Canadian Journal of Agriculture and Crops
Vol.1, No. 2, 70-82, 2016

Soil Fertility Status of Some Soil Orders and NuMaSS Fertilizer Recommendation at Bench-Maji Zone, South West, Ethiopia

Masresha Abitew[1] --- Solomon Kebebew[2]
[1]*Debremarkos University, College of Agriculture and Natural Resources, Debremarkos, Ethiopia*
[2]*Wolkitie University, College of Agriculture and Natural Resources, Wolkite, Ethiopia*
(*Corresponding Author*)

Significance and Impact of the Study: Evaluating the fertility status of the area and determining the amount of N and P fertilizer being recommended for maize across locations using NuMaSS.

ABSTRACT

The study was carried out to evaluate the fertility status of some soil orders in Bench Maji zone districts and to determine the amount of N and P fertilizer being recommended for maize across locations using NuMaSS for better crop production and productivity. A total of 16 surface and profile soil samples were collected from four locations or soil orders and analyzed for the selected soil physical and chemical properties and Nutrient Management Decision Support System (NuMaSS) was used as diagnostic tool to recommend N and P fertilizers for maize across the locations. Soil of Gurafarda, Debub-Bench, Mianit-Goldia had no exchangeable Ca^{2+}, Mg^{2+} and K^{+} problems but the soil of Semenh-Bench had low Ca^{2+}, medium Mg^{2+} and deficient to marginal K^{+} contents.Thus; the soil in Semenh-Bench probably requires improvements of these cations. The result revealed that the sampled soils of all locations showed, a serious nutrient limiting status and available P. The soil pH-H_2O was also below the critical level in the sampled soils. Moreover, high probabilities of N and P deficiency were observed in all locations this correspondingly required higher rate of fertilizer dosage as depicted by NuMaSS. Finally, 68 kg N/ha and 67 kg P/ha, 0 kg N/ha and 52 kg P/ha, 98 kg N/ha and 47 kg P/ha, and 69 kg N/ha and 0 kg P/ha fertilizer rates were recommended using NuMaSS for maize at soils of Semenh-Bench, Gurafarda, Debub-Bench and Mianit-Goldia, respectively. Besides, the nutrient recommendation, other management activity for the amelioration of these acidic soils is advisable. In general, management activities for these soils should be practiced and appropriate strategies for which should be determined according to the crops being grown.

Keywords: Critical level, Fertilizer recommendation, NuMaSS, Soil nutrient.

DOI: 10.20448/803.1.2.70.82

Citation | Masresha Abitew; Solomon Kebebew (2016). Soil Fertility Status of Some Soil Orders and NuMaSS Fertilizer Recommendation at Bench-Maji Zone, South West, Ethiopia. Canadian Journal of Agriculture and Crops, 1(2): 70-82.

Funding: This study received no specific financial support.

Competing Interests: The authors declare that they have no competing interests.

History : Received: 10 October 2016/ Revised: 11 November 2016/ Accepted: 17 November 2016/ Published: 29 November 2016

Publisher: Online Science Publishing

1. INTRODUCTION

Sustaining soil and environmental quality is the most effective method for ensuring sufficient food supply and support life [1]. The quality of soil is controlled by its physical, chemical and biological components and by their interactions [2].

The maintenance of soil for its quality mainly depends on the knowledge of the physicochemical properties of a given soil [3]. Results of physical and chemical tests are quality indicators which provide information about the capacity of soil to supply mineral nutrients. Therefore, understanding soil properties and their effect on productiveness under different land use systems has proved useful for sustainable development and efficient utilization of limited land resources [4]. Some research results showed that the success in soil management to maintain soil quality depends on the understanding of how soils respond to agricultural use and practices over time [5]. This implies that the sympathetic of the characteristics of soils is prerequisite for designing appropriate management strategies thereby solving many challenges with regard to overall causes of soil degradation and fertility depletion.

Moreover, soil degradation and nutrient depletion caused by a number of socio-economic factors and other related inappropriate farming practices reduced productive capacity of the soil these have gradually increased and become serious threats to agricultural productivity [6]. The rate of soil degradation is related to the management systems, soil properties, vegetation, topography of the area and the prevailing climatic condition [7].

In Ethiopia, soils have been surveyed and classified Mesfin [8] however, this local classification of soils became crude and this hampers recommendations what area specific and problem oriented on soil management practices should be implemented but such types of soil studies are vital to explore soil potentials, shortfalls and spatial variability. Thus; with such crude information, decision makers, and development workers usually give blanket recommendations of agricultural technologies to increase crop productivity [9].

In Bench-Maji Zone; there have not been any systematic works documented aimed to identify any inherent constraints which might affect soils' productivity for crop production in sustainable manner. Beyond taxonomic classification of soils, effort is rarely made to interpret such classification in terms of how soil constraints might affect sustainable crop production, forage or pastures and how this information can provide guidance on managing these soil fertility constraints [10].

On the other hand, depletion of soil nutrient is considered as a reversible constraint as long as soil test based fertilizer application is in place [6]. Hence, fertilizer recommendations for specific area should be supported by some tools that basis management practices in the area to properly diagnose and prescribe best management alternatives for location-specific nutrient problems become more complicated and tiresome and beyond the capacity of human expert.

Furthermore, study on soil characteristics in particular classification, physico-chemical properties and fertilizer recommendation will provide the whole information for soil productivity enhancement and implementing an appropriate soil and crop management practices and hence the components mainly for the farmers in the study area.

