EFFECT OF LAND USE CHANGES AND SOIL DEPTH ON SOIL ORGANIC MATTER, TOTAL NITROGEN AND AVAILABLE PHOSPHORUS CONTENTS OF SOILS IN SENBAT WATERSHED, WESTERN ETHIOPIA

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ABSTRACT

Land use changes, mainly shift from natural ecosystems into managed agro ecosystems, and subsequent deterioration in quality of soil resources have become common phenomena in western Ethiopia. Soil reaction (pH), organic matter, total N and available P contents are some of the vital soil properties affected by such changes. This study was therefore conducted with the objective to assess the response of these vital soil chemical properties to changes in management practices arising from varying land uses (forest, shrub, grass and cultivated) and soil depth (0-20 and 20-40 cm). Results revealed that these four vital soil properties significantly ($P \le 0.01$) responded to changes in land use. Contents of soil organic matter and total N were highly significantly affected by soil depth but pH and available P. The interaction of land use and soil depth affected pH and total N highly significantly, organic matter significantly ($P < 0.05$) and available P non-significantly. Both soil organic matter and total N contents under the grazing and cultivated fields were significantly lower ($P \le 0.05$) than in soils under natural forest. However, the C: N ratios between land uses, and interaction between soil depth and land use did not reveal statistically significant ($P > 0.05$) differences but varied with soil depth significantly ($P \le 0.05$). Available P contents were also significantly ($P \le 0.01$) reduced due to shift of land uses from natural forest to agricultural land uses but with soil depth and interaction effect. It can be noted that this situation is far from sustainability and has tremendous implications for productivity of the traditional low-input agriculture in the study area.

Keywords: available phosphorus, crop-livestock systems, land use change, organic matter.

INTRODUCTION

In the sub-humid tropical agro ecologies of western Ethiopia, the extents of deforestation in the natural forests and subsequent conversion into low-input agricultural systems have been tremendous. These changes are driven by complex interaction of multitude of factors, and have resulted in changes of land use and management practices that affect the way ecosystem and its components function. Among others, soils form principal components of such dynamic and traditional mixed crop-livestock systems, and are subject to alterations as different management practices affect their attributes. Soil reaction (pH), organic matter, nitrogen and available phosphorus contents, *inter alia* form vital soil properties are considerably affected due to such changes. These changes often involve changes in vegetation cover, total biomass production, microbial decomposition of organic residues and nutrient cycling (Turrion *et al*., 2000; Solomon *et al*., 2002). The level of response to such changes, however, depends on the intensity of human action and management practices across soil depth.

Soil pH is one of the attributes sensitive to changes in the natural environment and soil management processes because of human activity. In tropical and sub-tropical environments two major reasons cause changes in pH and acidification process. These are deforestation followed by cultivation of the same land resulting in export of basic cations in agricultural products, and leaching due to adequate rainfall (Smith *et al*., 1995). In such sub-tropical environments, excessive disturbance of the soil at seedbed preparation causes high rate of organic matter turn over and its rapid decomposition. Through the process of decomposition, the reaction of CO_2 with H_2O forms both organic (H_2CO_3) and inorganic acids (H_2SO_4, HNO_3) which are potential suppliers of hydrogen ions in the soil encouraging the development of acidic cations. There is a generally decreasing trend in soil pH with increasing number of years in cultivation as soils tend to be slightly leached and become acidic in reaction (Jaiyeoba, 2003).

Soil organic matter (OM) is a dynamic and large reservoir of carbon which is subject to change due to changes in management practices as a result of varying land uses (Post and Kwon, 2000). It constitutes one of the most complex components of such terrestrial ecosystems. Organic matter plays vital role in regulating the flow and supply of plant nutrients and water flow, and determining physical attributes of soils (Cotrufo *et al*., 2011). Climatic conditions, particularly temperature and rainfall, in turn bring about significant influence on amounts of nitrogen and organic matter found in soils. In tropical environments where forest ecosystems are usually converted to agricultural systems, OM and total nitrogen content of soils tend to turn down quickly. Meanwhile, many factors that change soil organic matter levels and forms are controlled by management, and the processes governing its dynamics are complex. This makes OM the most sensitive soil characteristic to land use changes (Sanchez *et al*., 2002). However, the level of response to changing management practices differs across eco-regions and strongly interact with local climate, land use, farming systems and soil/crop management systems (Post and Kwon, 2000; Powers *et al*., 2004).

