Physico-Chemical Properties and Agricultural Potentials of Soils of Tembaro Woreda, Kembata Tembaro Zone, Southern Ethiopia

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Abstract
Physico-chemical properties of soils of a particular area is crucial for determination of its potential and constraints based on which appropriate management interventions could be applied for enhanced and sustained agricultural production and productivity. Therefore, the objectives of this study were to determine physico-chemical properties of the soils of Ambukuna microcachment and to identify its potentials and constraints for crop production. Five sites representing a soil each were opened and profile in each site was described for its morphological, physical and chemical characteristics according to standard procedures. A total of 20 disturbed soil samples and 16 core ring samples were collected from five representative sites. The samples were analyzed in the laboratory for texture, BD, FC, PWP, Soil pH, EC, OC, TN, av.P, av.K, exchangeable bases and CEC. The results of the study showed that the proportions of soil separates varied among sites. The BD varied from 1.13 in the surface site 1 to 1.26 gcm^{-3} in the site 3. Soil pH ranged from 5.4-6.8 in the surface of all sites with further decrease with depth indicating that the soils in the watershed are strongly acidic to slightly acidic. The OM and TN contents ranged from 2.96-5.95 and 0.26-0.45% in the surface soil and they were in the low, low to medium and high categories, respectively. Available P was below critical values for all sites except for sites 1 and 4. Exchangeable K was above critical value in all sites. Exchangeable Mg varied from 2.87 in surface soils of site 3 to 3.98 cmolc kg^{-1} in the surface soils of site 4. The observation with exchangeable K and Mg implies that there is leaching phenomenon in the study area. Ca ranged from 5. 37 cmolc kg^{-1} in site 5 to 16.80 cmolc kg^{-1} in site 2. The CEC from 19.22 cmolc kg^{-1} soil in surface of site 5 to 36.43 cmolc kg^{-1} soil in the surface soil site 1 indicating they are in the medium to high ranges. Most of the soil physical and some of the chemical characteristics studied could be ranked as good indicating that the area has high potential for agricultural production. However, acidic soil reaction observed in the study area should attract attention for its management now and in the future. P is also found to be the most important limiting nutrient for crop production in the area. Thus, management of P is indispensible for enhanced agricultural production in the area. Maintenance and enhancement of organic matter content of the soil in the watershed is also recommended for improving soil quality and sustainability.
Keywords: Morphological Characteristics, exchangeable bases, total nitrogen

INTRODUCTION

The overall productivity and sustainability of a given agricultural sector are functions of fertile soils and productive lands. However, soil fertility depletion is the fundamental biophysical cause for declining per capita food production in sub- Saharan African countries in general (Sanchez *et al*., 1997, Sanginga and Woomer, 2009). The study and understanding of soil properties and their distribution over an area has proved to be useful for the development of soil management plan for efficient utilization of limited land resources. Moreover, it is very important for agrotechnology transfer (Buol *et al*., 2003).

Ethiopian agriculture accounted for 41.6% of GDP, 83% of export earrings and 90% of total employment (MoFED, 2014). As a result, agriculture remains to be Ethiopian economy's most important sector. Ethiopia has great agricultural potential because of its vast areas of fertile land, diverse climate, generally adequate rainfall, and large labour pool (CSA, 2008). The country has a total surface area of 111.8 million ha (Mabbutt, 1984); of which 62.81million ha are estimated agriculturally productive (Mishra *et al.*, 2004). However, Ethiopia's agriculture is characterized by low production per unit area and the sector is dominated by about 11.7 million smallholders responsible for about 95 percent of the national agricultural production while large farms contribute only 5 percent of the total production (MoA, 2011). This shows that the overall economy of the country and the food security of the majority of the population depend on small-scale agriculture.