On the other hand; farmers in the area have been applying the blanket fertilizer recommendation regardless of the fertility status of soil, the soil types and environmental conditions that would differ the agro-ecology of the area in the crop production.

Therefore, such problems can be alleviated by adopting a new system called nutrient management decision support system (NuMaSS) that diagnoses soil constraints and selects the appropriate management practices, based on agronomic, economic and environmental criteria, for location-specific conditions.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The study was carried out in the Bench-Maji Zone (BMZ) at four districts (soil orders) during the 2013/2014 main cropping season, which is situated at $60^{0}52^{"}$N to 70 N latitude and $35.50^{0}21^{"}$ E longitude with altitude ranging from 1400-2500 meter above sea level (masl) with a total estimated area of 19,252.00 square kilometer.

The Zone is characterized as a forest dominating areas that include tropical mountain rainforest, bamboo trees to savanna grasslands and characterized by its a bimodal rainfall pattern with a long rainy season receiving a mean annual rainfall of 1800 mm with a mean minimum and maximum temperature of 22 to 29 ^{0}C, respectively.

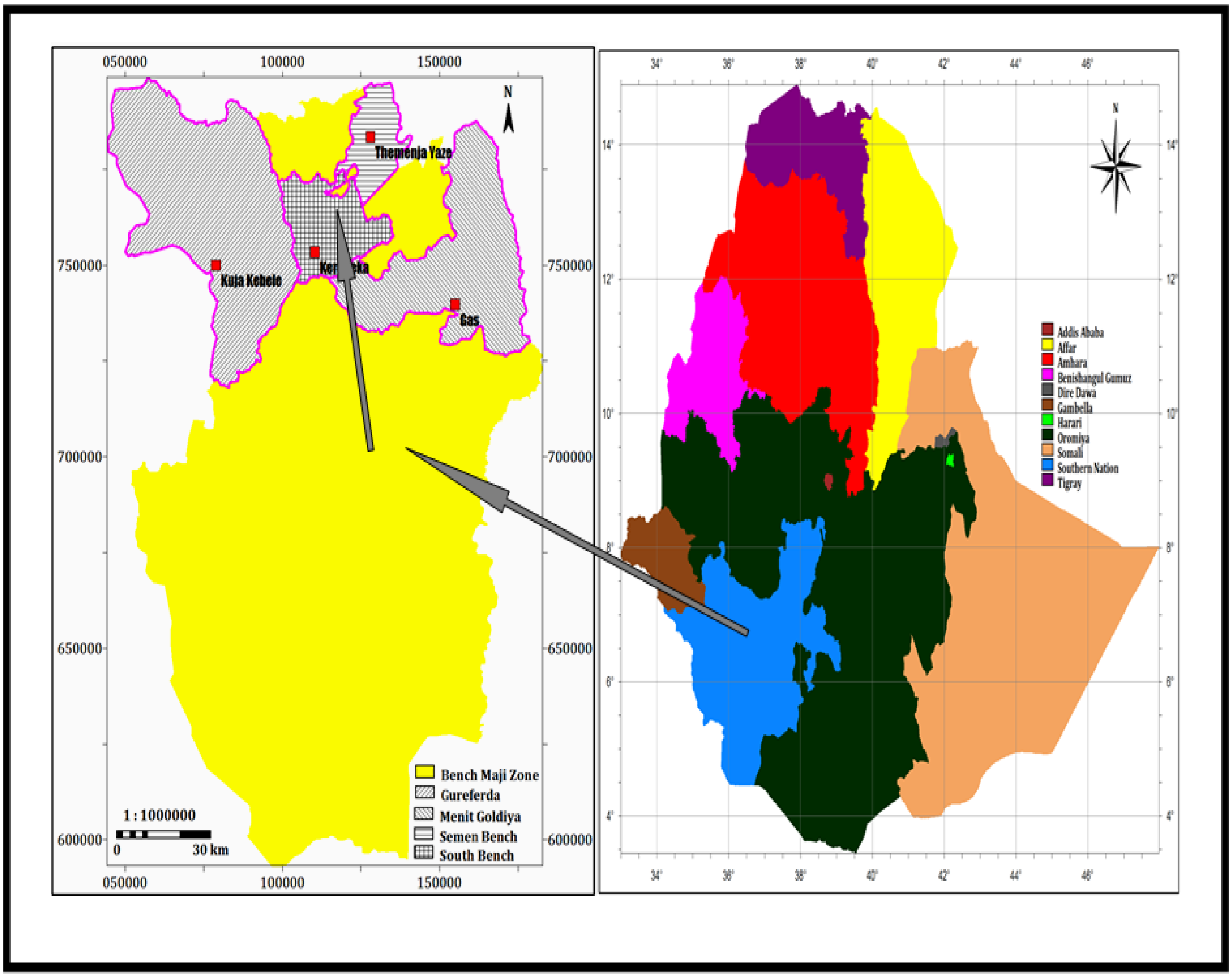

Figure-1. Location map of the study areas

2.2. Soil Sampling and Analysis

A representative composite surface soil samples were collected randomly prior to profile opening from the surface soils (0-20 cm depth) of each selected sites to determine the different physical and chemical properties of soils. The representative soil profiles (1m x 1m x 1.5m) for each sites were opened and described by its morphological properties at the field. A total of 16 surface and profile soil samples were collected and air dried, mixed well, grounded, and passed through 2 mm sieve and the laboratory analysis were conducted using the following standard procedures. Particle size distribution was determined by hydrometer method to identify textural class. Bulk density (BD) was determined from disturbed soil samples collected from each horizon. The average soil particle density (PD) (2.65 g cm^{-3}) was used for estimating total porosity as follows:

$$\text{Total porosity (\%)} = [1-(BD/PD)] \times 100$$

Soil color was described using the Munsell Soil Color Chart [11] and soil pH-H_2O and pH-KCl were measured by using pH meter in a 1:2.5 soil: water and soil: KCl ratios, respectively.

