southwestern Ethiopia, which is located between $7^013'$ – $8^o56'$N latitude and 35^049 -$38^038'$E longitude with an estimated area of 19,506.24 km^2 and elevation between 1000-3500 m.a.s.l. The zone constitute three major climates 78%, 12% and 10% belongs to subtropical, temperate and tropical or thermal zones, respectively. The major soil orders of the zone are Nitosol 6827 km^2 (35%), Vertisol, 2925.9km^2 (15 %) and others 9553 km ^{2} (50%). Almost 49.6% of the zone total area devote to cultivation. The remaining 50.4% of the total area of land were under vegetation cover (22.8% under forest, 18% under woodland, and 9.6% under grassland (BPEDORS, 2000). For the present study, five study areas which have good agricultural potential and dominated by Eutric Nitisol were selected from different agroecosystems (Table 1).

Soil Sampling and Analysis

Prior to soil sampling, soil profile studies were carried out in order to characterize and classify the dominant soil groups in the study areas using WRB (2006). Accordingly, ten soil samples from each site were collected randomly from different farmlands at the depth of 25cm that make a total of fifty soil samples. The soil samples were air dried, mixed well, ground, and passed through 2 mm sieve and the laboratory analysis were conducted using the following standard procedures. Soil texture was determined by hydrometer. Soil pH-H2O and pH-KCl were measured using a pH meter in a 1:2.5 soil: water and soil: KCl ratios, respectively. Soil organic carbon was determined by the Walkley-Black oxidation method, total nitrogen (micro-Kjeldahl method), and available phosphorus was determined using Bray I extraction method as described by Van Reeuwijk (1992). Total exchangeable bases were determined after leaching the soils with ammonium acetate. Amounts of Ca^{2+} and Mg^{2+} in the leachate were analyzed by atomic absorption spectrophotometer and K^+ and Na^+ were analyzed flame photometrically. Cation exchange capacity was determined at soil pH level of 7 after displacement by using 1N ammonium acetate method in which it was, thereafter, estimated titrimetrically by distillation of ammonium that was displaced by sodium (Chapman, 1965). Percent base saturation was calculated by dividing the sum of the base forming cations (Ca, Mg, Na and K) by the CEC of the soil and multiplying by 100. Available micronutrients (Fe, Mn, Zn, and Cu) were extracted with DTPA as described by Lindsay and Norvell (1978).

Table 1: Detail description of the study sites.

Location	Altitude (m)	Coordinates	Mean Annual Rainfall (mm)	Mean Annual Temperature (^{0}C)
Dedo	1500-2000	7° 31' 0" N, 36° 52' 0" E	1500.00	20-25
Agaro	1716-1836	7°49'N 36°39'E	1663.00	19.9
Serbo	1640	7°35' N, 36°46'-37°14'E	1150.00	18-22
Dimtu	2166	7° 58' 0" N, 37° 11' 0" E	1168.00	27.6
Asendabo	1750	7° 53' 0" N, 35° 25' 0" E	1131.08	27.6

Source: BPEDORS, 2000

Statistical Analysis

The data were analyzed using descriptive statistics and analysis of variance using SAS 9.2. Duncan's multiple range was also employed to test the significance difference between locations. Correlation analysis was also performed in order to determine the relationship between the selected soil properties. The recommended amounts of nitrogen and phosphorous fertilizers for maize across different agroecologocal zones were determined using Nutrient Management Support System (NuMaSS) version 2.2.

RESULTS AND DISCUSSION

Soil texture

The textural class of Eutric Nitisol across all locations was clay; however, there was high variation in soil separates between the sampled soils. The coefficients of variation between the soil samples were 19.70%, 21.06% and 40.49% for clay, silt and sand contents, respectively. Significance difference ($P<0.05$) in the percentage of soil separates across locations was also observed (Table 2). All of the soil samples have clay content more than 30%, which is the marginal ranges of total clay requirement for Nitisol (WRB, 2006). The highest percentages of clay, silt and sand were observed at Dimtu, Sebo and Dedo, respectively while the lowest values were recorded at Dedo, Dimtu and Asendabo, respectively (Table 2).