Although the country has enormous potential for agricultural production (such as in terms of land, climate and water resources), it is not uncommon facing a serious and chronic problem of food crop shortage in the country (Yohannes, 1989). Ethiopia with its immense potential soil resource base suffers from food insecurity (Mishra *et al.,* 2004). This is a paradox, which invites researchers to investigate the causes of the problem and suggest feasible solutions.

As Ethiopia is an agricultural country, its development is strongly linked with the agricultural resource base. The soil as one component is the basic resource that provides opportunities and constraints for agricultural development. Therefore, knowledge about the soils of the country is important for technology transfer, decision making and planning and policy formulation. However, the soil information currently available is very limited and derived from small scale studies. As a consequence, it is not possible to give site specific appropriate recommendation for agricultural problems based on spatial variability of soil properties. As a result, decision makers and development workers usually give a blanket recommendation of agricultural technologies on agro-climatic basis in the effort of increasing crop productivity. Hence, there is a need to conduct soil research that includes characterization and classification of soil at a watershed level, which is useful to determine the full production potentials of the country together with the identification of the factors, which are likely to limit production.The objectives of the present study were to investigate the major morphological, physical and chemical characteristics of the soils and agricultural potentials and constraints for crop production of the soils of Ambukuna microcachment.

MATERIALS AND METHODS

The study site, Ambukuna microcachment, is located at about 8 km south east of Mudulla town in the Kembata-Tembaro zone, Tembaro woreda, southern Ethiopia. It is situated just 392 km south of Addis Ababa and 172 km west of Hawassa town. Geographically, the microcachment is located between latitude 79°83'79" to 80°09'79" N and longitude 34°32'70'' to 34°20'96" E. The total area of the Tembaro woreda and Ambukuna microcachment is about 27,917 ha and 341 ha, respectively (WAO, 2011). Data from field survey and soil sampling were collected to satisfy the objectives of the study in the Ambukuna microcachment. Two phases of field survey were accomplished in studying the soil of the watershed. First, a preliminary or reconnaissance survey was performed with the help of 1:50,000 topo-sheet (EMLS, 1976) to acquire general information on soils and environment of the proposed study area. At this level tentative soil units and map were prepared on the same map based on landscape vegetation relationships and surface soil characteristics (e.g. colour, structure, texture) as field guide. The detailed survey was conducted during the second phase. Using the tentative soil map as supplementary, soils were studied from auger holes, gully cuts and site observations. A number of auger holes observations were made and site characteristics and land use patterns were recorded on standard form. Then with this information, the tentative soil units were adjusted through manipulations of tentative soil boundaries. The final soil field boundaries were then delineated on the 1:50000 toposheet. In delineation of boundaries topographic factors, vegetation characteristics, surface colour and land use patterns were used in addition to auger hole and other observation points. A toposequence was selected along east-west facing slopes encompassing landform components from upper slope to bottom slope of the watershed. After a proper identification of soil mapping units, five soil pits were opened and profiles described according to procedures and criteria indicated in FAO (2006), for their environmental and morphological characteristics. Colours of the soils were determined using Munsell soil colour chart (Munsell colour company, 1975). The FAO-WRB (2006) classification legend was followed in the classification of the soils. Profile observation points were geo-referenced with the help of geographical positioning system (GPS) and located on the 1:50,000 scale base and then finally in the soil map. Total 20 disturbed and 16 undisturbed soil samples were collected from recognized genetic horizons of the 5 representative pits. From each recognized genetic horizon, disturbed soil samples using bag were taken, and from which 1 kg of soil was transferred into plastic bag and labeled. Then the soil samples were transported to National Soil Testing Center (NSTC), where they were analyzed for their physical and chemical characteristics.

