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Assessment of micronutrient status in different land use soils in Maybar lake watershed of Albuko District, South Wello Zone, North Ethiopia

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Abstract

The study was conducted at the Maybar watershed, which is located in the Albuko District of South Wello Zone in the Amhara National Regional State. The aims of the study were to identify the effects of different land uses on the magnitudes and directions of major soil fertility parameters and within and among land use types and soil depths. The results showed that soil organic carbon declined exponentially following deforestation and subsequent conversion to cultivated land. The imbalance in soil organic carbon addition from the crops and loss of soil organic carbon have led to the continuous decline of soil organic carbon in the cultivated land soils by 41.6% and 86.5% as compared to the forest and grazing lands, respectively. Soil texture (sand, silt and clay) and all of the soils chemical properties studied were significantly affected ($P \leq 0.05$ and/or $P \leq 0.01$) by land use. Furthermore, considering the soil depths, higher mean values of Fe (38.59 mg/kg) were recorded in the surface (0-20 cm) soil layer than in the subsurface (20-40 cm) depth. The results obtained from the study indicated that the direction and magnitude of changes in soil attributes under land uses reflect the long-term impact of human being on the landscape as the consequences of increasing human as well as livestock populations.. All the above values were higher than the critical values of 4.2, 0.2, 0.5 and 1.0mg/kg for Fe, Cu, Zn and Mn, respectively. Also the test analysis showed that the content of Fe, Cu, Zn, Mn and organic matter were significantly higher ($P \leq 0.05$) in grazing soils than in forest and cultivated soils, while pH was higher in forest soils. The results of correlation analysis revealed that Cu had significant ($P \leq 0.05$) positive correlation with silt content and Fe (r = 0.56* and 0.51*, respectively) but negative and non-significant with clay fraction. Iron and Cu were significant with organic matter (r =0.55* and 0.89, respectively). The manner in which soils are managed has a major impact on agricultural productivity and its sustainability. Therefore, strategies to feed the expanding population in the country have to seek a sustainable solution that better addresses soil fertility management.**

Keywords: Micronutrients, land uses, forest, grazing and cultivated lands

INTRODUCTION

Agriculture is largely influenced by controlling factors like climate, soil topography while soil erosion is a serious problem for agricultural productivity. As a result, soil fertility maintenance is a major concern in tropical Africa, particularly with the rapid population increase. Fageria *et al*, (2002) in their review of micronutrients in crop production, maintained that micronutrient deficiencies in crop plants are widespread worldwide. The term micronutrients refer to number of essential nutrients or elements that are required by plants in very small quantities. This term usually applies to elements that are contained in plant tissues in amounts less than 100 mg/kg (Foth and Ellis, 1997). According to the same authors, the four essential micronutrients that exist as cations in soils unlike to boron and molybdenum are zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn). Although they are needed in trace quantities, it does not affect their significance in plant nutrition. For instance, one atom of nickel would impair the biochemical advantages arising from the presence of 1,000,000 atom of nitrogen (Katyal, 2004).

Changes in land use and soil management can have a marked effect on the soil organic matter stock**.** Soil organic matter not only plays a major role in soil fertility by affecting physical and chemical properties, but also controls soil microbial activity by serving as a source of mineralizable carbon and nitrogen. Adsorption of micronutrients, either by soil organic matter or by clay-size inorganic soil components is an important mechanism of removing micronutrients from the soil solution (Foth and Ellis, 1997). Factors affecting the availability of micronutrients are parent material, soil reaction, soil texture, and soil organic matter (Brady and Weil, 2002). Tisdale *et al.* (1995) stated that micronutrients have positive relation with the fine mineral fractions like clay and silt while negative relations with coarser sand particles. This is because their high retention of moisture induces the diffusion of these elements (Tisdale *et al.*, 1995).