Soil organic carbon (SOC) was determined by the wet acid dichromate digestion method [12] and soil organic matter (SOM) was calculated by multiplying OC by a factor of 1.724 whereas total N by Kjeldahl digestion followed by ammonium distillation and titrimetric determinations [13] and available phosphorus was determined using Bray-I extraction method as described by Van [14]. Total exchangeable bases were extracted after leaching the soils with ammonium acetate (NH_4OAc) solution at pH 7.0 [15]. Amounts of Ca^{2+} and Mg^{2+} in the leachate were analyzed by atomic absorption spectrophotometer and K^+ and Na^+ were analyzed by flame photometer. Cation exchange capacity (CEC) was determined at soil pH level of 7 after displacement by using 1N ammonium acetate method , thereafter, was estimated titrimetrically by distillation of ammonium that was displaced by sodium [16]. Percent base saturation (PBS) 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 (DTPA Extract Flame AAS) as described by Lindsay and Norvell [17]. Electrical conductivity (EC) contents of the soils were analyzed using FAO- conductivity-water extract.

2.3. Statistical Analysis

Data were analyzed using descriptive statistics and soil morphological and chemical properties were characterized and described according to the Guidelines for Soil Description of FAO-WRB (Food and Agriculture Organization-World Reference Base) [18]. The recommended amounts of N and P fertilizers were determined using Nutrient Management Support System (NuMaSS) version 2.2 software.

3. RESULTS AND DISCUSSIONS

3.1. Soil Physical Properties

3.1.1. Soil Texture

The result revealed that, the textural class at Gurafarda and Debub-Bench was clay; whereas both the Semen-Bench andMianit-Goldia showed sandy clay at upper horizon. However; in the bottom horizon the textural classes of all locations were clay except Gurafarda which was sandy clay. Furthermore; high (74%) and lowest (38%) percentage of clay at surface soil was observed at Debub-Bench and Semen-Bench locations, respectively (Table 1).

On the other hand, Gurafarda the clay content decreased within the profile with depth from 65% in the surface layer to 37% at the bottom (98 cm) depth of the profile whereas the sand content increased with depth from 8% in the surface layer to 48% at the bottom layer of the profile, whereas; the clay content of the soil within the profile decreased from 74% at the surface to 15% at the third soil horizon at Debub-Bench location (Table 1).

At Semen-Bench location, the textural classes of subsurface layers wereclay, hence higher content of finer fractions (silt + clay) in lower depths. This might be due to the translocation of finer particles from the surface horizons and subsequent illuviation in sub surface horizons. These observations are in accordance with the results of Tekalign [19]. Furthermore, in Mianit-Goldia, there was an increasing trend in clay content with depth ranged from 44 to 77%. This implied that clay accumulation in the subsurface horizon could have been contributed by the *in situ* synthesis of secondary clays, the weathering of primary minerals in the B horizon, or the residual concentration of clays from the selective dissolution of more soluble minerals of coarser grain sized in the B horizon.

3.2. Bulk Density

Soil bulk density was decreased, but total porosity consistently increasing with depth (110cm) soil layer at Gurafarda. On the other hand, there was no significant variation in soil bulk density at Debub-Bench, but soil layer with high bulk density had low percentage of total porosity. In general, the lower and higher bulk densities in case of Mianit-Goldia site at the surface and subsurface soil layers might be due to high soil organic matter, porosity and less disturbance of the subsurface soil. Furthermore, the total porosity (TP) of the soils of the area was ranged from 55.8 at the subsurface to 56-57 % at the soil surface. Higher OM content in the surface horizons makes soils loose, porous and well aggregated, thereby reducing bulk density and increasing total soil porosity (Table 1).

Table-1. Selected Physical Properties of Selected Districts and soil orders in Bench-Maji Zone

Districts/Soil Orders	Soil depth (cm)	Particle Size (%)			Textural Class	BD (g/cm^3)	TP (%)
		Clay	Silt	Sand			
Gurafarda (CAMBISOLS)							
	0-30(Surface)	65	27	8	clay	1.3	50.9
	30-65	38	40	22	clay loam	1.18	55.5
	65-110	40	15	45	Sandy clay	1.16	56.3
	110- 140	37	15	48	Sandy clay	1.32	50.2
Debub-Bench (NITISOLS)							
	0-30(Surface)	74	22	4	clay	1.15	56.6
	30-50	48	19	33	clay	1.19	55.1
	50-105	15	28	57	Sandy Loam	1.11	58.1
	105-135	75	2	23	clay	1.17	55.8
Semen-Bench (ALISOLS)							
	0-30(Surface)	38	2	60	Sandy clay	1.07	59.6
	30-55	31	7	62	Sandy clay loam	0.95	64.2
	55-98	60	20	20	clay	1.07	59.6
	98- 145	79	15	6	clay	0.99	62.6
Mianit-Goldia (VERTISOLS)							
	0-30(Surface)	44	9	47	Sandy clay	1.16	56.2
	30-57	50	22	28	clay	1.17	55.8
	57-117	64	30	6	clay	1.14	57.0
	117-144	77	20	3	clay	1.17	55.8