The undisturbed core samples were used for the determination of bulk density and soil moisture contents at field capacity (FC at -0.33 bar) and permanent wilting point (PWP at -15 bars). The disturbed soil samples were air-dried, ground and passed through a 2 mm sieve and analyzed for physical and chemical parameters. The bulk density of undisturbed soil was determined by the core method as described by Gupta (2000). Total porosity was estimated using the following formula: Total Porosity (%) = 100-[(BD/Pd) x100] (Brady, 1990). The bulk density of undisturbed soil was determined by the core method as described by Gupta (2000) where Pd (particle density) is assumed to be 2.65 g cm^{-3} and BD is bulk density (g cm^{-3}). The soil moisture contents at field capacity and at permanent wilting point were measured by the pressure plate apparatus. Finally, the available water holding capacity was determined from the difference between water content at FC and PWP (Hillel, 1980). The particle size distribution was determined by the hydrometer method (Van Reeuwijk, 1993). Electrical conductivity was measured by conductivity meter in 1:2.5 soil-water ratio (Okalebo *et al.,* 2002). Soil pH was determined using pH meter with combined glass electrode at 1:2.5 (soil: water) ratio as described by Carter (1993). The organic carbon was determined by the Walkley and Black (1934) method and organic matter content was obtained by multiplying the OC content by a factor of 1.724. The total N content in soil was determined by using the Kjeldahl procedure (Gupta, 2000) and available P was determined by the Olsen method (Olsen *et al.,* 1954). To determine available K in the soil, the soil samples were extracted with Morgan's solution and K was read by flame photometer (Morgan, 1941). Exchangeable bases (Ca, Mg, K and Na) and CEC in the soil were estimated by the ammonium acetate (1$\underline{N}$ NH_4OAc at pH 7.0) extraction method. Then, Ca and Mg were measured with the help of atomic absorption spectrophotometer (AAS), and K and Na by flame photometer in the ammonium acetate extract. Cation exchange capacity was determined through distillation and titration after leaching the ammonium saturated soil with 10% NaCl (Van Reeuwijk, 1993). Percent base saturation (PBS) was calculated by dividing the sum of exchangeable bases by the CEC of the soil and multiplied by 100. The CEC clay was obtained by dividing CEC of the soil by amount of clay of each horizon and expressed on the bases of percentage. The relative proportion of each exchangeable base was calculated by dividing the amount of respective cation by the CEC of the soil and multiplying by 100 for each horizon (Buol *et al*., 1997).

Simple linear correlation analysis was carried out to reveal the relationships between and among selected physicochemical properties of the soils according to the procedures described by Gomez (1984) and used in the interpretations of data. Statistical Package for Social Science (SPSS) software model was employed in the statistical analysis procedure.

RESULTS AND DISCUSSION

Site and Morphological Characteristics

In the study area, surface soil colour patterns showed great variability in relation to position in the landscape, slope gradient and organic matter content (Table 1). It changed from dark brown with moist hues of 7.5YR in surface to dark reddish brown hues (5YR or 2.5YR, moist) in subsoil horizons. The relatively dark brown surface soil colour could be attributed to a relatively high content of organic matter of the surface soils. According to Foth (1990), reddish color is due to the presence of iron compounds in various states of oxidation. The type, size and grade of structure in the surface horizons were uniformly described to have sub angular blocky, fine to medium and moderate, respectively.

Table 1. Selected morphological characteristics

Depth (cm)	Colour		Consistence	Structure	Root
	Dry	moist	dry/moist/wet	grade/size/type	Abundance/Size
			Site-1		
0-35	7.5YR4/4	7.5YR2.5/3	SHA/FI/SST/SPL	MO/ME/SB	M/M-C
			Site-2		
0-35	7.5YR3/3	7.5YR2.5/3	SHA/FR/SST/SPL	MO/ME/SB	C/F-M
			Site-3		
0-35	5YR4/4	5YR3/2	HA/FR/SST/SPL	MO/F/SB	C/M
			Site-4		
0-35	5YR4/4	5YR3/2	SHA/FR/SST/SPL	ST/FI-ME/SB	M/F-M
			Site-5		
0-35	7.5YR4/6	7.5YR3/3	SHA/FI/SST/PL	MO/FI-ME/SB	M/M

Abbreviations are as per FAO-WRB (2006).