According to Yohannes (1999), the major agricultural constraints at Maybar areas are shortage of land for crop cultivation and livestock grazing, decline of soil fertility, rainfall variability and pests and diseases. Nowadays, due to increasing population pressure and shortage of land, deforestation and cultivation activities are being carried out on steep slopes, which accelerate soil erosion. Moreover, the shortage of land for production of food crops has eliminated the practice of fallowing and crop rotation on the flatter areas. On the other hand, shortage of grasslands (grazing areas) has forced the farmers to remove crop residues for animal feed. Cow dung is used mainly for firewood rather than as manure for maintenance of soil fertility and productivity. This in turn has led to reduction in soil depths, soil nutrients (soil fertility) and soil organic matter content. According to Dar (2004), there is need for monitoring the micronutrient status through analysis of soils and plant tissues in farmers' fields. Farmers are unaware of hidden hunger and there is an urgent need to ensure that each farmer knows the health of the soil in order to ensure the development of agriculture. The objective of this study, therefore, was to assess the micronutrient status of soils of three land use types – cultivated, grazing and forest in the sub humid tropical highland of Maybar areas in Albuko District. This is with a view to optimizing the productivity of these soils for agricultural production.

MATERIALS AND METHODS

Site Description

The study was conducted at the Maybar watershed, which is located in Albuko District of South Wello Zone in the Amhara National Regional State (ANRS). The ANRS is located in the northwestern part of Ethiopia between 9^0 00^l-13^0 45^l N latitude and 36^0 00^l-40^0 30^l E longitude covering a total land area of 170,152 km^2. Maybar is situated at about 25 km distance from Dessie city in the south-southeast direction and at about 425 km north of Addis Abeba. Geographically, the study site lies at 10^0 59^l N latitude and 39^0 39^l E longitude and at an altitude ranging from 1940 to 2850 meters above sea level. The cultivated land accounts for an average of about 40% and the grazing and forest lands and area closure sites together account for about 50% of the Maybar watershed area. The remaining 10% of the total area coverage of the watershed constitute settlement areas and others.

It is also representative of the moist agro-climatic zone, characteristically erosion prone, low potential, and oxen-plowed cereal belt of the northeastern escarpment regions of the Ethiopian highlands. Maybar areas are characterized by bimodal rainfall pattern with erratic distribution. The total annual rainfall is 1279 mm. The annual mean minimum and mean maximum temperatures at the study area are 11.43 and 21.6 ^oC, respectively. According to Mulugeta (1988), the study area has quite marked topographic variation, of which steep and very steep slopes cover about three-forth of the total area. The rest is made up of moderately steep slopes of colluvial deposits. The watershed is dominated by hilly landforms with 25.82% of the total area being very steep (> 60% slope), 38.42% steep (30-60% slopes), 32.63% located in the upper most and foothill slope parts are moderately steep to sloping (5-30%) and the rest 3.13% is gently slopping to flat (0-5%).

Soil Sampling Techniques

A necessary assumption made in this research approach was that soil conditions or parameters for all the sites should be similar before changes in the land use have been introduced. Because any differences before land use changes should have been small and associated with lateral movement of soil materials on the watershed slopes, the observed differences in present soil conditions or other parameters can be assumed as being caused by the present land use practices or introduction of the new land management.

Table 1: Interaction effects of land use and soil depth on particle size (sand, silt and clay) distribution of the soils in the Maybar watershed

Land use type	Sand (%)*		Silt (%)*		Clay (%)*	
	Soil depth (cm)		Soil depth (cm)		Soil depth (cm)	
	0-20	20-40	0-20	20-40	0-20	20-40
Forest	60[d]	60[d]	18[de]	16[e]	22[b]	24[a]
Grazing	68[a]	64[c]	26[a]	24[ab]	6[e]	12[d]
Cultivated	66[b]	64[c]	20[cd]	22[bc]	14[c]	14[c]
LSD (0.05)	1.151		2.228		1.522	
SEM (±)	0.365		0.707		0.483	

* Interaction means within a specific soil parameter followed by the same letter(s) are not significantly different from each other at $P \leq 0.05$; LSD = least significant difference; SEM = standard error of mean

