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Research Article

Evaluation of Soil Fertility Status at various depths for Maize (*Zea mays L.*) Production in Assosa District, Benishangul Gumuz Region, Ethiopia

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ABSTRACT

Purpose: This study was designed to be conducted in Assosa district to evaluate depth based soil fertility status in relation to maize production. What are the potentials and limiting soil fertility parameters along the root depth of maize in the area?

Methods: For this, three soil profile pits were dung in the year 2017 and 2018 and a total of 27 composite soil samples were taken from three depth categories (0-30, 30-60 and 60-90cm). The physico-chemical parameters of the sampled soil were analyzed in Assosa Soil laboratory center and Amhara Design & Supervision Works Enterprise soil laboratory. Descriptive statistical analysis was made by SAS 2002.

Results: The result indicated that clay was the textural class of the soil in the entire three soil depth. The soil of the area shows moderately acidic condition in their reaction. Medium level of total nitrogen (N) and Cation Exchange Capacity (CEC) was observed in all the three soil depth categories. Lower level of soil organic carbon (OC), available phosphorus (P), available potassium (K) and Zinc (Zn) was observed on the upper (0-30cm) soil layer which is the root zone for maize crop. Soil micronutrients of the study area revealed a decreasing trend vertically down ward across the three soil depths. In terms of maize nutrient requirement, relatively medium level of total nitrogen was observed in the surface soil layer while serious limitations in available phosphorus, potassium and zinc content of the soil were observed.

Conclusion: Therefore, it is suggested that fertilizer management practices addressing P, K and Zn deficiencies in the study area are recommended in order to ensure increased maize productivity.

Keywords: Soil Fertility; Maize production; Soil nutrients; Soil depth; Soil layers

INTRODUCTION

It is a well-known recent fact that resources are diminishing both in quality and quantity [1]. The fact is worse when it comes to soils. Research findings over the world reveals that millions of hectares of arable land worldwide are low in available nutrients and many of these deficiencies were further aggravated by the increased demands of more rapidly growing crops for available forms of micronutrients [2]. Soil fertility has received increased attention since it is now widely recognized that nutrient availability drives ecosystem functioning and processes [3]. Soil fertility and plant nutrition are two closely related subjects that emphasize the forms and availability of nutrients in soils, their movement to and their uptake by roots, and the utilization of nutrients within plants [4]. Without maintaining soil fertility, one cannot talk about increment of agricultural production in feeding the alarmingly increasing population. Therefore, to get optimum, sustained-long lasting and self-sufficient crop production, soil fertility has to be maintained. Soil test based nutrient management approaches are very little practiced in Ethiopia in general and in the study area in particular. Therefore, evaluating all factors affecting soil fertility, demarcating the changes, understanding their optimistic and pessimistic interaction can help growers, researchers, and all stakeholders to easily manage the constraints and generate best available soil fertility management technologies for the area [4].

Core constraints of Ethiopian soils include depletion of soil organic matter (SOM) due to widespread use of biomass as fuel, depletion of macro and micro-nutrients, removal of topsoil by erosion, change of soil physical properties, and increased soil salinity with

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time [5]. The loss of soil nutrients in Ethiopia is related to cultural practices like cultivation. The removal of vegetative cover (such as straw or stubble) or burning plant residues as practiced under the traditional system of crop production or the annual burning of vegetation on grazing lands are major contributors to the loss of nutrients [6], while the use of chemical fertilizer is also minimal. Soil fertility is a quality of a soil to supply nutrients in proper amounts without causing toxicity, whereas soil productivity is the capacity of a soil to produce a specific crop or sequences of crops at a specific management system. Optimum productivity of any cropping system depends on adequate supply of plant nutrients. When the soil does not supply sufficient nutrients for normal plant development and optimum productivity, application of supplemental nutrients is required. The proper application rates of plant nutrients are determined by knowledge about the nutrient requirement of the crop and the nutrient supplying power of the soil. Even though there is an obvious reduction in maize production potential of the study area from time to time, there is no conducted research that tries to identify the problem of this reduction. Therefore this study was conducted to evaluate soil fertility status at various depths for Maize production in Assosa district. Specifically, the study was focused to examine the soil nutrient potential and limitation with respect to the requirement of maize production in the area.

METHODS AND MATERIALS

Area Description

The study was conducted in Asosa District, Benishangul Gumuz Region, Western Ethiopia. Assosa District is bordered in the North West direction by Kurmuk and Homosha District of Benishangul Gumuz Region; it is bordered in the Southern Direction by Mao Komo Special District of Benishangul Gumuz Region. The District is bordered in the West direction by Sudan and in the Eastern direction bordered by Bambasi District of Benishangul Gumuz Region. It is located at an altitudinal range of 1570m above sea level and the geographic location of the study area is range between 09.170_12.060 N latitudes and 34.100_37.040E longitudes. Assosa District Board, 2018. (Figure 1).