The changes in land use definitely impact soil OM pools and fluxes. Nonetheless, the impact due to land use changes on soil OM content depends on a number of factors such as the old and new land use types, the soil type, management and climate (Lettens *et al*., 2004). These changes typically result in differing rates of soil erosion, aggregate formation, biological activity, and drainage. These all have profound effects on OM accumulation and CO_2 evolution. However, forest and pasture lands make up the potential to build up large amounts of soil OM, whereas conversion of natural ecosystem to croplands which results in high rate of its turnover leads to declined level of OM (Batjes, 2004).

In addition, soils under different land use types and related management practices have also been shown to differ markedly in pool sizes and distribution of P within soil profiles. The forms and dynamics of soil P, however, can be greatly affected by management practices, which often involve dramatic changes in vegetation cover, biomass production, soil organic matter level and nutrient cycling in the ecosystem (Ross *et al*., 1999; Genxu *et al*., 2004). In most natural ecosystems, the P cycle is essentially closed with minimal short-term losses or gains of soil P (Reijneveld *et al*., 2010). The forms and extent thus reflect the history, present structure and functioning of the natural and managed agro ecosystems. However, in such tropical ecosystems where conversion of forest ecosystems into low-external-input managed agro-ecosystems is the most likely case, contrasting results were obtained.

For example, shift of land use changes from natural forest to cultivation led to a significant decline in available P content of soils in the sub-humid highlands of the south-western Ethiopia (Solomon *et al*., 2002) and in tropical farmlands of Hainan, China (Zhang and Zhang, 2005). The authors attributed this scenario to the remarkable depletion of phosphorus associated with OM, as deforestation led to its decline and loss of associated nutrients. However, monitoring and managing such changes from soil quality perspectives need improved understanding of ecosystem processes. Therefore, this study is initiated aimed at assessing the effects of land use changes on soil reaction, organic matter, total nitrogen and available phosphorus contents of these tropical soils.

METHODS

Study area

The study was conducted in Senbat watershed located in the mid-western part of the country at about 260km road distance west of the capital, Addis Ababa (Figure-1). The watershed covers about 1952 hectares (ha) and is part of the Gibe river valley which ultimately drains into the Omo river system. Geographically, it lies between 9^o 10' and 9^o 20' N latitude, and 37^o 00' and 37^o 05' E longitude. The area receives a mean annual rainfall of 1250mm characterized by a uni-modal pattern, with peak in July.

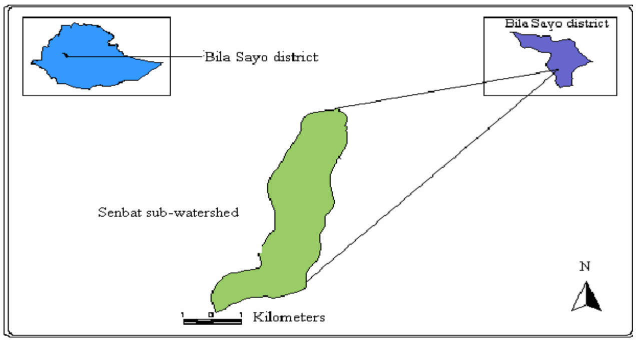

Figure-1. Location map of the study area, Senbat watershed, Ethiopia.

It is part and parcel of the western Ethiopian mixed crop-livestock systems where Nitosols (FAO/UNESCO) and Alfisols (USDA) form the dominant soil group (Berhanu, 1997). These highly weathered tropical soils are characterized by deep layers and high contents of weathered mineral predominantly kaolinite. The area has diverse vegetation species ranging from little dense and old natural forest domains in pocket areas at tips of both up and down stream sides, to widespread patch of sparse shrub-grass mixtures. Subsistent and mixed crop-livestock agriculture characterizes the farming system. The community depends on agriculture for their livelihood. Agriculture forms the dominant consumer of land in which crop production receive the lions share while livestock farming is an integral component. In terms of its potential, it belongs to the few agro ecological regions of the country corresponding to high agricultural potential based on its climate, soil and production systems (MoA, 1998).