Three main factors such as depth, sampling intensity per unit area of site sampled, and the sampling design are usually considered when developing soil-sampling protocols to monitor change in major soil fertility parameters. At the beginning, a general visual field survey of the area was carried out to have a general view of the variations in the study area. Global Positioning System (GPS) readings were used to identify the geographical locations and the coordinate system where samples were taken, and clinometers were used to identify slopes of the sampling sites. Representative soil sampling fields were then selected based on vegetation and cultivation history and they are categorized forest, grazing and cultivated lands. Depending on their similarities three forest land representative fields, three grazing land representative fields and three cultivated land representative fields were selected, and from each representative field of land use types, fifteen soil samples were collected from the depths of 0-20 and 20-40 cm each in a radial sampling scheme using an auger (Wilding, 1985). We collected a total of two hundred seventy samples (ninety samples per land use type) of soil which is one hundred thirty five samples from 0-20 cm and one hundred thirty five samples from 20-40 cm of soil horizon. A total of eighteen composite samples were collected and each composite sample is made from a pool of fifteen samples. We placed the sample in a numbered calico bag with tightly fitting lid and labeled carefully with the location, representative field and depth of soil. The soil samples collected from representative fields' were then air-dried, mixed well and passed through a 2 mm sieve for the analysis of selected soil physical and chemical properties. Separate soil core samples from the 0-20 and 20-40 cm depths were taken with a sharp-edged steel cylinder forced manually into the soil for bulk density determination. Before sampling, forest litter, grass, dead plants and any other materials on the soil surface were removed, and during collection of samples; furrow, old manures, wet spots, areas near trees and compost pits were excluded.

Soil Laboratory Analysis

Standard laboratory procedures were followed in the analysis of the selected physicochemical properties considered in the study. Soil particle size distribution was determined by the Boycouos hydrometric method (Bouyoucos, 1962; Van Reeuwijk, 1992) after destroying organic matter using hydrogen peroxide (H_2O_2) and dispersing the soils with sodium hexameta phosphate ($NaPO_3$). The pH of the soils was measured in water and potassium chloride (1M KCl) suspension in a 1:2.5 (soil: liquid ratio) potentiometrically using a glass-calomel combination electrode (Van Reeuwijk, 1992). The Walkley and Black (1934) wet digestion method was used to determine soil carbon content and percent soil OM was obtained by multiplying percent soil organic carbon by a factor of 1.724 following the assumptions that organic matter is composed of 58% carbon. Available micronutrients (Fe, Cu, Zn and Mn) were extracted by DTPA as described by Sahlemedhin and Taye (2000) and all these micronutrients were measured by atomic absorption spectrophotometer.

Data Analysis

The soil physical and chemical properties were subjected to analysis of variance using the general linear model procedure of the statistical analysis system (SAS Institute, 1999). The least significance difference (LSD) test was used to separate significantly differing treatment means after main effects were found significant at $P \leq 0.05$. Moreover, simple correlation analysis was executed with the help of Gomez and Gomez (1984) to reveal the magnitudes and directions of relationships between selected soil fertility parameters and within and among land use types and soil depths.

RESULTS AND DISCUSSION

Soil Texture: The sand and clay fractions were significantly ($P \leq 0.01$) affected by land use, soil depth and the interaction of land use and soil depth. Similarly, the silt fraction was highly significantly affected by land use and significantly ($P \leq 0.05$) by the interaction of the two factors (Tables 1 and 9). The highest average (surface and subsurface) sand content (66%) was observed under the grazing land and the lowest (60%)

Table 2: Main effects of land use and soil depth on selected physical properties of the soils in the Maybar watershed