The development of blocky structure types could be related to the low level of organic matter, reduction in abundance of plant roots and higher clay percentage of subsoil horizons. The change in consistence characteristics from site to site in surface soil reflects the high contents of clay and low contents of organic matter. This is a typical characteristic of most tropical soils (Young, 1976).

Physical Characteristics

Soil physical characteristics for representative profiles were described in Table 4. Clay content varied between 58% (site 4) and 39% (site 2) in surface soil.

Table 2. physical parameters of the soils of Ambukuna catchment.

Depth (cm)	particle size distribution			Textural Class	water content			Bulk density g cm^{-3}	Porosiy %
	Sand %	silt %	clay%		FC%	PWP %	AWC%		
			Site 1						
0-35	21	26	53	C	30	26	4	1.13	54
			Site 2						
0-35	27	24	39	CL	31	27	4	1.22	46
			Site 3						
0-35	29	21	50	C	29	24	5	1.26	47
			Site 4						
0-35	20	22	58	C	30	25	5	1.20	45
			Site 5						
0-35	29	25	46	C	-	-	-	-	-

C=Clay, CL= Clay loam, "-" not determined, FC=field capacity, PWP=permanent wilting point, AWC=Available water content

The bulk densities of the studied soils showed great variability with respect to contents of organic matter and position of horizons in a profile (Table 2). In most of the profiles, bulk density values were lower in the surface than in the underlying horizons. Bulk density varied from 1.13 g cm^{-3} (site 1) to 1.24 g cm^{-3} (site 3) in surface soil. This reveals that the high amount of organic matter and well structure characteristics of profile 1 resulted in low value of bulk density of surface soils. Hence, the unsystematic increasing pattern in bulk densities with depth of profiles could be related to a decrease in contents of organic matter and a presence of blocky type of soil structure. Higher OM content in the surface soil makes soils loose, porous and well aggregated, thereby reducing bulk density and bulk densities range for agricultural soils from values of the order of 1g cm^{-3} to 1.7g cm^{-3} (Hillel, 1980). This implies that no excessive compaction and no restriction to root development (Werner, 1997). The bulk density of the study area was within the average range for good agricultural soils. The soil porosity varied from 54 to 45 in the surface soil. According to Brady and Weil (2002), ideal total pore space values, which are acceptable for crop production, are around 50%. Hence, the soils of Ambukuna microcachment have an acceptable range of total porosity values for crop production. According to rating Beernaert (1990), available water content values in the Ambukuna microcachment were rated very low due to low organic matter in the study profiles.

Chemical characteristics

Soil chemical characteristics of representative sites are presented in Table 3. According to Churchman *et al*., (1983), these values reveal the absence of calcium carbonate in the study area, where values of pH-H_2O less than 6.5 are generally considered as non-calcareous. According to Brook (1983), the studied soils can be rated to range from moderately acidic to slightly acidic in reaction. Currently, it is estimated that about 40% of arable lands of Ethiopia are affected by soil acidity/Al^{3+} toxicity (Taye, 2007). According to Benton (2003), the soils of Ambukuna microcachment of surface soils were rated as very low which considered as non-saline, mainly as a result of high rainfall of the area leaching much of salts in the sites (Table 3).

According to Brook (1983), rating for soils of tropical and subtropical regions, organic matter content of the surface soils in the study area of sites 1 and 2 was in medium level and sites of 3, 4 and 5 were low class which is due to differing intensity of erosion, addition of organic material and level of the mineralization/decomposition of organic matter. According to Landon (1991), organic carbon content of the study area soils were low in all study sites. According to Havlin *et al.* (1999), TN content of study area soils were categorized under the medium to high category. The results are in accordance with the findings of Wakene and Heluf (2003) and Tuma (2007) who reported that intensive and continuous cultivation forced oxidation of OC and thus resulted in reduction of TN. Moreover, a result from simple correlation analysis indicated that total nitrogen and organic matter are positively and significantly correlated (r =0.55*) and organic matter and clay content, water field capacity and permanent wilting point are negatively correlated r= -0.76**, -0.54* and -0.7, respectively.