BD= bulk density, TP= total porosity

3.2. Soil Chemical Properties of Locations

3.2.1. Soil pH, EC and ESP

The soil pH-H_2O at all locations; Gurafarda, Debub-Bench, Semen-Bench and Mianit-Goldia were characterized as slightly acidic, moderately acidic (5.6) to neutral (6.78), strongly acidic and moderately acidic, respectively as per the rating indicated by Khan and Chatterjee [20]. On the other hand, the soil pH-

H_2O of Semen-Bench showed that a declining fashion toward very strongly acid levels (Table 2). This could be an indication of high leaching intensity of bases and their probable replacement by acid forming elements that are caused by the high amount of rainfall [21].

Furthermore, the pH value for each districts, was acidic, having a pH (H_20) value less than 7.0 and base saturation less than 100%. The acidic nature of these soils could be attributed partly to the high precipitation in the areas. Reports indicated that in regions of high rainfall, soils, even from alkaline parent materials, become acidic by the leaching away of the basic cations (Ca^{2+}, Mg^{2+}, K^+, Na^+) by rainwater and the replacement of many of them by H^+ [22].

The Electrical conductivity (EC) of soil of Gurafarda and Debub-Bench was varied from 0.03 to 0.27 dS/m and from 0.03 to 0.07 ds/m, respectively. Similarly, the EC values of soil of Semen-Bench and Soils of Mianit-Goldia was ranged from 0.01 to 0.03 ds/m and from 0.03 to 0.06 ds/m, respectively (Table 2). The relative lower EC value (0.01 - 0.03 ds/m) of Semen-Bench could be due to the very strongly acid chemical nature of soil of the area (Table 2).

In general, the soils of all districts were not found to be salty, hence their EC values were less than 0.75 ds/m which depicts no salinity problem. In addition, the ESP values were less than 15%, therefore soils of all districts were not sodic.

Table-2. Soil pH, EC and ESP values for Selected Districts and soil orders in Bench-Maji Zone

Districts/Soil Orders	Soil depth (cm)	pH-H_2O	pH-KCl	EC (dS/m)	ESP (%)
Gurafarda (CAMBISOLS)					
	0-30 (Surface)	6.5	4.77	0.03	0.8787
	30-65	6.6	5.72	0.27	0.7649
	65-110	6.4	5.1	0.07	0.3937
	110- 140	6.2	4.59	0.04	0.8482
Debub-Bench (NITISOLS)					
	0-30 (Surface)	5.6	4.38	0.03	0.3540
	30-50	6.78	5.56	0.05	0.2953
	50-105	6.5	5.44	0.07	0.2512
	105-135	5.6	4.36	0.03	0.3743
Semen-Bench (ALISOLS)					
	0-30 (Surface)	5.2	4.05	0.03	0.3223
	30-55	5.12	3.93	0.03	0.1328
	55-98	5.15	4.1	0.01	0.2783
	98- 145	5.3	5.05	0.02	0.6331
Mianit-Goldia (VERTISOLS)					
	0-30 (Surface)	5.94	4.75	0.05	0.1880
	30-57	5.75	4.68	0.06	0.3628
	57-117	5.81	4.51	0.03	0.2368
	117-144	5.94	4.77	0.03	0.2302

EC = electrical conductivity, ESP = exchangeable sodium percentage, dS = decisemeens, m= meter,

3.3. Exchangeable Bases and Cation Exchange Capacity (CEC)

The exchangeable Ca and Mg through soil profile of Gurafarda were ranged from 25.61 to 37 cmol(+)/kg and 11.1 to 16.87 cmol(+)/kg respectively. According to Landon [23] exchangeable Ca and Mg is categorized as very high which implies that returns are less likely optimized with additions of magnesium as external inputs in the form of fertilizers and the same trend was observed at Debub-Bench that exchange sites of the soil in horizons of both locations were mainly occupied by Ca and Mg as depicted under Table 3. However, the exchangeable K content in the soil of Gurafarda and Debub-Benchwere ranged from 0.75 to 1.24 cmol(+)/kg (classified rich) and 0.14 to 0.47 cmol(+)/kg (classified as marginal to adequate), respectively [23].

Furthermore, the range of critical values for optimum crop production for Ca, Mg and K are from 1.25-2.5, 0.25-0.5 and 0.28-0.51 cmol (+)/kg soil, respectively. Therefore, in sites except the exchangeable K, both exchangeable Ca, and Mg contents were higher than the critical values; this increment in general attributed to the leaching of exchangeable cations hence the sites receives high rainfall.

However, the exchangeable Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} contents of Semen-Bench were relatively low compared to other sites, i.e. (low Ca^{2+}, medium Mg^{2+} and deficient to marginal K^{+}) contents as given by Landon [23].

However, the highest exchangeable Ca^{2+} (5.42cmol (+)/kg), Mg^{2+} (2.41 cmol(+)/kg) and K^{+} (0.2 cmol(+)/kg) contents were observed in the site at the surface soil except the exchangeable Na^{+} with high contents (0.19 cmol(+)/kg) in the bottom layer. This non-systematic variation with depth further reconfirms existence of variable level of leaching intensity between horizons within a profile [21].