The agro ecological zone of Assosa district is fully Kola. The average temperature of the district is 27 0C. The rainfall pattern of the district is monomodal rainfall distribution. The rainy season starts in May and extends to October and the dry season starts in November and extends up to end of April. The dry season have a wider temperature differences mainly on the onset it is too cold in the morning and at the night and too hot in the midday. The dry season in the district has also a windy and cloudy nature .The annual rainfall of district ranges between 900mm to 1400mm by using the moisture available from rain water most of the crops are cultivated in the district. Assosa Agricultural Development Office, 2014.

Site selection and Sampling techniques

This study is proposed to evaluate soil fertility status of Assosa District following investigative techniques on selected soil physico-chemical property analysis. At the beginning, a general visual field survey of the area and interviews with the district agricultural expertise was carried out in order to have a general view of the variations in the study area. Based on this village Amba 01 was selected as a representative study site for the district. From this village a representative plot with 20m x 20m dimensions was identified. From the plot three soil profiles with one meter depth, two meters length and one meter width was opened and ten up to fifteen sub-samples taken from each depths of 0-30, 30-60 and 60-90cm in a zigzag sampling scheme by scuffing the wall of the soil profile for respective depth; the lowest first and the top soil at last to avoid contamination between the layers. Then, the soil samples from each pit with their respective depth was bulked together to obtain composite soil samples [7]. For each respective pits and soil depths, about one kilogram of composite soil samples was taken. Sampling depth is decided based on the average root depth of maize which is 1.0-1.7 cm [8] and maximum nutrient distribution along the root zone. A total of nine composite soil samples which is the product of three sampling pits with the same history of maize production multiplied by three soil depths were collected. Similarly, nine undisturbed or separate soil core samples from the above depths was taken with a sharp-edged steel cylinder having

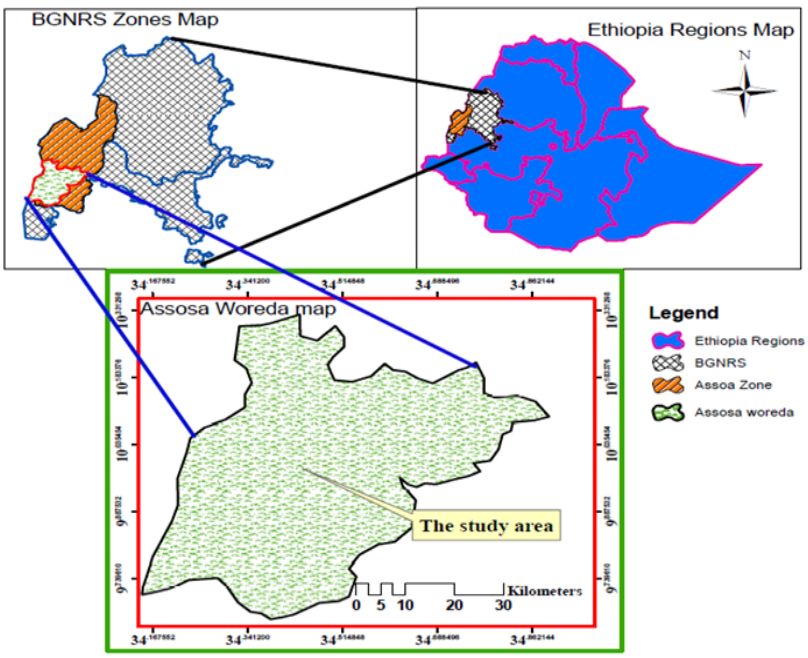

Figure 1: Map of the study area.

one hundred centimeter cub volume and forced manually into the soil horizontally at each respective soil depth for bulk density determination.

During collection of samples; dead plants, furrow, old manures, wet spots, areas near trees and compost pits was excluded. This was done to minimize differences, which may arise because of the dilution of soil Organic Matter due to mixing through cultivation and other factors.

Sample preparation and Soil analysis

The soil samples collected from representative fields' was then air-dried, mixed well and passed through a 2 mm sieve for the analysis of selected soil physical and chemical properties. Among soil physical properties, the percentage of sand, silt, and clay was determined by using hydrometer method [9, 10] after destroying OM using hydrogen peroxide (H2O2) and dispersing the soils with sodium hexameta phosphate (NaPO3). Soil bulk density was determined by the undisturbed core sampling method after drying the soil samples in an oven at 105 Co to constant weights [11].

As: Total pore space (%) = (1-BD/PD) x 100

From soil chemical properties, PH was measured potentiometrically in 1:1.25 soil water suspensions by using PH meter as outlined by [12]. Exchangeable acidity was determined by titration method. Organic carbon content of the soil was determined by wet digestion, Walky and Black method [13].