Table 3. Some chemical properties of Ambukuna catchment

Depth(cm)	PH–H_2O	EC(ds/m)	O.C%	O.M%	T.N%	C/ N	av. P(ppm)	av. K(ppm)
		Site -1						
0-35	6.8	0 .11	2.87	5.95	0.28	10	6.52	383.18
		Site -2						
0-35	6.5	0.04	2.77	4.77	0.45	9	3.58	559.13
		Site -3						
0-35	5.8	0.03	1.72	2.96	0.30	6	4.58	359.72
		Site -4						
0-35	5.7	0.03	1.82	3.14	0.27	7	13.72	320.62
		Site-5						
0-35	5.4	0.03	1.74	3.00	0.26	8	3.72	324.44

EC=electrical conductivity, O.M=organic matter, T.N= total nitrogen, C/N= carbon/nitrogen, av .P=available phosphorus, av.K=available potassium

In general, a C/N ratio of about 10 suggests relatively better decomposition rate and indicates improved availability of nitrogen to plants and there will be possibilities to incorporate crop residues to the soil without adverse effect of nitrogen immobilization (Yerima, 1993). According to Yihenew (2002), optimum range of the C:N ratio is about 10:1 to 12:1 that provides nitrogen in excess of microbial needs. Accordingly, the C:N ratio of the surface soils across the sites may be considered to be below the optimum range in all soils for microbial needs except site 1.

According to the ratings for some tropical soils (Olsen and Dean, 1965; Brook, 1983; Havlin *et al*., 1999), available P contents in the study Ambukuna microcachment were low (soil indicates a crop response to P fertilizers) in the sites of 2, 3 and 5, medium (indicates a probable response) in site 1 and high (indicates a crop response is unlikely) in site of 4 of the topsoils. Topsoil phosphorus is usually great that in surface soil due to sorption of the added phosphorus, greater biological activity and accumulation of organic material in the former. Moreover, Wakene and Heluf (2003) have suggested that the existence of low contents of available phosphorus is a common characteristic of most Ethiopian soils. The greater the proportion of clay minerals high in potassium, the greater will be the potential potassium availability in a soil (Tisdale *et al.*, 2002). As Benton (2003) has suggested the index values for available potassium (K) in Morgan method, values of K in the study area was adequate.

According to Brook (1983), rating of exchangeable Ca (in cmol(+) kg^{-1}), Ambukuna microcachment was rated low in site 5 and medium to high in sites 1, 2, 3 and 4 in both surface. These revealed relatively low levels of exchangeable Ca in the sites may suggest relatively advanced developed soils. According to Sims (2000), the range of critical values for optimum crop production for Ca are from 1.25 - 2.5 cmol (+) kg^{-1} soil and the exchangeable Ca content of the soils Ambukuna microcachment were above the critical values. As Brook (1983) has suggested, exchangeable Mg (cmol(+) kg^{-1}) was rated medium to high in surface soil of the studied sites of Ambukuna microcachment. A continuous cultivation and inorganic fertilizers application resulted in declining of soil pH that caused loss of basic cations and especially under intensive cropping of inherently poor soils, the deficiencies of calcium and magnesium are common (Wakene, 2001).

As Brook (1983) rating of exchangeable potassium (cmol(+) kg^{-1} soil), Ambukuna microcachment exchangeable K was medium to high in surface soil for crop cultivation. According to the same auother rating of sodium for tropical soil, amount of exchangeable sodium was very low to low or trace amount in the surface soils of the study microcachment soils. In general, magnitude of exchangeable cations was in the order of Ca> Mg> K> Na. The ratios of K/M 0.21 to 0.46 in the surface soils (Table 4). This result showed that, according to Loide (2004) , the soil Mg was dominant in the exchange site than K and cause Mg induced K deficiency. The K deficiency due to high Mg in the study areas should be considered as a major challenge for achieving higher yields. Therefore, application of K fertilizer is needed.