At Mianit-Goldia, the exchangeable Ca^{2+} and Mg^{2+} contents showed the highest (6.17-9.23 cmol(+)/kg) and (3.7-6.84 cmol(+)/kg) level at the first and second horizon, respectively.

In general, irregular trends with an increasing depth were observed for exchangeable Ca^{2+}, Mg^{2+} and Na contents. But, decreasing trends with an increasing depth was observed for K^{+} content. According to Landon [23] soil of the site is classified as medium Ca^{2+}, medium to high Mg^{2+} and marginal to adequate K^{+}contents.

Table-3. Exchangeable Bases and CEC properties for Selected Districts and soil orders in Bench-Maji Zone

Districts/Soil Orders	Soil depth (cm)	CEC & Exchangeable Bases (cmol (+)/Kg Soil)						PBS (%)
		Ca	Mg	Na	K	CEC	ECEC	
Gurafarda (CAMBISOLS)								
	0-30(Surface)	25.61	16.87	0.5	0.75	56.9	43.73	76.85
	30-65	37	11.1	0.47	0.98	61.44	49.55	80.647
	65-110	31.39	16	0.2	1.24	50.79	48.83	96.140
	110- 140	27.64	14.45	0.48	0.77	56.59	43.34	76.585
Debub-Bench (NITISOLS)								
	0-30(Surface)	3.63	1.81	0.07	0.14	19.77	5.65	28.578
	30-50	13.54	4.12	0.07	0.39	23.7	18.12	76.455
	50-105	7.79	3	0.05	0.47	19.9	11.31	56.834
	105-135	5.9	1.77	0.07	0.2	18.7	7.94	42.459
Semen-Bench (ALISOLS)								
	0-30(Surface)	5.42	2.41	0.12	0.2	37.23	8.14	21.864
	30-55	5.03	1.89	0.05	0.15	37.65	7.12	18.911
	55-98	1.81	0.6	0.07	0.09	25.15	2.57	10.218
	98- 145	5.41	1.2	0.19	0.07	30.01	6.88	22.925
Mianit-Goldia (VERTISOLS)								
	0-30(Surface)	8.5	5.47	0.05	0.46	26.59	14.48	54.456
	30-57	9.23	5.54	0.1	0.22	27.56	15.09	54.753
	57-117	8.08	6.84	0.08	0.21	33.77	15.21	45.039
	117-144	6.17	3.7	0.05	0.16	21.72	10.08	46.408

CEC = cation exchange capacity, ECEC = effective cation exchange capacity, PBS = percent base saturation.

The CEC values of sampled soils at Gurafarda and Debub-Bench ranged from 50.79 to 61.44 cmol(+)/kg and 18.7 to 23.7 cmol(+)/kg hence rated as very high and medium soil CEC values, respectively [23]. Furthermore, in both sites higher values of ECEC and PBS were obtained, particularly at middle layers than the upper and lower for Debub Bench (Table 4).

On the other hand, the CEC contents of Semen-Bench and Mianit-Goldia showed variations among the soil layers that can be rated as higher and high, respectively [23]. For instance; the highest CEC value (37.23 cmol(+)/kg) and (37.65 cmol(+)/kg), respectively was obtained from surface and the nearby subsurface soil layers at Semen-Bench site. Generally, the higher the CEC of the soil, the more capable the soil can retain mineral elements.

Higher ECEC values (8.14 and 7.12 cmol(+)/kg) were recorded in upper two soil layers, than the two subsurface soil layers (2.57 and 6.88 cmol(+)/kg) at Semen-Bench, but ECEC at Mianit-Goldia showed an increasing trend through soil profile except the bottom horizon. Furthermore, at this site the PBS indicates a high fertility of the soil because many of the bases those contribute to it, are plant nutrients particularly layer two (45.039 %) and (54.753 %) at layer one Table 3.

3.4. Organic Carbon (OC), Total Nitrogen (TN), Organic Matter (OM) and Available Phosphorus (P)

The OC content of soils of Gurafarda was lowest (2.52%), highest (9.2%) and higher (6.49%) for surface, first and second layers, respectively (Table 4). This might be due to accumulation of OM in surface layer and its recycling is due to litter fall [24]. On the other hand, an increased level of OC was obtained from the surface layer(1.38 %) to the third (5.98%) layer (in the sub-surface layers) of soil layers at Debub-Bench site.

Therefore, according to Landon [23] the OC contents of soils for both sites are categorized as low to medium. Furthermore, the OC content of Seme-Bench was medium at surface soil (8.28%) and first layer (8.57%) and low in the second (1.66%) and third layer (0.85%). At Mianit-Goldia, generally the OC content in the soil profile was decreased with depth.

It showed that high in the top soil layer (5.75%) and the second soil layer (4.67%) and the lowest two soil layers containing 3.46 % and 1.86 OC were categorized as medium and low carbon content, respectively [23]. Tuma [25] reported that intensive and continuous cultivation forced oxidation of OC and thus resulted in reduction of TN.

The highest TN content (0.44%) was obtained in the first layer followed by the second layer (0.33%) at Gurafarda. Moreover, the highest OM content and C to N ratio (C:N) were observed in the first soil layer. According to Havlin, et al. [26] TN contents of the soils ranged from medium to high.