From the percent of organic carbon content of the soil organic matter content was calculated by the

Formula: % Organic matter = 1.724 x % Carbon

Total nitrogen was determined by using kjeldahl method [14]. Available phosphorous determination was Bray-II method as outlined by [12]. Flame photometer was used to measure available potassium through conversion of potassium concentration in to milligram (mg) of potassium per kilogram of soil by curve method [13]. Cation Exchange Capacity was determined at PH of 7.0 by using ammonium acetate method. Among exchangeable bases, calcium and magnesium in the original ammonium acetate leachate was measured by atomic absorption spectrophotometer [15]. Again from this leachate, exchangeable potassium and sodium was determined by using flame photometer [15]. In the ammonium acetate method, the saturating ammonium displaced by neutral salt is measured by distillation in kjeldahl immediately following the determination of exchangeable bases [15]. Available micronutrient (Fe, Zn, Mn and Cu) were extracted by Diethylenetriaminepenta acetic acid (DTPA) as described by [16] and was measured by Atomic Absorption Spectrum.

Statistical Data Analysis

Data will be subjected to analysis of variance (ANOVA) using SAS version 9.2 software in order to assess the significance of differences in soil parameters between soil depths. Treatment means was compared using appropriate test type at 0.05 significance level. A correlation analysis was also conducted among soil parameters. Soil fertility index or critical levels from various sources was used as a base for evaluating the status of soil fertility for maize production in the area. Finally, the results were interpreted, narrated and presented in the form of tables.

RESULT AND DISCUSSION

Soil Property analysis and nutrient rating

Results of Selected Soil Physical Properties

Soil texture

The soil laboratory analysis result of the study area revealed that particle size distributions were varied significantly at ($p \leq 0.05$) as it is affected by the soil depth (Table 1). Accordingly, clay is the dominant soil separate in the study area having the highest percent value which is 78.66% for the surface soil with the depth range of 0-30cm followed by 76.33% which is not statistically different from that of the first one and observed at the mid surface layer (30-60cm). While the lowest clay fraction which is 70.66% having a statistical significant difference from others was observed at 60-90cm depth (Table.1). The highest clay content observed in soils of the area could be attributed to the mixing of soil during tillage activities as was also reported by [17, 18]. The distribution of sand particle in the soil significantly vary across the three depth with a relatively higher accumulation in the lower soil depth (20.66%) and significantly higher silt contents (14.66%) was recorded in the surface soil 0-90cm soil depth. Although the statistical analysis showed a significant difference in the contents of the three soil separates, the textural class which is clay remained the same across soils of the three soil depths. Absence of textural class difference with soil depth indicates that the existence of weak vertical downward translocation of materials within the soil system. Clay textural class of the soil of the area is categorized under highly suitable range for maize production [19].

Soil Bulk density across various depths

Mean soil bulk density across the three soil depths in the study area were significantly different ($p \leq 0.05$) (Table 1). Consequently, the highest (1.42 g cm-3) and the lowest (1.16 gcm-3) mean bulk density values were recorded at the 60-90 cm and 0-30cm soil layers, respectively. The lowest bulk density recorded at the surface layer of the study area could be attributed to the relatively high organic matter contents, whereas the highest bulk density in the bottom layer of the soils might be the result of compaction from the upper soil layers, low organic matter and weight of the overlying soil material. The lowest bulk density observed in surface soils could be attributed to the high organic matter contents as was also reported by [20, 21] (Table 1).

The bulk density of the studied soils was fallen with the specified range as was suggested by [22] who revealed that bulk density is < 1 g cm-3 in high organic matter soils to 1.2 and 1.8 g cm-3 in sands and compacted horizons in clayey soils and it is largely affected by soil depth. Generally, the bulk density recorded in the present study was not greater than the critical limits (1.63 g/cm3) stated by [23] for all soil depths as a result they generally had lower bulk densities and better aggregation status. The bulk density of the soil was revealed a negative correlation($r=-0.87^{**}$) with the organic matter content of the soil. This relation is in line with the conceptual theory that states soil organic matter content and bulk density have inverse relation. The increase in the percent soil organic carbon directly reduces the bulk density of the soil [11].

Results of Selected Soil Chemical Properties

Soil Reaction, Exchangeable Acidity and Exchangeable Al+3

The soil chemical analysis result for pH, OC, OM, exchangeable

Table 1: Means of some soil physical properties at various depths in the study area.

Soil depth (cm)	Bulk density (gm/cm^3)	Particle size distribution (%)			Textural class
		Clay	Silt	Sand	
0-30	1.16^c±0.02	78.66^a±2.08	14.66^a±1.52	6.66^c±0.57	Clay
30-60	1.33^b±0.03	76.33^a±1.52	10.66^b±1.15	12.66^b±1.52	Clay
60-90	1.42^a±0.05	70.66^b±1.52	9.33^b±1.57	20.66^a±1.52	Clay
CV	2.88	2.34	9.12	8.66	
LSD(0.05)	0.085	3.99	2.38	2.62	