Treatment	Sand (%)	Silt (%)	Clay (%)	STC
Forest	60.00[c]	17.00[c]	23.00[a]	SL
Grazing	66.00[a]	25.00[a]	9.00[c]	SL
Cultivated	65.00[b]	21.00[b]	14.00[b]	SL
LSD (0.05)	0.814	1.575	1.076	
SEM (±)	0.365	0.706	0.483	
0-20 cm	64.66[a]	21.33	14.00[b]	SL
20-40 cm	62.66[b]	20.66	16.67[a]	SL
LSD (0.05)	0.664	NS	0.878	
SEM (±)	0.296	0.577	0.394	

Main effect means within a column followed by the same letter are not significantly different from each other at P ≤ 0.05; NS = not significant; STC = soil texture class; SL = sandy loam

Table 3: Main effects of land use and soil depth on some chemical properties of the soils in the Maybar watershed

Treatment	pH (H_2O)	pH (KCl)	OM (%)
Land use			
Forest	6.82[a]	6.05[a]	1.42[b]
Grazing	6.52[b]	5.62[b]	1.85[a]
Cultivated	5.83[c]	4.80[c]	0.99[c]
LSD (0.05)	0.222	0.332	0.028
SEM (±)	0.100	0.149	0.013
Soil depth			
0-20 cm	6.50[a]	5.57	1.55[a]
20-40 cm	6.28[b]	5.40	1.28[b]
LSD (0.05)	0.182	NS	0.023
SEM (±)	0.081	0.122	0.010

Main effect means within a column followed by the same letter are not significantly different from each other at P ≤ 0.05; NS = not significant; OM = Organic Matter

was recorded in the forest land, Whereas the average clay fraction of the forest, grazing and crop lands were 23, 9 and 14%, respectively (Table 2). In all the land use types, the contents of sand and silt fractions decreased with soil depth except for sand in the forest land and silt in the cultivated land soils (Tables 1 and 8). There were no textural class differences among the three land use types. The textural class of the surface (0-20 cm) and the subsurface (20-40 cm) soils was also sandy loam (Table 2). Considering the two soil depths, higher mean sand fraction (64.66%) was observed within the surface soils (Table 2). Opposite to sand, higher clay fraction (16.67%) was found in the subsurface soil. Unlike the other land use types, the clay fraction in both layers of the cultivated land was the same (14%) (Tables 1 and 8). This may be due to the intensive and continuous cultivation which might cause compaction on the surface that reduces translocation of clay particles within the different layers and due to mixing up by tillage activities in agreement with the findings reported by Wakene (2001) and Jaiyeoba (2001). Generally, there were significant differences in the soil particle size distribution among the land use types and between the soil depths except for silt which was not affected by soil depth (Tables 1, 2 and 9).
Considering the interaction effects of land use by soil depth, the highest values of both sand (68%) and silt (26%) contents were recorded at the surface (0-20 cm) layer of the grazing land while clay content was highest (24%) at the subsoil (20-40 cm) layer of the forest land (Table 1). On the other hand, the lowest interaction mean values of sand, silt and clay were observed in both the surface and subsoil layers of the forest land, the subsurface layer of the forest land and the surface layer of the grazing land, respectively. With the exception of the two soil depths in the cultivated land, which had the same clay content, the mean clay contents of the remaining treatment combinations were significantly different (P ≤ 0.05) from each other due to the interaction effects (Table 1). Sand and silt were negatively and non significantly (r = -0.39 and -0.29, respectively) correlated with pH of the soils (Table 7)

Despite the fact that texture is an inherent soil property, management practices may contributed indirectly to the changes in particle size distribution particularly in the surface layers as result of removal of soil by sheet and rill erosions, and mixing up of the surface and the subsurface layers during continuous tillage activities. Therefore, differences in particle size distribution, which can be attributed to the impact of deforestation and farming practices such as continuous tillage or cultivation and intensive grazing, can be observed. In this study, there were relatively less differences in particle size distribution among the subsurface layers of the soils under different land use types because these depths are relatively little affected by changes in land management. The results were in agreement with those reported by