According to Brook (1983), the CEC of Ambukuna microcachment was rated as medium in the sites 2, 4 and 5 to high in sites 1 and 3 for surface soils. There exists a strong relationship (r=0.84**) between CEC and sum of exchangeable cations and (r=0.78**) between CEC and available P of the soil sites but sum of exchangeable bases and water field capacity have negative correlation (r=-0.73**) (Table 4). Accordingly, the increase in clay contents with depth of the sites did not match with increase in CEC. The CEC/clay values were also found to be high for the surface soil of the studied sites.

Table 4. Exchangeable bases, CEC and percent base saturation of soils of Ambukuna catchment

Depth, Cm	Exchangeable bases, cmol(+)/kg soil				K/Mg	Ca/Mg	CEC,cmol(+)/kg soil	PBS, %	CEC/clay, %
	Na	K	Ca	Mg					
			Site-1						
0-35	0.00	1.65	13.89	3.35	0 .39	4.65	27. 87	75	63
			Site -2						
0-35	0.00	1.43	16.80	3.22	0.46	4.84	36.43	76	64
			Site -3						
0-35	0.00	0.82	12.86	3.77	0.37	4.98	24.70	67	44
			Site-4						
0-35	0.00	0.82	11.50	3.98	0.21	2.89	23.56	72	42
			Site-5						
0-35	0.00	0.84	5.37	2.87	0.29	1.22	19.22	43	37

Na=sodium, K=potassium, Ca=calcium, Mg=magnesium, CEC=cation exchangeable capacity, PBS=percentage saturation, EA=Exchangeable Acidity, K/Mg= ratio of potassium to magnesium, Ca/Mg=ratio of calcium to magnesium

The decline in total CEC or CEC/clay with depth of sites reflects the role of clay mineralogy. The measured values of CEC from site1, 2, 3, 4 and 5 may indicate presence of mixed clay mineralogy. These facts indicate that CEC could also be explained by stages of soil development. The percentage base saturation (PBS) was generally above 50% in most of the sites. PBS varied from 86 % of site 2 to 41 % of site 5 in the surface horizon. In the subsoil, PBS varied between 80 % of site 2 and 42 % of site 3 (Table 6). According to Brook (1983) suggestion for tropical soils (PBS %) of the Ambukuna microcachment has medium PBS for site 5 and high PBS for sites 1, 2, 3 and 4.

Agricultural constraints and potentials of the soils

Soils in the study area are the extensively cultivated soils. Almost all identified units of the study site soils had uniform characteristics with slight variation in physical properties (structure, texture, water holding, consistence, bulk density, colour); thus could have similar potentials and constraints for crop cultivation. The very deep solum, well drained condition, clay loam to clay texture, moderate - strong granular structure and relatively low bulk density values could form favorable soil conditions for agriculture. These properties allow free drainage, proper aeration, and ready infiltration of water and resist erosion- runoff processes. Furthermore, the friable to firm consistence, absence of a hard pan and/or of rock fragments imply that the soils are good for agriculture, as it is easy to cultivate and for penetration and development of plant roots.