Means followed by the same letter(s) within column for a given variable are not significantly different at 5% level of significance

acidity, available P and Total N are presented in Table 2 below. The pH value of the soil varies from 5.70 which were recorded for 60-90cm soil depth to 5.53 for 30-60cm soil depth (Table 2). The pH value of the area reveals an increase across soil depths. The higher soil pH in the sub surface soil which might be related with the relatively low exchangeable acidity and low exchangeable Al+3 than the surface soil of the studied area. Whereas the lower pH value for the mid soil layer might be the result of relatively high exchangeable acidity and exchangeable Al+3 concentrations and removal of exchangeable cations. According to the [24] pH category, the pH value of the study area is classified into moderately acidic condition. Soil pH is the most important factor influencing the availability of micronutrients. The most favorable pH for availability of most plant nutrients correspond roughly with the optimum range of 6 to 7 [25]. The range of soil reaction in experimental site may limit maize production by influencing the availability of important plant nutrients. According to [26], Soil pH value below 5.5 could be an indication for the presence of appreciable amount of exchangeable acidity and exchangeable Al+3, and removal of exchangeable cations, such as calcium and magnesium. These levels of soil pH could further indicate that phosphorus availability would be lowered through the binding effects of Al and Fe. As soil pH increases the availability of Fe, Mn, Cu and Zn decreases [27]. The pH value the area shows a negative relation(r=-0.58) with the CEC of the soil. This relation indicated that an increase in the pH value of the soil will directly reduce the CEC of the soil.

The highest (0.32) and the lowest (0.05) exchangeable acidity (H2+) were recorded from 0-30cm and 30-60cm soil depths, respectively. While the highest amount of exchangeable Al+3 value which was 1.15 was observed in the middle layer (30-60cmdepth) and the lowest exchangeable Al+3(0.73) for the 60-90cm soil depth were recorded (Table 2). Exchangeable acidity consists of any aluminum or iron, as well as any exchangeable H2+ that may be present in the exchange sites of the soil colloidal surface [28]. Exchangeable Al3+ normally occurs in significant amounts only at soil pH values less than about 5.5 [29].

Organic Carbon, Organic Mater, Total Nitrogen and Available Phosphorus

The organic carbon of the soil revealed a statistically significant variation ($p \leq 0.05$) among the three soil depths and it shows a decreasing trend with the depth of the soil. This result is similar with [30] those found the organic carbon of soil had significantly decreased from the surface soil down to the sub surface soil. The organic carbon content of the study area across the three depths varied from 1.4% to 0.53% for surface and sub-surface soil layers, respectively. The relatively high organic carbon content of surface soil could be related with organic matter content due to litter fall, crop residue etc. of the soil surface. The amounts of organic carbon content recorded can be categorized as low (2-4%) at surface soil, and very low (< 2%) in sub surface soils [26]. Studies made in Ethiopia [31] show that levels of soil organic carbon are generally expected to be low in cultivated surface soils and decrease across soil depths. Generally, the study area reveals very low organic carbon content and this might be attributed that farmers frequently use the above ground biomass of the crops for animal feed and fire wood. This leads to less recycling and incorporation of organic carbon to the soil.

In a similar way the organic matter content of the soil across the three depths significantly vary ($p \leq 0.05$) with a relatively higher organic matter content at the surface soil (2.4%) while lower organic matter content (0.91%) for the subsurface soil. Similar to that of the organic carbon content, the organic matter content of the soil reveals a decreasing trend across the three depths from the surface down to the subsurface layer. Based on Murphy 1968, SOM content of soils are categorized as very low (<1 %), low (1-2 %), medium (2 to 3 %), high (3 to 5 %) and Very high (>5 %). Therefore, the organic matter content of the study area is categorized as medium for the surface soil and very low for the sub surface soil. Yihenew G [32] reported that most cultivated land soils of Ethiopia are poor in their organic matter content due to low amount of organic materials applied to the soil and complete removal of the biomass from the field.

The organic matter content of the soil reveals a strong negative correlation with bulk density (r= -0.87**), sodium ion (r= -0.94**) and sand (r= -0.96**) implying that an increase in bulk density and sodium content in the soil directly reduce the organic matter content of the soil. In contrast to this the organic matter content of the soil depicts a strong positive correlation with TN, Ca, Mg, CEC, Cu, Fe, Silt and clay content of the soil with their r value 0.85**,0.84**, 0.76**,0.94***,0.78*,0.81**,0.85** and 0.88**, respectively. These positive relations are an indication for the presence of direct relation between the organic matters content and the concentration of these elements in the soil. Laekemariam F [33] reported similar result from Walita zone, southern Ethiopia.

According to the results of fertilizer trials carried out in Ethiopia [34], the critical SOM values for the common cereals grown are 2.5% for barley and wheat; 3.0% for maize; 2.0% for sorghum and teff. This index reveals that the organic matter content of the soils of the study area is below the national standard requirement for maize production. [Table 2].

Total nitrogen contents of the soils also showed the same trend as soil organic carbon. That means the surface soil (0-30cm depth) reveals relatively higher total nitrogen content (0.22%) while the subsurface soil (60-90cm depth) of the area shows lower value (0.2%) [35]. Again the result of soil total nitrogen content

Table 2: Means of soil pH, Exchangeable acidity, Organic Carbon, Total Nitrogen and Available Phosphorous.