Soil pH, EC and exchangeable acidity

The statistical analysis showed that soil pH-H_2O varied significantly ($P<0.01$) across locations (Table 2). Soil pH-H_2O ranged from 5.23 at Agaro to 5.60 at Dimtu. All of the soil samples had pH-H_2O less the critical level (6.5-8.5) given by Landon (1991). From the sampled soils, 16% rated as strongly acidic while the rest rated as moderately acidic. According to Landon (1991) and Tisdale et al. (1993), most nutrients for field crops are available at pH value of above 5.5; however, 67% of the sampled soils have pH less than 5.5. The lowest values of soil pH at the study sites could be because of loss of base forming cations down the soil profiles even beyond sampling depth through leaching and drain to streams in runoff generated from accelerated erosion. This enhances the activity of Al^{3+} and H^+ in the soil solution, which reduces soil pH and thereby increases soil acidity. The depletion of basic cations in crop harvest, as indicated in their significant reduction is the other cause for the fall in soil pH. The second reason is continuous use of ammonium based fertilizers such as diammonium phosphate, $(NH4)_2HPO_4$, in such cereal based cultivated fields, which upon its oxidation by soil microbes produces strong inorganic acids. These strong acids in turn provide H^+ ions to the soil solution that in turn lower soil pH. Acidic nature of Nitisol was also reported by Yihenew (2002). Thus, it is pertinent to raise the soil pH through liming to increase crop productivity of the study areas.

Due to high amount of rainfall (>1000mm) that results leaching of cations, all of the soil samples had also very low electrical conductivity. The values of exchangeable acidity were also rated as low for most of the sampled soils. A significance ($P<0.01$) variation in exchangeable acidity was also observed between locations. Exchangeable acidity ranged from 0.15meq/100g at Asendabo to 0.80meq/100g at Serbo (Table 2). The observed small values of exchangeable acidity indicate the easiness to manage the acidity problem of the study areas.

Table 2: Mean values of soil separate, pH, EC, exchangeable acidity, OC, TN and available phosphorous across different agroecological zones in Jimma.

Location	Dedo	Agaro	Serbo	Dimtu	Asendabo	Critical level	P-value
Clay (%)	41.34^{b}	44.67^{b}	50.08^{ab}	63.33^{a}	58.67^{a}	-	*
Silt (%)	34.33^{ab}	32.00^{ab}	37.92^{a}	23.67^{c}	28.33^{bc}	-	*
Sand (%)	24.33^{a}	23.33^{a}	12.00^{b}	13.00^{b}	13.00^{b}	-	*
Textural class	Clay	Clay	Clay	Clay	Clay	--	-
pH-H_2O	5.48^{ab}	5.23^{c}	5.35^{bc}	5.60^{a}	5.57^{a}	6.5-8.5	**
pH-KCl	4.37^{ab}	4.28^{b}	4.04^{c}	4.39^{ab}	4.45^{a}	-	**
EC (mmhos)	0.043^{c}	0.057^{b}	0.046^{c}	0.050^{bc}	0.068^{a}	-	**
Ex.Ac (meq/100g)	0.25^{b}	0.30^{b}	0.80^{a}	0.20^{b}	0.15^{b}	-	**
OC (%)	2.71^{a}	2.39^{ab}	1.50^{d}	2.20^{bc}	1.88^{c}	0.5-1.0	**
TN (%)	0.25^{a}	0.22^{b}	0.16^{c}	0.18^{c}	0.17^{c}	<1.00	**
C/N	11.17	10.96	9.72	12.10	10.83	10-20	NS
AVP (ppm)	6.97^{b}	6.69^{b}	7.33^{ab}	6.63^{b}	8.96^{a}	10-15	*

Means in the same row followed by the same letters are not significantly different at 5% level of significance; *significant at P<0.05; **significant at P<0.01; NS = non significance; EC = electrical conductivity; Ex.Ac = Exchangeable acidity; OC = organic carbon; TN = total nitrogen; C/N = carbon to nitrogen ratio; AVP = available phosphorus

Organic carbon, total nitrogen and available phosphorous

The mean values of organic carbon, total nitrogen and available phosphorous across different locations is given in Table 2. Organic carbon and total nitrogen varied significantly (P<0.01) across locations. Organic carbon also showed high variability in the investigated soil samples (CV=26.57%). It ranged from 1.50% at Serbo to 2.71% at Dedo (Table 2). According to Landon (1991) and Sanchez et al, (1982), all of the sampled soils had organic carbon greater than the critical level (0.5-1%). High organic carbon in Nitisol was also reported by Shimeles *et al* (2006), Wakene and Heluf (2002), Mesfin (1998), and Eylachew (1999). The surface soils of Nitisol may contain several percent of organic carbon (WRB, 2006). The highest values of organic carbon could be because of poor drained condition of the soil and high amount of rainfall that reduces the rate of organic matter decomposition in the study sites.