Table 4: Interaction effects of land use and soil depth (cm) on organic matter

Land use type	OM (%)*	
	Soil depth	
	0-20	0-20
Forest	1.58^{b}	1.23^{c}
Grazing	2.16^{a}	1.54^{b}
Cultivated	0.92^{e}	1.06^{d}
LSD (0.05)	0.041	
SEM (±)	0.013	

*Interaction means within a specific soil parameter followed by the same letter (s) are not significantly different from each other at P ≤ 0.05; OM = Organic Matter

Table 5: Main effects of land use and soil depth on available micronutrients

Treatment	Available micronutrients (mg/kg)			
	Fe	Mn	Zn	Cu
Land use				
Forest	20.55^{b}	29.46^{c}	0.21^{b}	0.87^{b}
Grazing	29.35^{a}	32.18^{a}	0.89^{a}	1.86^{a}
Cultivated	19.11^{c}	31.39^{b}	0.15^{b}	0.23^{c}
LSD (0.05)	0.279	0.063	0.062	0.010
SEM (±)	0.125	0.028	0.028	0.004
Soil depth				
0-20 cm	38.59^{a}	50.06^{a}	0.70^{a}	1.22^{a}
20-40 cm	7.42^{b}	11.96^{b}	0.13^{b}	0.75^{b}
LSD (0.05)	0.230	0.050	0.050	0.010
SEM (±)	0.102	0.030	0.023	0.004

Main effect means within a column followed by the same letter are not significantly different from each other at P ≤ 0.05

Table 6: Interaction effects of land use and soil depth on available micronutrients of the soils in the Maybar watershed

Land use type	Fe (mg/kg)*		Mn (mg/kg)*		Zn (mg/kg)*		Cu (mg/kg)*	
	Soil depth (cm)		Soil depth (cm)		Soil depth (cm)		Soil depth (cm)	
	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40
Forest	33.46^{c}	7.63^{e}	48.70^{b}	10.22^{e}	0.28^{b}	0.13^{c}	1.38^{c}	0.36^{d}
Grazing	47.66^{a}	11.04^{d}	48.08^{c}	16.28^{d}	1.57^{a}	0.21^{bc}	1.93^{a}	1.78^{b}
Cultivated	34.64^{b}	3.58^{f}	53.40^{a}	9.37^{f}	0.26^{b}	0.04^{d}	0.34^{e}	0.12^{f}
LSD (0.05)	0.394		0.081		0.081		0.014	
SEM (±)	0.125		0.028		0.028		0.004	

* Interaction means within a specific soil parameter followed by the same letter (s) are not significantly different from each other at P ≤ 0.05

Sanchez *et al*. (1985) and these also support the assumption that the soil conditions prior to the shifts in land management were more or less similar.

Soil Chemical Properties:

The soils pH-H_2O value was significantly affected by land use (P ≤ 0.01) and soil depth (P ≤ 0.05), whereas pH-KCl was significantly (P ≤ 0.01) affected only by land use (Tables 3 and 10). On the other hand, both pH-H_2O and pH-KCl values were not affected by the interaction of land use by soil depth (Table 10). Land use changes for example from forest to crop land, resulted in reduction of soil pH of the study area. For instance, the highest (6.82) and the lowest (5.83) soil pH-H_2O values were recorded under the forest and the cultivated lands, respectively (Table 3). The lowest value of pH under the cultivated land may be due to two major reasons. The first is the depletion of basic cations in crop harvest and drainage to streams in runoff generated from accelerated erosions. Secondly, it may be due to its highest microbial oxidation that produces organic acids, which provide H ions to the soil solution and thereby lowers soil pH. Generally, the pH values observed in the study area are within the ranges of moderately acidic to neutral soil reactions as indicated by Foth and Ellis (1997). Considering the two soil depths, the higher mean values of pH-H_2O (6.50) and pH-KCl (5.58) were observed within the surface soils. In general, pH values decreased with increasing soil depth (Tables 3 and 8).