Soil depth (cm)	Statistical descriptions	pH (1:2.5 H_2O)	H^{+2}	Al^{+3}	OC (%)	OM (%)	TN (%)	AP (mgkg^{-1} soil)
0-30 (n=3)	Mean	**5.61^a**	**0.32^a**	**0.85^b**	**1.4^a**	**2.4^a**	**0.22^a**	**1.23^a**
	CV(%)	0.17	2.05	7.15	7.14	7.28	0.00	4.68
30-60 (n=3)	Mean	**5.53^b**	**0.05^b**	**1.15^a**	**1.1^b**	**1.89^b**	**0.22^a**	**0.58^c**
	CV(%)	2.08	6.27	8.82	9.09	8.99	0.00	3.93
60-90 (n=3)	Mean	**5.70^a**	**0.06^b**	**0.73^c**	**0.53^c**	**0.91^c**	**0.2^b**	**0.79^b**
	CV(%)	1.75	8.23	4.14	10.82	10.70	5.00	10.96
LSD(0.05)		0.14	0.11	0.35	0.23	0.41	0.013	0.14
Critical levels for Maize growth		5.5-7.0	-	-	4-10	3-7	0.1-0.3	8
Reference		FAO,2006 [35]	-	-	FAO,2006 [35]	EthioSIS, 2014 [24]	EthioSIS, 2014 [24]	Tekalign & Hague, 1991 [36]

Where: SD (Standard Deviation), CV (Coefficient of Variation), LSD (Least Significance Difference), pH (Power of hydrogen),H^{+2} (Hydrogen ion), Al^{+3} (Aluminum ion), OC (Organic Carbon), OM (Organic matter), TN (Total nitrogen and AP (Available phosphorus)
Means followed by the same letter(s) within column for a given variable are not significantly different at 5% level of significance.

of the area revealed a slight decrease across depth [36] (Table 2). According to EthioSIS [24], the rating of total Nitrogen of > 1% as very high, 0.5 to 1% high, 0.2 to 0.5% medium, 0.1 to 0.2% low and < 0.1% as very low N status. Therefore, the soils of the study area qualify for medium level in terms of total Nitrogen content for the surface layer. Total nitrogen was considered as the indicator of plant available N in the soil.

The very low organic carbon and medium total nitrogen content in the study area indicate low fertility status of the soil. This result is similar with [37], those report low OC and medium total Nitrogen content of Assosa area indicated low fertility status of the soil which could be due to continuous cultivation and lack of incorporation of organic materials. Since the nitrogen content of the studied soils were generally rated as low to medium. The distribution pattern of nitrogen across depth was also similar to that of SOM. This is because SOM contents are a good indicator of available nitrogen status in the soil. Intensive and continuous cultivation aggravated OM/OC oxidation which resulted in reduction of nitrogen. The results are in accordance with the findings of [38] who reported that intensive and continuous cultivation forced oxidation of OC and thus resulted in reduction of nitrogen in the soil. Available phosphorus content of the soil in the three soil depths of the study area depicts a significant variation ($p \leq 0.05$) having relatively higher amount (1.23mg/kg) in the surface soil and lower amount for the mid soil depth (0.58mg/kg). According to Landon JR [26] available (Olsen extractable) soil P level of less than 5 mg kg-1 is rated as low, 5-15 mg kg-1 as medium and greater than 15 mg kg-1 is rated as high. Thus, the available (Olsen extractable) P content of the studied soil (Table 2) was below the critical level.

The low P content of the soils could be related to P fixation by Al and Fe. This relation has confirmed by the result of correlation analysis between available P and Fe which shows a strong positive relation(r=0.87**). From this relation one can conclude that whenever the soil shows higher concentration in Fe, there will be high phosphorus fixation and reduction in the availability of phosphorus for crops. Also studies in Ethiopia indicate that Ethiopian agricultural soils particularly Nitisols and other acidic soils due to their inherently low P content and high P fixation capacity, available phosphorous contents is by far lower than what is required for maize production [32]. Similarly, the critical value of available (Olsen extractable) soil P level for maize production is given to be 8mgkg-1 soil [36,39]. While the available phosphorus level of the study area is by far less than that of the critical levels suggested for optimum maize production. Consequently, low available P of the soils could form one of the major soil fertility limiting factors in Assosa district for Maize production. Most location of Assosa District of Benishangul Gumuz Region had very low available phosphorous [40].

Therefore, at values less than these critical levels of extractable Phosphorus, P supplementing fertilizer should be applied to increase maize yield. Mustefa R et al. [39] reported a maize grain yield increase from 19.8 to 35.3% by applications of P fertilizers in Pawi, Benishangul Gumuz region.