Current land use types

The area in the watershed is known to have gone through a series of changes in land use/land cover and the resultant markedly differing management practices (Nega and Heluf, 2009). A land use and management survey carried in the years 2005 and 2006 in relation to this study revealed that the watershed is characterized by four major land use categories, namely forest land, shrub land, grass land and cultivated land. Table-1 presents a brief description of the four land use categories identified in the watershed. Identification and classification of the present land use types through surveys were supported by interpretation of aerial photographs and satellite images of the study area. Aerial photographs were interpreted after intensive use of stereo magnifying lenses for visual verification because photos were black and white. Satellite images were interpreted using a supervised classification which involves detailed field cross checking.

Table-1. Description of the land use classes identified in the watershed (2005).

Land use type	Description
Forest land	Areas covered with long and dense trees forming closed canopy or nearly closed canopy (70-100%), and without apparent and reported human impacts. This unit also includes undercanopy trees mixed with short bushes and open areas. Dominant tree species in this group include *Celtisa africana*, *Calpurina subdecandra* and *Croton mycrostachyus*. This land use type covers 448 ha (23.0%) of the total area of the landscape.
Shrub/bush land	Areas covered with small trees, short shrubs and thorny bushes with little useful wood, usually stony with a highly rugged micro-relief. Scattered large trees can sometimes be found, and browsing by livestock is common. The shrub land covers 364 ha (18.6%) of the total area.
Grazing land	Areas with degraded temporary or permanent grass cover, with continuous grazing systems and overgrazing a prevailing situation. Short grass species dominate these grazing land units. This land use covers 559 ha (28.6%) of the total area of the watershed.
Cultivated land	This unit covers 581 ha (29.8%) of the total area of the watershed and includes areas used for rain-fed and irrigated agriculture, including fallow plots. i.e. cultivated land mixed with sparse bushes and trees, and rural homesteads. Major crops grown include cereals (maize, *teff*, sorghum), legumes (beans, pea) and oil crops (*noug*).

The research protocol: Soil sampling and laboratory analysis

The spatial analogue method was used as a guiding technique which is widely used in studying the dynamics in ecosystem and its components. The method involves spatial sampling on sites that are subject to different land uses but operating within a similar local environment and soil types (Mulugeta *et al*., 2005). The method was widely adopted in tropical ecosystem studies where temporal monitoring in ecosystem dynamics and long-term data is lacking, which is the case in Ethiopia.

Soil samples were collected from the four land use systems (natural forest, shrub, grazing and crop lands) and two soil layers (0-20 and 20-40 cm) in three replicates using an auger. These sampling plots were checked for their presence under the natural forest cover during the reference year 1957 so as to maintain having the same land use originally. Composite soil samples were prepared after thoroughly mixing the sub-samples collected from plots. At sampling, similarity in slope and topographical conditions among sampling plots were maintained as much as possible in order to reduce extraneous errors. The soil samples were air dried and ground to pass through a 2 mm sieve in preparation for lab analysis.

Following sample preparation, soil pH, organic matter, total nitrogen and available phosphorus contents were determined in the laboratory using standard analytical methods. Soil pH was measured potentiometrically in a 1:2.5 soil to water ratio suspension using a digital pH-meter. Organic carbon was determined by the Walkley-Black oxidation method and organic matter content was then calculated by multiplying the percent organic carbon by a factor of 1.724. This follows the standard practice that organic matter is composed of 58% carbon. Total nitrogen was determined by the micro-Kjeldahl digestion, distillation and titration method. Similarly, available phosphorus was determined using the standard Olsen extraction method (Olsen *et al*., 1954).

Statistical analysis

In order to allow statistical analysis, treatments were arranged in a factorial randomized complete block design format with land use and soil depth layer as two factors. The soil property data generated through laboratory analysis were then subjected to a two-way analysis of variance (ANOVA) to detect whether differences in soil attributes between the land uses and sampling depths are significant or not. The least significant difference (LSD) test was employed for mean separation for the soil properties that were found to be significantly different in statistical terms. The general linear model (GLM) procedure of the Statistical Analysis System (SAS Institute, 1996) was used as a tool for statistical analysis to breakdown the variance and test significance of differences between treatment means.