Organic matter content was significantly (P ≤ 0.01) affected by land use, soil depth and the interaction of land use by soil depth (Tables 3, 4 and 10). Soil organic matter content was highest (1.85%) under the grazing land and lowest (0.99%) on the cultivated land (Table 3). The decline in soil organic matter contents in the cultivated land following deforestation and conversion to farm fields might have been aggravated by the insufficient inputs of organic substrate from the farming system due to residue removal and zero crop rotation**.** This general truth was assured by different individuals (Duff *et al*., 1995; Grace *et al*., 1995). Besides this, leaching problem that can be attributed to the relatively high sand content (Tables 1 and 2)

Table 7: Pearson's Correlation between selected soil properties

	Sand	Silt	Clay	pH (H_2O)	OM	Fe	Cu
Sand	1						
Silt	0..61**	1					
Clay	-0.89**	-0.90**	1				
pH (H_2O)	-0.39	-0.29	0.38	1			
OM	0.34	0.51*	-0.47*	0.48*	1		
Fe	0.43	0.29	-0.40	-0.15	0.55*	1	
Cu	0.24	0.56*	-0.45	0.42	0.89**	0.51*	1

**Significant at P = 0.01 level; * significant at P = 0.05 level; OM = Organic Matter

Table 8: Mean values of soil physicochemical properties as affected by land use and soil depth

Soil properties	Surface (0-20 cm)				Subsurface (20-40 cm)			
	FRL	GRL	CUL	Mean	FRL	GRL	CUL	Mean
Soil physical properties								
Sand (%)	60.00	68.00	66.00	64.66	60.00	64.00	64.00	62.66
Silt (%)	18.00	26.00	20.00	21.33	16.00	24.00	22.00	20.66
Clay (%)	22.00	6.00	14.00	14.00	24.00	12.00	14.00	16.67
Soil chemical properties								
pH (H_2O)	6.90	6.63	5.96	6.50	6.73	6.40	5.70	6.28
pH (KCl)	6.06	5.70	4.96	5.58	6.03	5.53	4.63	5.40
OM (%)	1.58	2.16	0.92	1.55	1.23	1.54	1.06	1.28
Fe (mg/kg)	33.46	47.66	34.64	38.59	7.63	11.04	3.58	7.42
Mn (mg/kg)	48.70	48.08	53.40	50.06	10.22	16.28	9.37	11.96
Zn (mg/kg)	0.28	1.57	0.26	0.70	0.13	0.21	0.04	0.13
Cu (mg/kg)	1.38	1.93	0.34	1.23	0.36	1.78	0.12	0.75

FRL = forest land; GRL = grazing land; CUL = cultivated land; OM = organic matter

Table 9: Mean square (MS) and results of two-way analysis of variance of soil physical properties under three land uses and two soil depths in the Maybar watershed

Physical properties	Land use			Soil depth			Interaction		
	MS	F	P	MS	F	P	MS	F	P
Sand (%)	62.000	155.00	0.000**	18.000	45.00	0.000**	6.000	15.00	0.001**
Silt (%)	96.000	64.00	0.000**	2.000	1.33	0.275ns	8.000	5.33	0.027*
Clay (%)	302.000	431.43	0.000**	32.000	45.71	0.000**	14.000	20.00	0.000**

* Significant at P ≤ 0.05; ** Significant at P ≤ 0.01; ns = not significant; P = probability. CV (%) = coefficient of variation (%) ranges ≥0.99 for clay

Table 10: Mean square (MS) and results of two-way analysis of variance of soil chemical properties under three land uses and two soil depths in the Maybar watershed