Cation Exchange Capacity and Exchangeable Bases

The variations of mean cations exchange capacity (CEC) as a result of the effect of soil depth were significant ($P \leq 0.05$). The highest mean CEC (26.86 meq100g-1) was recorded in the upper (0-30cm) while a relatively lower amount of CEC (22.52 meq100g-1) was observed from the subsurface (60-90cm) soil layers. The highest CEC in the upper layers could be the result of the high clay content accumulation as was also reported by [41,42]. As per the ratings suggested by [35], the CEC of the studied soils qualified in the range of medium level across all the three soil depths of the study area. The higher the CEC in surface soils, the more capable the soil can retain mineral elements [26] and it is generally accepted that SOM is responsible for 25 to 90 % of the total CEC of surface mineral soils [43]. The high CEC values have been implicated with high yield in most agricultural soils and CEC values in excess of 10 cmolkg-1 are also considered satisfactory for most crops including maize [44]. Soils with high CEC are considered more fertile since it is the reservoir for most of the cations of the soil. This is also confirmed by the presence of a strong positive relation between CEC and the basic cations such as Ca2+ and Mg2+ having their respective r value (r= 0.83** and r=0.78*).

Similarly, the result of exchangeable bases (Ca2+, Mg2+, K+ and Na+) from the study area has provided in (Table 3 below). Comparatively higher concentration of Ca+2 (3.36 meq100g-1) was recorded from the subsurface layer (60-90cm depth) followed by 2.30 meq100g-1 from the upper surface layer (0-30cm depth).

A significantly lower concentration of Ca2+ (1.56 meq100g-1) was observed from the mid layer (Table 3). Landon JR [26] categorized Ca2+ as <2.0 Cmol (+) kg-1 soil very low, 2.0 to 5.0 Cmol (+) kg-1 low, 5.1 to 10.0 Cmol (+) kg-1 medium, 10.1-20.0 high and >20.0 Cmol (+) kg-1 as very high. Based on this categorization, the status of Ca2+ in the experimental area is low (2.72 meq/100g soil). Leaching and downward movement of this ion could be the reason for a relatively higher concentration of Ca2+ ion in the subsurface layer (60-90cm) as was also reported by [41,42] but in accordance to the standard rating of Ca2+, the availability of calcium ion in the studied soil is in the low level category. A significantly higher concentration of Mg2+ (2.06 meq100g-1 soil) was recorded from the surface soil layer (0-30cm). While the remaining two subsurface soil layers revealed 1.00 meq100g-1 soil and 0.70 meq100g-1 soil Mg2+ ion concentration, respectively for 30-60cm and 60-90cm soil depths.

Significantly high level of Na+ content (1.00 Cmolkg-1) was recorded from 30-60cm soil depth while the sodium ion concentration for surface soil layer is 0.4 Cmolkg-1 and for that of subsurface soil layer the concentration of this monovalent ion was 0.43 Cmolkg-1. This depth wise study about the soils of the area reveals a significance difference in the level of Exchangeable K+. According to FAO [35] rating of exchangeable potassium content in the soil, low level K+ content (0.150Cmolkg-1) was recorded from 0-30cm soil depth while medium and high concentration of this ion(0.21 and 0.54 Cmolkg-1), respectively was recorded for 30-60 and 60-90cm soil depth. Leaching and downward movement of K+ could be the reason for its high concentration in the subsurface soil layer. Still the study shows that potassium is one of the limiting factors for maize production in the study area as its availability in and around the root zone is in limited level. Similar to this study, Tigist et al., [45,29] reported the scarcity and limitation of potassium in Assosa and Bambasi district of Benishangul Gumuz Region is one the major limiting factor that affect maize production. (Table 3).

The status of Micronutrients in the study area

The inherent depth wise concentration of available micronutrients (Fe, Zn, Mn, Cu) in the soils of the study area were given in (Table 4). The depth wise distribution of Fe in the soils the study area widely varied from 4.52ppm in the surface soil to 0.63ppm in the subsurface soil (Table 4) with a mean value of 1.01ppm in the mid layer or 30-60cm soil depth. Considering even the highest value of critical limits of Fe (4.5 ppm), the surface soil of the study area has sufficient available Fe concentration while the subsequent subsurface layer shows deficiency in Fe content. The most probable reason for a relatively high concentration of Fe in the surface soil could be the presence of intensive rainfall leading to leaching and downward movement of the soluble divalent basic cations (Ca2+,Mg2+) leaving the surface layer to be dominated by Fe.

Fe shows a strong positive correlation with clay (r= 0.73*) and silt(r= 0.92***) which indicates that the availability of Fe increased as clay and silt content increases in the soil. But Fe shows a strong negative correlation with sand (r= -0.87**) which indicates that the availability of Fe decreased as sand content increases in the soil. The Fe content was negatively and very significantly correlated with bulk density of the soil (r= -0.91***). Thus, the availability of Fe decreases as bulk density of the soil increases. Fe content of the soil reveals a strong positive correlation with OM (r= 0.81**). Thus, the availability of Fe increased with OM content which might be attributed to greater availability of chelating agents through OM which implied that Organomineral complexes, particularly metallic ions such as Fe2+, Cu2+, Zn2+, and Mn2+. These results are in agreement with [46].