Soils of the present study area are marked by low pH value (5.5 to 6.2) for surface soils. These values imply that the soil is moderately acidic to slightly acidic in reaction. According to Brook (1983) the most favourable pH for availability of most nutrients correspond roughly with the optimum range of 6-7 for most of the crop plants. This level of soil reaction of the soils may limit crop production and productivity by influencing availability of important nutrients as discussed above. Therefore, crops that are highly sensitive to acidity either cannot grow or their yield would be markedly reduced. Based on Table 10, profiles 1, 2, 3, 4 and 5 are commonly suitable for Carrot, Citrus-Lemon, Citrus-Orange, Coffee, Potato (sweet), Pumpkin and Sorghum. Soil acidity limits or reduces crop production primarily by impairing root growth there by reducing nutrient and water uptake (Marschner, 1995). Moreover, low pH or soil acidity converts some available soil nutrients in to unavailable form and also acidic soils are poor in their basic cations such as Ca, K, Mg and some micronutrients (e.g. Mo) which are as essential to crop growth and development (Wang *et al*., 2006).

According to the rating of Landon (1991), CEC of the surface soil of the study area can be rated as medium to high. Furthermore, such high CEC value provides the soil with high buffering capacity so that one can apply the required amount of fertilizer dosage without any immediate negative effects on the soils. On the other hand, the medium CEC values in the surface and subsoil horizons show the potential danger of nutrient losses due to leaching.

The percentage base saturation is frequently considered to be an indication of soil fertility. Soils with percentage base saturation of <20%, 20-60% and >60% are considered as low, medium, and high in fertility quality (Landon, 1991). Thus, the soils of the present study area exhibited medium to high percentage base saturation levels (Table 6) which implies that basic cations were lost from the soil through the processes of leaching due to the high rainfall. Thus, as mentioned above low potential levels of basic cations could be the other major constraints of these soils. However, for sites 4 and 5, Mg may limit crop production predominantly as the Ca: Mg ratios between 4 and 6 are higher values that sites 1, 2 and 3 are found in optimum range for agricultural production (Table 6; Brook, 1983). The exchange complex of the soils is dominated by Ca followed by Mg, K and Na (Table 6). According to Havlin *et al.* (1999), the prevalence of Ca followed by Mg, K, and Na in the exchange site of soils is favourable for crop production. The exchangeable Na content of the soils is low and the exchangeable sodium percentage (ESP) of the soils was also less than 2%. This indicates that there is no sodicity problem in these soils. According to Brady and Weil (2002), ESP of 15% is considered as critical for most crops. According to Sims (2000), the range of critical values for optimum crop production for K, Ca and Mg are from 0.28 - 0.51, 1.25 - 2.5, and 0.25 - 0.5 cmol (+) kg^{-1} soil, respectively. Accordingly, the exchangeable K, Ca and Mg content of the soils are above the critical values. However, this does not prove a balanced proportion of the exchangeable bases. Potassium uptake would be reduced as Ca and Mg are increased; conversely uptake of these two cations would be reduced as the available supply of K is increased (Havlin *et al.,* 1999). In addition, the ratio of exchangeable Ca/Mg should not exceed 10/1 to 15/1 to prevent Mg deficiency and also the recommended K/Mg are < 5/1 for field crops, < 3/1 for vegetables and sugar beets and < 2/1 for fruit and greenhouse crops (Havlin *et al*., 1999). The Ca/Mg ratio of the studied soils was in the range of 1.22 – 5.98 indicating that the response of crops to Mg is not likely. The K/Mg ratio of the studied soils varied from 0.21 to 0.46 and hence it is less than critical level (0.8) indicating Mg induced K deficiency and Calling for K fertilize applications for optimum crop production.

Potassium (K) is one of the essential elements required by plants for their growth and development. It plays a very important role in activation of enzymes, photosynthesis, starch synthesis, nitrate reduction and sugar degradation (Askegaard *et al*., 2004). K availability would not be a limiting factor for crop production as the soils of the present study area were rich according to Landon (1991) and Benton (2003). Kapkiyai *et al*. (1998) indicated that soil organic matter (OM) content is a critical component of soil productivity and its maintenance is a sound approach to maintaining productivity of continuously cropped soils. The same publication showed that changes in soil OM results from imbalances between organic inputs and losses, and declining soil OM are frequently observed when lands are converted from natural vegetation to agriculture. The status of organic matter and total nitrogen of the soils of the study area were low to medium and medium for agricultural use respectively (Landon, 1991).