Chemical properties	Land use			Soil depth			Interaction		
	MS	F	P	MS	F	P	MS	F	P
pH (H_2O)	1.524	50.90	0.000**	0.222	7.43	0.021*	0.004	0.13	0.880ns
pH (KCl)	2.417	36.32	0.000**	0.142	2.14	0.175ns	0.034	0.51	0.616ns
OM (%)	1.106	2374.81	0.000**	0.342	733.94	0.000**	0.225	482.73	0.000**
Fe (mg/kg)	184.530	3931.53	0.000**	4371.740	93141.40	0.000**	43.673	930.47	0.000**
Mn (mg/kg)	11.736	4938.03	0.000**	6534.530	2749452.00	0.000**	56.249	23667.40	0.000**
Zn (mg/kg)	1.098	447.96	0.000**	1.496	653.30	0.000**	0.692	304.02	0.000**
Cu (mg/kg)	4.037	71236.20	0.000**	0.971	17129.80	0.000**	0.353	6233.63	0.000**

*, ** = significant at p ≤ 0.05 and at p ≤ 0.01, respectively; P = probability; OM = organic matter; CV (%) = coefficient of variation (%) ranges from 0.16 for Mn to 7.02 for exchangeable available Zn

and the resultant light texture of soils also might be the cause of organic matter reduction. This is apparent because the clay particles unlike the sand particles, have substantial exchange surface areas, and therefore adsorb and stabilize organic matter and soil nutrients (Saggar *et al*., 1994; Saggar *et al*., 1996). Considering the two soil depths, higher average organic matter (1.55%) was observed in the surface (0-20 cm) than subsoil (20-40 cm) layers (Table 3). With regard to the interaction effect of land use by soil depth, the highest (2.16%) and the lowest (0.92%) values of organic matter contents were recorded at the surface (0-20 cm) layer of the grazing and the cultivated lands, respectively (Tables 4 and 8). With the exception of the surface layer in the forest land and the subsoil layer in the grazing land which had almost the same organic matter content, the mean organic matter contents of the remaining treatments combination were significantly different (P ≤ 0.05) from each other due to the interaction effects (Table 4).

Soil organic matter contents in the 0-20 cm and 20-40 cm soil depths were highest on the grazing lands and lowest under the cultivated lands (Table 4). Similarly, except on the cultivated land, soil organic matter content decreased with increasing soil depth. Unlike to other land use types, organic matter content under the cultivated land was higher in the subsoil layers than in the surface layers. This might be due to soil organic matter incorporation from surface layer to subsoil layer as a result of the mixing effect of tillage activities and down ward movement due to its higher sand content. Furthermore, the substantial amount of organic materials added from root biomass after the crop is harvested as stated by Van Noordwijk *et al*. (1997) coupled with rapid decrease of soil microorganism activity with increasing soil depth may explain the higher soil organic matter stocks in the subsoil of the crop fields.

According to the classification of soil organic matter as per the ranges suggested by Landon (1991), the soils of Maybar are very low to low (0.99-1.85%) in organic matter content. The capacity of the soil to accumulate, stabilize or protect and gradually mineralizing the organic matter and release plant nutrients that are accumulated in the soils during the period the land was under the forest as well as from the slash is influenced by the sandy loam texture property of the soils.

The low carbon input from the agricultural crop of the subsistence agricultural system could not compensate for the large mineralization of organic matter on the farm fields and N-losses. This phenomenon in the Maybar watershed had eventually resulted in a progressive decline in the soil total N along with deforestation and continuous cultivation rendering the lands infertile and the agricultural production unsustainable. In the study area, the fraction of the soil organic matter attributed to crop origin is mainly that contributed by crop roots. This may imply that crop residue management in the farming system can potentially increase the soil organic matter contribution from the cropping system**,** which may help to reduce the progressive decline of total N in the soils. In general, as organic Matter is the main supplier of soil N, S and P in low input farming systems, a continuous decline in the soil organic matter content of the soils is likely to affect the soil productivity and sustainability**.**

The contents of available micronutrients (Fe, Mn, Zn and Cu) were significantly ($P \leq 0.01$) affected by land use, soil depth and the interaction of land use by soil depth (Tables 5, 6 and 10). Considering the main effects of land use, the highest contents of Fe (29.35 mg/kg), Mn (32.18 mg/kg), Zn (0.89 mg/kg) and Cu (1.86 mg/kg) were recorded under the grazing land (Table 5), while the lowest (19.11, 0.15 and 0.23 mg/kg) contents of Fe, Zn and Cu were observed under the cultivated land, respectively, and Mn content was lowest (29.46 mg/kg) on the forest land. The results of the study also indicated that the contents of all these micronutrients were higher at the surface (0-20 cm) layer than in the subsoil (Tables 5 and 6).