Total nitrogen also showed high variability (CV = 22.87%) among the soil samples. Total nitrogen ranged from 0.16% at Serbo to 0.25% at Dedo. Based on the classification of Landon (1991) and Sanchez et al, (1982), total nitrogen was found as one of the limited plant nutrient in the study sites. The values of total nitrogen in all soil samples were below the critical level (<1%) (Table 2). The observed nitrogen deficiency in all soil samples could be because of low input of plant residues, nitrogen rich organic materials like manure and compost in cereal based farming systems. As the area receives high rainfall, the nitrogen leaching problem can be another reason for the decline of total nitrogen in cropped fields. Moreover, farmers of the study area do not integrate leguminous plants on their farmlands. Shimeles *et al* (2006) also reported nitrogen deficiency in the cultivated Nitisol.

A significance (P<0.05) difference in available phosphorous was also observed between locations. High variability (CV = 75.31%) in available phosphorus was also observed among the sampled soils. Available phosphorous ranged from 7.19 ppm at Agaro to 12.16 ppm at Asendabo (Table 2). From the soil samples, 88% had available phosphorous below the critical level (10-15 ppm) given by Landon (1991) and Sanchez et al, (1982). The low level of available phosphorous in the study area might be due to its fixation by Al and Fe, as their presence is expected at the pH values of the soils of the study areas (Tisdale et al, 1993). High phosphorous sorption capacity of Nitisol was also reported by WRB (2006). The correlation matrix (Table 5) also showed a positive and significance (r = 0.37*) relationship between soil pH and available phosphorous. Unlike total nitrogen and available phosphorus, the carbon to nitrogen ratio; however, was with in the critical level except at Serbo which was below the critical level set by Sanchez et al, (1982). About 18% of the sampled soils had C/N ratio less than 10 whereas the rest have C/N ratio within the critical level.

Cation Exchange Capacity CEC) and exchangeable bases

Cation exchange capacity (CEC) showed a significance ($P<0.05$) difference between locations (Table 3). High variability (CV% = 16.81%) in CEC was also observed among the sampled soils. The value of CEC ranged from 22.97 at Serbo to 28.36 Cmolec/kg at Dedo. The mean value of CEC rated as medium at all study sites except for Dedo which is rated as high (Landon, 1991; Sanchez et al, 1982). From the sampled soils, 32% had the CEC between 25 to 30 Cmolec/Kg while the rest have CEC less than 25 Cmolec/Kg. The relative small amount of CEC in the sampled soil could be because of the amount and nature of the clay. Fasil and Charles (2009) reported that the amount of clay and mainly the type of clay mineral are responsible factors for CEC. The clay assemblage of Nitisol is dominated by kaolinite/(meta) halloysite which has the CEC value of 3-15Cmol(+)/kg (WRB, 2006). The presence of high organic matter in the soil samples; however, contributes to the slight increase in CEC. The correlation matrix (Table 5) also showed a positive and significant ($r = 0.59^{**}$) relationship between organic carbon and CEC. Moreover, charges from broken edges and exposed OH planes dominate the CEC of kaolinite and charges on kaolinite are pH dependant (Chi and Richard, 1999). In harmony with this, the correlation matrix (Table 5) of the study showed a positive and significant ($r = 0.58^{**}$) relationship between pH-H_2Oorganic carbon and CEC.