On the other hand, the TN content of sampled soils at Debub-Bench was ranged from 0.12% in the surface to 0.39 % in the subsurface soils, hence similar distribution pattern of TN and OM with depth, but at Seme-Bench TN generally, varied from 0.08%in the bottom layer to 0.49% in the first layer. According to Havlin, et al. [26] the TN content of the soils at both sites is categorized as low to high rate.

The TN and OM content of soils of Mianit-Goldia showed a declining trend with an increase soil depth and categorized as high rate for the above two soil layers and low for the bottom soil layer. Furthermore, the C:N at Seme-Bench, generally higher than the common range of 8:1-15:1, as Brady [27] proposed for arable soils.

Table-4. Available P, OC, TN and OM properties for Selected Districts and Soil Orders in Bench-Maji Zone

Districts/Soil Orders	Soil depth (cm)	Av.P (mg/Kg)	OC (%)	TN (%)	OM %	C/N ratio
Gurafarda (CAMBISOLS)						
	0-30 (Surface)	3.89	2.52	0.14	4.34	18.00
	30-65	124.58	9.2	0.44	15.86	20.90
	65-110	92.54	6.49	0.33	11.18	19.66
	110- 140	6.61	2.66	0.14	4.58	19.00
Debub-Bench (NITISOLS)						
	0-30 (Surface)	4.32	1.38	0.12	2.37	11.50
	30-50	2.81	4.67	0.28	8.05	16.67
	50-105	3.37	5.98	0.39	10.30	15.33
	105-135	1.14	2.16	0.17	3.72	12.70
Semen-Bench (ALISOLS)						
	0-30 (Surface)	2.27	8.28	0.46	14.27	18.00
	30-55	5.39	8.57	0.49	14.77	17.48
	55-98	0.09	1.66	0.13	2.86	12.76
	98- 145	0.4	0.85	0.08	1.46	10.62
Mianit-Goldia (VERTISOLS)						
	0-30 (Surface)	41.96	5.75	0.32	9.91	17.96
	30-57	9.87	4.67	0.26	8.05	17.96
	57-117	0.69	3.46	0.19	5.96	18.21
	117-144	0.87	1.86	0.13	3.20	14.30

Av.P = available phosphorus.

At Gurafarda the sampled soils depicted that available P content generally ranged from 3.89 mg/kg, in the surface soil to 124.58 mg/kg in the first layer (Table 4). However, FAO-Olsen and Bray method explained that, the distribution of available P with soil depth ranged from 1.14 mg/kg (very low) in the bottom soil layer to 4.32 mg/kg (low) in the surface soil which is lower than P content through soil profile.

Therefore, the low available P in soil of Debub-Bench related mainly to the low pH status of the soil. According to Havlin, et al. [26] the available P contents of the soils of both sites ranged from low to high (Gurafarda) and very low to low (Debub-Bench). However, sampled soils for available P content at Semen-Bench highly varied at different soil layers ranged from 0.09 to 5.39 mg/kg (Table 4). But at Mianit-Goldia, it was ranged from 0.69to 41.96 mg/Kg through soil profile. Therefore, as the rate given by Havlin, et al. [26] the available P content was categorized very low to low content for Semen-Bench and very low to high for Mianit-Goldia. In general, the low OM content coupled with the highly acidic conditions may explain the low available P levels in the soils [28].

3.5. Available Micronutrients Properties of Soils

The result revealed that sampled soils of Gurafarda had the higher levels of available Mn and Fe than the Cu and Zn in all layers. The concentrations of Mn ranged from 16.34 to 36.76 mg/Kg. Generally, the surface soils contain higher concentration of Mn than the lowest subsurface soil conversely, Fe concentration in the surface soil was very low than the remaining layers (Table 5). However, higher available Mn in soil of Debub-Bench was observed compared to Gurafarda. Furthermore, in this site available Fe concentration was increased with soil depth except for the extreme bottom layer. The concentrations of Zn and Cu were far lower than the concentrations of Mn and Fe within a profile (Table 5).

Table-5. Available Micronutrients Properties for Selected Districts and soil orders in Bench-Maji Zone

Districts/Soil Orders	Soil depth (cm)	Available Micronutrients (mg/Kg)			
		Mn	Fe	Cu	Zn
Gurafarda (CAMBISOLS)					
	0-30(Surface)	36.56	27.26	0.59	1.09
	30-65	24.12	42.14	0.52	3.1
	65-110	36.76	39.88	0.56	1.9
	110- 140	16.34	30.52	0.54	1.03
Debub-Bench (NITISOLS)					
	0-30(Surface)	60.1	12.66	0.62	0.66
	30-50	13.98	22.9	1.41	2.04
	50-105	138.7	29.9	1.35	3.46
	105-135	56.1	11.34	0.92	8.98
Semen-Bench (ALISOLS)					
	0-30(Surface)	57.1	38.9	1.78	1.32
	30-55	47.3	34.8	1.76	3.3
	55-98	16.16	15.52	0.45	0.32
	98- 145	0.58	3.02	0.11	0.5
Mianit-Goldia (VERTISOLS)					
	0-30(Surface)	96	73.52	3.6	0.54
	30-57	41.5	52.5	3.33	0.69
	57-117	50.24	26.74	2.83	0.66
	117-144	29.56	8.2	1.08	0.32

At, Semen-Bench, the highest levels of Mn (57.1 mg/kg) and Fe (38.9 mg/kg) contents were recorded at the surface soil but the lowest levels of Mn (0.58 mg/kg) and Fe (3.02 mg/kg) contents were recorded at the lowest subsurface soil. Similarly, available Cu concentrations decreased consistently from the highest level (1.78 mg /kg) at surface to the lowest level (0.11 mg /kg) at the lowest subsurface soils of Semen-Bench. Similarly, highest levels of available Mn (96 mg/kg), Fe (73.52), and Cu (3.6mg/kg) concentrations were observed on the surface soil of Mianit-Goldia.