With regards to the interaction effects of land use by soil depth, the highest contents of available Fe (47.66 mg/kg), Zn (1.57 mg/kg) and Cu (1.93 mg/kg) were observed at the surface (0-20 cm) layer of the grazing land while the highest (53.40 mg/kg) of available Mn was at the surface layer of the cultivated land (Table 9). On the other hand, the lowest interaction mean values of available Fe (3.58 mg/kg), Mn (9.37 mg/kg), Zn (0.04 mg/kg) and Cu (0.12 mg/kg) contents were recorded at the subsoil layer of the cultivated land. The mean values of available Fe, Mn and Cu contents in all treatment combinations were significantly different ($P \leq 0.05$) from each other due to the interaction effects.

Sims and Johnson (1991) indicated that the critical or threshold levels of available Fe and Mn for crop production are 2.5-4.5 mg/kg and 1-50 mg/kg, respectively. Therefore, the results observed in this study revealed that the average mean values of available Fe and Mn were in adequate range for the production of most crop plants. Generally, available Fe under land uses and soil depths was positively and significantly correlated with organic matter ($r = 0.55^{*}$) (Table 7) similar to the report by Wakene (2001) and Dereje (2004). The lowest available micronutrients under the cultivated land compared to the other land use types might be due to crop harvest, organic matter degradation, and sheet and rill erosions that were aggravated by continuous cultivation with very low input of farming system.

SUMMARY AND CONCLUSIONS

The results of this study are evidences of significant changes in the quality attributes of the soils in the study area following the removal or destruction of vegetative cover and frequent tillage that lead to soil erosion and thereby declining soil fertility. The direct causes of land degradation, including decline in the use of fallow, limited recycling of dung and crop residues to the soil, limited application of external sources of plant nutrients, deforestation, and overgrazing, are apparent and generally agreed. The attributes of the soils under the cultivated lands showed overall change towards the direction of loss of their fertility compared to the soils attributes of the adjacent forest and grazing land soils. Major declines were observed for soil organic matter, which is the principal source of plant nutrients (such as N, S and P) and helps to sustain soil fertility by mineralization and nutrient retention in low input tropical farming systems. The decreased values of the soil organic matter on the cultivated fields would indicate higher N and organic carbon losses from the agroecosystem compared to the forest system. The higher OM values in the grazing and forest lands indicate low activities of N-losing processes, which is due to the relatively closed nutrient cycling and minimal disturbance in the natural forest system. The process of declining soil organic matter following land use changes has apparently caused significant impacts not only on the continuous decline in plant nutrient pools such as the pool of total N, but also on the soil physical properties such as pore space and water-holding capacity of the soils. For instance, the average values of selected soil physical properties under the forest, grazing and cultivated lands showed changes in clay (23, 9 and 14%), respectively. Similarly, there was also changes in soil OM (1.42, 1.85 and 0.99%), in the forest, grazing and cultivated lands, respectively. On the other hand, the available P under the cultivated land was highest (4.51 mg/kg) compared to the other adjacent land use systems, and this might be due to application of DAP fertilizer in crop field. The contents of available micronutrients (Fe, Mn, Zn and Cu) under the different land management practices were significantly different ($P \leq 0.01$) and except for Mn, they showed reduction from the forest land (20.55, 29.46, 0.21 and 0.87 mg/kg) to the cultivated land (19.11, 31.39, 0.15 and 0.23 mg/kg), respectively. These variations of soil physicochemical properties between land use types indicate the risk to the sustainable crop production in the area. Therefore, strategies to feed the expanding population in the study areas will have to seek a sustainable solution that better addresses integrated soil management.

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