The exchange sites of Eutric Nitisol at Jimma zone are mainly occupied by Ca and Mg and to a lesser extent by K and Na. Except exchangeable Ca, all exchangeable bases showed significance difference between locations. High variability in exchangeable bases was also observed among the soil samples. The mean values of exchangeable K ranged from 1.24 at Dedo to 3.54 $Cmol_c$/Kg at Agaro; exchangeable Ca reanged from 6.98 at Agaro $Cmol_c$/Kg to 18.58 $Cmol_c$/Kg at Asendabo; exchangeable Mg ranged from 1.97 $Cmol_c$/Kg at Serbo to 3.63 $Cmol_c$/Kg at Asendabo (Table 3). The values of exchangeable K were above the critical level in all sampled soils. However, 4% and 14% of the sampled soils had exchangeable Mg and Ca, respectively below the critical level given by Landon (1991) and Sanchez et al, (1982).

A significant ($P<0.05$) difference in percentage of base saturation was also observed between locations. High variation (CV = 30.23%) in percentage of bases saturation was also observed among the soil samples. According to Landon (1991) and Sanchez et al, (1982), the percentages of base saturation for all soil samples are rated as medium to high.

Table 3: Mean values of CEC and exchangeable base across different agroecological zones in Jimma.

Location	Dedo	Agaro	Serbo	Dimtu	Asendabo	Critical level	P-value
CEC ($Cmol_c$/Kg)	28.36^{a}	23.44^{b}	22.97^{b}	24.02^{b}	24.33^{b}	-	*
K ($Cmol_c$/Kg)	1.24^{b}	3.54^{a}	1.32^{b}	1.34^{b}	2.80^{ab}	<0.2	**
Na ($Cmol_c$/Kg)	0.11^{b}	0.26^{b}	0.12^{b}	0.22^{b}	0.47^{a}	-	**
Ca ($Cmol_c$/Kg)	9.80^{ab}	6.98^{b}	7.45^{ab}	8.08^{ab}	18.58^{a}	<5.0	NS
Mg ($Cmol_c$/Kg)	3.09^{ab}	2.62^{abc}	1.97^{c}	2.86^{abc}	3.63^{a}	<1.5	*
PBS (%)	49.99^{b}	58.02^{ab}	47.97^{b}	51.41^{b}	70.50^{a}	-	*
K (%)	4.45^{b}	16.21^{a}	5.87^{b}	5.57^{b}	11.43^{ab}	-	**
Na (%)	0.39^{c}	1.19^{ab}	0.54^{bc}	0.88^{bc}	1.73^{a}	-	**
Ca (%)	34.26	29.53	32.95	33.10	42.92	-	NS
Mg (%)	10.90^{bc}	11.09^{bc}	8.61^{c}	11.86^{ab}	14.40^{a}	-	**

Means in the same row followed by the same letters are not significantly different at 5% level of significance; *significant at P=0.05; **significant at P=0.01; NS = non significance; CEC = cation exchange capacity; PBS = percentage of base saturation

Micronutrient Status

Micronutrient status of Eutric Nitisol in Jimma Zone is presented in Table 4. Micronutrient status of soils of the study areas showed a significant ($P<0.01$) difference between locations. High variability in micronutrient status was also observed among the soil samples. The availability of trace elements in the soil is influenced by many soil and environmental factors (Jones, 1972). According to most literature, the availability of micronutrients increases in acidic soil (Vijay, 1997); however, according to the critical levels provided by Jones and Eck (1973), only available Mn and Fe were found above the critical level for all sampled soils. However, all soil samples had the concentration of available Cu and Zn below the critical value provided by Jones and Eck (1973). The correlation matrix (Table 5) also showed a non significance relationship between micronutrients and soil pH. Higher crop yields which increase plant nutrient demands, use of fertilizers containing lower quantities of micronutrient contaminants, and decreased use of farmyard manure results low Cu and Zn concentration in the sampled soils. Deficiency of micronutrients in Ethiopian soils was reported by Louis (2010); Wakene and Heluf (2001) and Teklu et al., (2007).

Table 4: Mean values of micronutrients across different agroecological zones in Jimma.

Location	Mn	Fe	Cu	Zn
		(ppm)		
Dedo	101.88^{b}	54.51^{b}	0.53^{b}	4.73^{ab}
Agaro	121.41^{a}	52.55^{b}	0.94^{a}	5.24^{a}
Serbo	97.07^{b}	53.50^{b}	0.51^{b}	3.54^{b}
Dimtu	102.17^{b}	45.80^{b}	0.40^{b}	1.98^{c}
Asendabo	114.06^{a}	71.95^{a}	0.84^{a}	4.58^{ab}
Critical level	50.00	20.00	4.00	20.00
P-Value	**	**	**	**

Means in the same column followed by the same letters are not significantly different at 5% level of significance; *significant at $P<0.05$; **significant at $P<0.01$

Table 5: Pearson's correlation matrix for the selected soil fertility parameters.