Available Zn contents of the soils across the three depths widely varied from 0.60ppm in the surface soil to 0.55ppm in the subsurface soil (Table 4). By using critical level of 1.5ppm suggested by Karltun et al. [47] the studied district is categorized under Zn deficiency. According to Teklu et al., [48] the deficiencies of the micronutrient like Zn, has significant effect on maize production. The studies conducted in Australia, Brazil, Ghana, India and Malawi, showed positive effects of zinc fertilization on yields of rice, wheat, maize and soybean, respectively [49,50].

When agricultural productivity is considered, Zinc deficiency is the most widespread soil micronutrient deficiency in the world [49]. The absolute Zinc contents tend to be low in highly weathered acid tropical soils. Chemically, Zinc has some similarities and positive relation with iron(r= 0.36) and manganese (r=0.85**) and in plant uptake there can be competition between these elements. Furthermore, high levels of phosphate in soils can strongly reduce Zinc availability [51]. Therefore, inclusion of Zn in blended

Table 3:- Means of Cation Exchange Capacity and Exchangeable Bases.

Soil depth (cm)	Descriptive statistics	CEC (meq/100g soil)	Exchangeable Bases			
			EDTA Titration(meq/100g)		Flame (Cmolkg^{-1})	
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
0-30 (n=3)	Mean	**26.86^{a}**	**2.30^{b}**	**2.06^{a}**	**0.4^{b}**	**0.15^{c}**
	CV(%)	1.54	11.50	9.16	5.00	0.467
30-60 (n=3)	Mean	**25.86^{b}**	**1.56^{b}**	**1.00^{b}**	**1.06^{a}**	**0.21^{b}**
	CV(%)	1.94	4.16	3.00	5.41	7.88
60-90 (n=3)	Mean	**22.53^{c}**	**3.36^{a}**	**0.70^{b}**	**0.43^{b}**	**0.52^{a}**
	CV(%)	1.84	11.24	4.74	5.25	2.35
LSD(0.05)		0.70	0.90	0.92	0.29	0.14
Critical levels for Maize growth		12-25	5-10	1-3	0.3-0.7	0.3-0.6
Reference		FAO,2006 [35]	FAO,2006 [35]	FAO,2006 [35]	FAO,2006 [35]	FAO,2006 [35]

Where: SD (Standard Deviation), CV (Coefficient of Variation), LSD (Least Significance Difference), CEC (cation exchange capacity), Ca (calcium), Mg (magnesium), K (Potassium), and Na (sodium). Means followed by the same letter(s) within column for a given variable are not significantly different at 5% level of significance.

Table 4: Mean distribution of Micronutrients along soil depths.

Soil depth (cm)	Descriptive statistics	Micro nutrients(ppm)			
		Fe	Zn	Cu	Mn
0-30 (n=3)	Mean	**4.52[a]**	**0.60[a]**	**1.24[a]**	**1.58[a]**
	CV(%)	4.38	12.47	4.96	3.11
30-60 (n=3)	Mean	**1.10[b]**	**0.55[a]**	**0.21[b]**	**0.55[b]**
	CV(%)	9.53	9.27	2.30	5.67
60-90 (n=3)	Mean	**0.63[b]**	**0.55[a]**	**0.13[b]**	**0.76[b]**
	CV(%)	9.69	4.12	2.89	2.79
LSD(0.05)		0.49	0.17	0.11	0.59
Critical levels for Maize growth		2.6-4.5	0.6-1.0	0.4-0.6	
Reference		FAO,2006 [35]	FAO,2006 [35]	EthioSIS,2014 [24]	

Where: SD (Standard Deviation), CV (Coefficient of Variation), LSD (Least Significance Difference), Fe (Iron), Cu (copper), Mn (manganese) and Zn (Zinc). Means followed by the same letter(s) within column for a given variable are not significantly different at 5% level of significance.

fertilizers could be beneficial for the district under study to get maximum Maize production.

Available Cu contents of the soils across the three soil depths widely varied from 1.24ppm in the surface soil to 0.13ppm in the subsurface soil (Table 4) with 0.21ppm for the mid soil layer (30-60cm) depth. According to EthioSIS' critical level [47] soil fertility rating, the Cu content of the two subsurface soil layers of the study area were low while the highest Cu content was recorded as 1.24ppm from the top surface soil layer (0-30cm) soil depth. These results are in agreement with various works done in Ethiopian soils [52]. Cu was negatively correlated with sand (r= -0.83**) which indicates that the availability of Cu decreased as sand content increases in the soil. (Table 4).