In general terms, the available P content of soils is below the critical limit for the growth of most crops based on Landon (1991). According to Benton (2003) rating the available P content of the study area soil indicated low in sites 2, 3 and 4 which indicates a crop response to P fertilizers; medium in site 1 which indicates a probable response and high in profile 4 which indicates a crop response is unlikely. Thus, the available P content of most of these soils appears to be the most limiting nutrient for crop production. According to Mishra *et al*. (2004), P in the Ethiopian soils poses different scenario wherein only a very low fraction of total P is available to plants. Phosphorus in soils of the highlands of Ethiopia is the limiting element in crop production, as a result 70 to 75% of the agricultural soils of the highland regions of the country are P deficient (Shiferaw, 2004). According to Anetor and Akinrinde (2006) report, with high rate of P fertilizer additions, soil sorption sites are satisfied and P level increases to sufficiency for crop production.

CONCLUSION AND RECOMMENDATION

The soils of the study area showed variations in morphological, physical and chemical characteristics. Soil colour showed variability due to variations in elevation and topographic position. The colour of the soils in the gently sloping to moderately sloping land were dark brown (7.5YR, moist) in the surface and dark reddish (5YR to 2.5YR) in the subsurface. Surface soils structure was very similar in all the studied profiles but showed variations among the surface and subsurface soils of study sites. The drainage condition in all sites of study area was relatively the same and well drained. The texture of the soils in the surface horizons exhibited to be clayey in all the studied profiles. Bulk densities of the soil showed spatial variability among the soils in accordance with the level of organic matter.

Generally, the reactions of the soils were acidic in the studied sites irrespective of their position in the landscape. Distribution of organic matter and total nitrogen varied among the studied sites in response to differences in landscape position, elevation and management history. It was observed that the level of organic matter increases with increase in elevation and decreases with depth in the sites. Distribution pattern of total nitrogen nearly resembled that of organic matter implying the major source of nitrogen for the soil system is organic matter. Therefore, preservation and maintenance of organic matter is essential for successful crop production. Available phosphorus shows irregular variability implying phosphorus availability is governed by complex processes. Besides, the level of available phosphorus was ranged from low (site 1) to high (site 4) in topsoil of the study soil; it is one of the major limiting nutrient elements in the study area. Therefore, management of phosphorus is essential to fully exploit the potential of the soils for crop production.

The concentration of exchangeable basic cations (Ca, Mg, K, Na) showed great variability among the soil sites in the surface soil. The contents of exchangeable and available K in the surface of all soils were very high. However due to low K:Mg ratio K fertilizer application is recommended. Exchangeable Na was low sites of the studied soils. As a result, adverse effect of Na would not be expected in the study area. Generally, exchangeable cations increased downward with depth in most of the sites. However, in a few cases it was observed that topsoil contained high exchangeable base in all sites of the study soils. The ratios of Ca/Mg in most cases were higher than 6:1 indicating the probable occurrence of an imbalance of Ca and Mg. Accordingly, the increase in clay contents with depth of the site did not parallel with increase in CEC. These suggest that CEC variations could not be explained by amount of clay and OM. The percentage base saturation was generally high in most of the soils in the studied site.

Based on this study finding, some specific recommendations are forwarded as follows:

- Organic matter was rated from low to medium in the soil of the Ambukuna microcachment and these should be managed by application of crop residue, compost, green manure and farmyard manure in order to improve agricultural potential of soils of the Ambukuna microcachment.
- The soil test of Ambukuna microcachment of P content was rated low which should be improved by applying organic materials and P-fertilizers (rock phosphate) to maximize agricultural production.
- There was less soil water conservation practice in the Ambukuna microcachment. The soil water conservation practice should be improved by applying different farmer participatory SWC structure practice.

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