	Clay	$pH-H_2O$	OC	TN	AVP	CEC	K
Clay	-						
$pH-H_2O$	0.13	-					
OC	0.09	0.37*	-				
TN	0.36*	0.17	0.77**	-			
AVP	0.51**	0.37*	-0.02	-0.10	-		
CEC	0.33	0.58*	0.59**	0.57**	0.34	-	
K	0.51**	0.13	0.18	0.13	0.25	-0.01	-
Na	0.32	0.53**	0.26	0.19	0.39*	0.41*	0.63
Mg	0.18	0.58**	0.39*	0.39*	0.33	0.72**	0.19
Ca	0.23	0.48**	0.19	0.18	0.45*	0.59**	0.16
PBS		0.23	0.02	-0.01	0.37*	0.08	0.69**
Mn	0.21	-0.22	0.12	0.18	0.10	-0.15	0.52**
Fe	0.12	0.12	-0.13	-0.18	0.16	-0.23	0.20
Zn	0.17	-0.23	0.12	0.10	-0.04	-0.16	0.48**
Cu	0.08	-0.17	0.08	-0.10	0.01	-0.19	0.40*

* Significant at $P<0.05$; ** significant at $P<0.01$; OC = organic carbon; TN = total nitrogen; AVP = available phosphorus; CEC = cation exchange capacity

Nitrogen and Phosphorous Fertilizer Recommendation using NuMaSS

The recommended amounts of nitrogen and phosphorous for maize across different agroecosystem using NuMaSS tool are presented in Table 6. According to the tool, high probabilities of phosphorous and nitrogen deficiencies were observed in all study sites. This finding is also in line with the field data recorded during the survey (Table 2). The recommended amount of phosphorous for maize ranged from 4.97Pkg/ha at Asendabo to 27kg P/ha at Dimtu while the recommended amount of N ranged from 73 kg/ha at Dedo to 100kg/ha at Serbo. The smallest phosphorous recommendation at Asendabo could be because of the residual effect of fertilization. Due to its proximity to the city, the intensive agricultural practices demand excess application of DAP at Asendabo. In line with NuMaSS fertilizer recommendation, the blanket fertilizer recommendation in the study areas for maize is 100kg DAP and 100kg urea which is equivalent to 20.08 kg/ha of phosphorous and 64 kg/ha of nitrogen. Moreover, 110 kg N and 20 kg P was recommended for maize in Nitisol (Wakene et al., 2001). Therefore, NuMaSS could be used as a tool to diagnose and recommend the amount of fertilizer required for maize in different agroecosystems of the study area.

Table 6: Nitrogen (N) and phosphorous (P) fertilizers recommendation for maize across different agroecological zones using NuMaSS.

	Maize			
	Prob. Level (%)	P (kg/ha)	Prob. Level (%)	N (kg/ha)
Dedo	91	24	87	73
Agaro	91	24	87	82
Serbo	90	20	87	100
Dimtu	92	27	87	94
Asendabo	85	4.9	87	97

CONCLUSION

The study revealed that the fertility status of Eutric Nitisol highly varied across location and it has serious nutrient limitations. All of the sampled soils have pH-H_2O below the critical limit for plant growth. Nitrogen, Cu and Zn deficiency was also observed in all soil samples. Similarly, 88% of the sampled soils have available phosphorous below the critical level. Therefore, management practices such as increase input of plant residues, nitrogen rich organic materials like manure and compost are required. Moreover, application of lime, micronutrients based fertilizers should be introduced in order to boost the crop productivity of the study area. Since the fertilizer recommendation from field experiment is in harmony with NuMaSS fertilizer recommendation, NuMaSS can be used as a tool in order to diagnose nutrient deficiency and recommended fertilizers for maize in different agroecological zones. Finally, for validation, it is recommended that the study should be repeated in different soils and agroecological zones in Ethiopia and elsewhere.

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