Cu was positively correlated with clay (r= 0.71*) and silt(r= 0.91***) which indicates that the availability of Cu increased as clay and silt content increases in the soil. This result is in line with Sharma et al., (2006) who reported positive correlation between Cu, clay and silt content of the soil. The Cu content was positively and significantly correlated with potassium (r= 0.95***), which indicates that the availability of Cu increased as potassium content increases in the soil. The Cu content was positively correlated with phosphorus, nitrogen and OM (r= 0.91***, 0.50, 0.78*), respectively. Thus, the availability of Cu increased as phosphorus, nitrogen and OM contents increase in the soil. The same finding with the result of this study was reported by [46]. Thus, the availability of Cu increased with OM content which might be attributed to greater availability of chelating agents through OM which implied that Organomineral complexes, particularly metallic ions such as Fe2+, Cu2+, Zn2+, and Mn2+.

The highest and lowest values of Mn were 1.58 and 0.55ppm which was recorded from 0-30cm and 30-60cm soil depths, respectively. The mean value of the extractable Mn for 60-90cm depth was 0.76ppm which is a mid-value for the two upper soil layers (Table 4). The concentration of Mn in the surface soil (0-30cm depth) is above the critical limit for this nutrient [53]. Accordingly, the concentration of Mn in 0-30cm soil depth was in the sufficient range while the two subsequent subsoil layers reveals insufficient Mn concentration which is below the critical limit of this nutrient. Mn was negatively correlated with sand (r= -0.59) which indicates that the availability of Mn decreased as sand content increases in the soil. But Mn was positively correlated with clay (r= 0.46) and silt (r= 0.67*), respectively. The result indicates that the availability of Mn increase as clay and silt content increases in the soil.

CONCLUSION AND RECOMMENDATION

CONCLUSION

Soil fertility and plant nutrition are two closely related subjects that emphasize the forms and availability of nutrients in soils, their movement to and their uptake by roots, and the utilization of nutrients within plants. Without maintaining soil fertility, one cannot talk about increment of agricultural production in feeding the alarmingly increasing population. Therefore, to get optimum, sustained-long lasting and self-sufficient crop production, soil fertility has to be maintained. Soil test based nutrient management approaches are very little practiced in Ethiopia in general and in the study area in particular. Therefore, evaluating all factors affecting soil fertility, demarcating the changes, understanding their optimistic and pessimistic interaction can help growers, researchers, and all stakeholders to easily manage the constraints and generate best available soil fertility management technologies for the area.

Maize (*Zea mays L.*) is one of the cereal crops used as the main staple food crop in Ethiopia. However, many factors limit maize production. These factors are inappropriate crop rotation, unreliable rainfall, use of traditional varieties, insect-pests attacks and diseases incidence. Apart from those factors, low soil fertility is major constraints that challenge maize production in Ethiopia. Improving soil fertility status is therefore very important in order to increase maize production. One of the possible solutions is to assess nutrients status of soils to know the plant nutrients deficit and the required amount of fertilizer to be added for the crop. Accordingly, this study was designed to be conducted in Assosa district to evaluate the soil fertility status in relation to maize production. For this three soil profile pits were dung in the year 2017 and 2018 and a total of 27 composite soil samples were taken from three soil depth categories (0-30, 30-60 and 60-90cm). The experiment was arranged in Randomized Complete Block Design. The physico-chemical parameters of the sampled soil were analyzed in Assosa Soil laboratory center and Amhara Design & Supervision

Works Enterprise soil laboratory. One way Analysis of variance and summary descriptive statistics were made by [54].

The result indicated that the clay texture was the textural class of the soil in the entire three soil depth category. The soil of the study area shows moderately acidic condition in their reaction. Medium level of total nitrogen (N) and Cation Exchange Capacity (CEC) was observed in all the three soil depth categories. Lower level of soil organic carbon (OC), available phosphorus (P), available potassium (K) and Zinc (Zn) was observed on the upper (0-30cm) soil layer which is the root zone for maize crop. The concentration of these nutrient elements revealed a significant difference across the three soil depths ($P < 0.05$). Highly significant ($P < 0.001$) and a strong positive correlation were observed between available Phosphorus and Potassium($r=0.97$), OC and CEC ($r=0.94$) and OC with clay content($r=0.87$). Contrary to this, a highly significant and strong negative correlation was observed between sand content of the soil and OC, TN & CEC($r=-0.96,-0.77$ and -0.92, respectively). Soil micronutrients of the study area revealed a decreasing trend vertically down ward across the three soil depths. In terms of maize nutrient requirement, relatively medium level of total nitrogen was observed in the surface soil layer while serious limitations in available phosphorus, potassium and zinc content of the soil were observed.

RECOMMENDATION

Based on the findings of this study, the following recommendations are forwarded:

Soil fertility management interventions such as soil conservation, locally accessible organic matter application, use of bio-fertilizers and balanced inorganic fertilizer application to restore the Organic matter, Phosphorus, Potassium and Zinc deficiencies in the study area are recommended in order to ensure increased maize productivity.

As this study gives something general about the status of soil fertility for maize production in the study area depending on soil physico-chemical characteristics, further study that focuses on the identification of appropriate methods, level and time of fertilizer, manure and compost application as well as the economic return of amending these limiting nutrients for sustainable maize production in Assosa District is highly recommended.

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