3.6. NuMaSS Diagnosis of Results of N and P Deficiency Probability

Results of probability calculation revealed that, there was a strong probability (78%) of P deficiency in the soil of Gurafarda but, with a strong likelihood that N was not limiting. Similarly, there was a moderate probability for P (63%) but a strong probability of N (85%) deficiency at soils of Debub-Bench. The soil of Semen-Bench was diagnosed as there were a strong probability of P (96%) and N (87%) deficiency. But there was a moderate probability (66%) of N deficiency for soils of Mianit-Goldia and there was a stronglikelihood that P was not limiting (Table 6).

Table-6. NuMaSS Diagnosis Results of N and P Deficiency Probability for Selected Districts and soil orders in Bench-Maji Zone

Soil Profile	Phosphorus Deficiency	Nitrogen Deficiency	Acidity Problem
Gurafarda (CAMBISOLS)	0.78	0.02	0.52
Debub-Bench (NITISOLS)	0.63	0.85	0.84
Semen-Bench (ALISOLS)	0.96	0.87	0.88
Mianit-Goldia (VERTISOLS)	0.21	0.66	0.74

Probability values range between 0.00 and 1.0. A probability of 0.5 indicates equal likelihood that there is or is not N, P and acidity problem. A probability of > 0.5 indicates a probable deficiency of N, P and an acidic condition. A probability of < 0.5 indicates that a condition where N, P and acidity are not a problem.

3.7. N and P Fertilizer Recommendation Using NuMaSS

Generally, a severe nutrient limitation was depicted in Table 6. Therefore, prediction of fertilizer requirement using NuMaSS showed that the recommended amount of P for maize crop ranged from 0 kg P/ha to 67 kg P/ha (Table 7). Highest P deficiency probability requiredhighest dose of P fertilizer (67 kg P/ha) for soil of Semen-Bench followed by 52 kg P/ha for soil of Gurafarda, 47 kg P/ha for soil of Debub-bench and no P required for soil of Mianit-Goldia.

Table-7. NuMaSS Prediction Results of N and P Fertilizer Requirementfor Selected Districts and Soil Orders in Bench-Maji Zone

Soil profile	Prob. Level (%)	Phosphorus Requirement	*Prob. Level (%)*	Nitrogen Requirement
Gurafarda (CAMBISOLS)	78	52 kg P/ha ± 25 kg P/ha	2	0 kg N/ha
Debub-Bench (NITISOLS)	63	47 kg P/ha ±25 kg P/ha	85	98 kgN/ha
Semen-Bench (ALISOLS)	96	67 kg P/ha ±27 kg P/ha	87	68 kg N/ha
Mianit-Goldia(VERTISOLS)	21	0 kg P/ha	66	69 kgN/ha

Predicted Nitrogen required= 0kg P/ha; Predicted Phosphorus required = 0kg P/ha, with a soil residual extractable P at 38 mg/L, Prob = probability

On the other hand, the recommended amount of N is ranged from 0 Kg/ha at soils of Gurafarda to 98 Kg/ha at Debub-Bench. The highest N deficiency probability was observed in soil of Semen-Bench. However, soils at Semen-Bench and Mianit-Goldia required 68 kg N/ha and 69 kg N/ha, respectively.

4. CONCLUSION AND RECOMMENDATION

The study result revealed that the sampled soils of all locations attested, the nutrient status of soils is limiting for better crop production particularly of available P was highly deficient (below the critical level) due to mainly low in soil pH-H_2O (likely acidic) hence fixation of P in the area. Moreover, the soil pH-H_2O showed an inconsistent from upper surface to bottom horizons. Therefore, management practices for the amelioration of these soils are advisable like proper application of recommended fertilizer at right time and place and use of liming materials in combination with supply of organic materials such as manure and compost has to be employed to enhance crop productivity and alleviate the serious nutrient limiting in the area. In general, NuMaSS nutrient diagnosis dictated that, high probability of P and N deficiency hence highest dose of P and N fertilizer recommendation is required for maize crop production though fertilizer recommendation for different agro ecology using NuMaSS requires verification and repetition of experiment.

5. ACKNOWLEDGEMENTS

The authors would like to acknowledge the financial support of Mizan-Tepi University and the technical support of Department of Plant Science. A special thanks to Bench-Maji Zone, Department of Agricultural and Rural Development and to all collaborative sectors for unreserved and back-up to carry out the research activities.

REFERENCES

[1] J. L. N. Soares, C. R. Espindola, and W. L. M. Pereira, "Physical properties of soils under soil acidity effects on nutrient use efficiency in exotic maize genotypes," *Plant and Soil,* vol. 192, pp. 9-13, 2005.

[2] M. F. Cotrufo, M. D. Wallenstein, C. M. Boot, K. Denef, and E. Paul, "The microbial efficiency-matrix stabilization (MEMS) framework integrates plant litter decomposition with soil organic matter stabilization: Do labile plant inputs form stable soil organic matter?," *Global Change Biology,* vol. 19, pp. 988-995, 2013.

[3] C. Achalu, G. Heluf, K. Kibebew, and T. Abi, "Status of selected physicochemical properties of soils under different land use systems of Western Oromia, Ethiopia," *Journal of Biodiversity and Environmental Sciences,* vol. 2, pp. 57-71, 2012.

[4] S. W. Buol, R. J. Southard, R. C. Grahm, and P. A. Daniel, *Soil genesis and classification*, 5th ed. Ames, USA: Iowa State University Press, 2003.

[5] N. Wakene, "Assessment of important physicochemical properties of dystric of dystric udalf under different management system in Baco area Western Ethiopia," Diss. MSc. Thesis, School of Gradate Study Alemaya University Ethiopia, 2001.

[6] K. Fassil and Y. Charles, "Soil fertility status and numass fertilizer recommendation of typic hapluusterts in the Northern Highlands of Ethiopia," *World Applied Sciences Journal,* vol. 6, pp. 1473-1480, 2009.

[7] R. Prasad and F. J. Power, *Soil fertility management for sustainable agriculture*. Boca Raton, New York, U.S.A: Lewis Publisher, Printed-Hall Inc, 1997.

[8] A. Mesfin, *Nature and management of Ethiopian soils*. Ethiopia: Alemaya University, 1998.

[9] L. Asmamaw and A. Mohammed, "Characteristics and classification of the soils of Gerado Catchment, North Eastern Ethiopia," *Ethiopian Journal of Natural Resources,* vol. 12, pp. 1-22, 2012.

[10] P. W. Moody and P. T. Cong, *Soil constraints and management package (SCAMP): Guidelines for sustainable management of tropical upland soils*. Australia: Australian Centre for International Agricultural Research, Canberra ACT 2601, 2008.

[11] KIC (Kollomorgen Instruments Corporation), *Munsell soil color charts Baltimore*. USA: KIC, 2000.

[12] J. M. Bremner and C. S. Mulvaney, "Nitrogen Total. In: A.L. Page, R.H. Miller and D.R. Keeney (eds.). Methods of soil analysis. Part 2. Chemical and microbiological properties," *Agronomy,* vol. 9, pp. 595-624. American Society of Agronomy, Madison, pp. 1149-1178, 1982.

[13] A. Walkley and C. A. Black, "An examination of different methods for determining soil organic matter and the proposed modification by the chromic acid titration method," *Soil Science,* vol. 37, pp. 29-38, 1934.

[14] R. L. P. Van, *Procedures for soil analysis*, 3rd ed. Wageningen, the Netherlands: International Soil Reference and Information Center (ISRIC), 1992.

[15] S. Sahlemedhin and B. Taye, *Procedures for soil and plant analysis*. Addis Ababa, Ethiopia: National Soil Research Center, Ethiopian Agricultural Research Organization, 2000.

[16] H. D. Chapman, *Cation exchange capacity. In: C.A. Black, et al. (Eds.), Methods of soil analysis*. Madison, Wisconsin: American Society of Agronomy. Inc, 1965.

[17] W. Lindsay and W. A. Norvell, "Development of a DTPA soil test for zinc, iron, manganese and copper," *Soil Science Society of American Journal,* vol. 42, pp. 421-428, 1978.

[18] FAO-WRB (Food and Agriculture Organization-World Reference Base), "A framework for international classification, correlation and communication, 2nd Edition," World Soil Resources Reports, No. 103. Rome, Italy2006.

[19] T. Tekalign, *Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13*. Addis Ababa: International Livestock Research Center for Africa, 1991.

[20] S. K. Khan and A. K. Chatterjee, "Effect of continuous rice cropping on changes in pedon characteristics in an Ustalf," *Journal of the Indian Society of Soil Science,* vol. 49, pp. 368 – 370, 2001.

[21] D. Shimelis and H. Mohammed, "Characteristics and classification of the soils of Tenocha-Wenchacher micro-catchment, South –West Shewa, Ethiopia," *Ethiopian Journal of Natural Resources,* vol. 9, pp. 37-62, 2007.

[22] I. C. Onwueme and T. D. Sinha, *Field crop production in tropical Africa: Principles and practice*. Netherlands: CTA, Ede, 1991.

[23] J. R. Landon, *Booker tropical soil manual: A handbook for soil survey and agricultural land evaluation in the tropics and subtropics. (Eds.)*. New York: John Wiley & Sons Inc, 1991.

[24] K. Ashok, "Studies on the properties of an Alfisols under selected forest plantations," M.Sc. Thesis, Submitted to University of Agricultural, Science, Bangalore (India), 1998.

[25] A. Tuma, "Effect of fruit based land use systems on soil physicochemical properties: The case of smallholders farming systems in Gamo Gofa, Southern Ethiopia," MSc Thesis, Hawassa University, Hawassa, Ethiopia, 2007.

[26] J. L. Havlin, J. D. Beaton, S. L. Tisdale, and W. L. Nelson, *Soil fertility and fertilizers*. New Jersely: Prentice Hall, 1999.

[27] N. C. Brady, *The nature and properties of soils*, 10th ed. London, UK: Collier Macmillan Publishers, 1990.

[28] D. N. Munns and A. A. Franco, *Soil constraints on legume production. In Biological nitrogen fixation technology for tropical agriculture (P. Graham and S. C. Harris, Ed)*. California: CIAT, 1982.