RESULTS AND DISCUSSIONS

Soil reaction (pH)

Soil pH was found to be significantly affected by land use ($P \leq 0.01$) and soil depth ($P \leq 0.01$) but the interaction of the two factors. It was found to be largest (6.6) in soils under forest land use whereas generally become small in agricultural fields: 3.7 for cultivated and 3.6 for grazing land soils. This variation can be attributed to two major reasons. The first is the loss of base forming cations down the soil profiles, even beyond sampling depths, through leaching and drainage into streams in runoff generated from accelerated erosion. This in turn enhances the activity of Al^{3+} and H^+ in the soil solutions, which reduces soil pH and thereby increases soil acidity.

The depletion of basic cations in crop harvest, as indicated in their significant reduction is the other cause for the fall in soil pH. The second reason is continuous use of ammonium based fertilizers such as diammonium phosphate, $(NH_4)_2HPO_4$, in such cereal based cultivated fields. Upon its oxidation by soil microbes it produces strong inorganic acids. These strong acids in turn releases H^+ ions to the soil solution that in turn lower soil pH.

Table-2. Mean squares for two-way analysis of variance for soil chemical properties due to land use, soil depth and interaction effect.

Source of variation	**Degree of freedom**	**pH** (H_2O)	**OM** (%)	**Total N** (%)	**C:N ratio**	**Available P** (mg kg^{-1} soil)
Land use	3	4.690^{**}	5.060^{**}	0.032^{**}	2.002	2411.210^{**}
Soil depth	1	0.183	20.745^{**}	0.149^{**}	12.823^{*}	591.828
LU x SD	3	0.268^{**}	1.136^{*}	0.011^{**}	2.430	2411.210
Error	14	0.041	0.219	0.001	2.288	175.816
CV (%)		3.81	8.10	12.61	14.46	103.69

Note: LU = Land use; SD = Soil depth; CV = Coefficient of variation.

Table-3. Main effects of land use and soil depth on soil pH, organic matter, total N, C: N ratio and available P contents.

Treatment	**pH** (H_2O)	**Organic matter/** (%)	**Total N** (%)	**C:N ratio**	**Available P** (mg kg^{-1} soil)
Land use					
Forest land	6.6^{a}	6.6^{a}	0.39^{a}	10	42.8^{a}
Shrub land	5.2^{b}	6.3^{ab}	0.38^{a}	10	2.1^{b}
Grazing land	4.6^{c}	5.8^{b}	0.31^{b}	11	2.9^{b}
Cultivated land	4.8^{c}	4.5^{c}	0.24^{c}	11	3.2^{b}
LSD (0.05)	0.252	0.579	0.052	NS	16.419
SEM(±)	0.118	0.270	0.024	0.873	7.655
Soil layer					
0-20 cm	5.4	6.7	0.41	10	17.7
20-40 cm	5.3	4.8	0.25	11	7.8
LSD (0.05)	NS	0.410	0.037	1.324	NS
SEM(±)	0.083	0.191	0.017	0.618	5.413
CV (%)	3.81	8.10	12.61	14.46	103.7

Note: NS = not significant; LSD = least significant difference; SEM = Standard error of mean. Means within a column followed by same letter are not significantly different from each other at P = 0.05.

The vertical trend has shown a generally decreasing pattern in soil pH (and increasing acidity) with increasing soil depth. This scenario can be explained for two reasons. For one reason, the larger organic matter content observed in the surface soils across all land uses helped. Humified organic matter can bind tightly with aluminum ions and reduce their activity in the soil solution which thereby raise soil pH and reduce acidity. Secondly, basic cations such as Ca^{2+} and Mg^{2+} ions have shown decreasing trend with increasing depth. The adsorption of basic cations such as Ca^{2+} and Mg^{2+} ions onto the colloidal complex gives replacement of H^{+} and Al^{3+} which lowers the percentage acid saturation causing an increase in the pH of the soil solution. Additionally, increasing clay percentage with depth also has the tendency to furnish hydrogen ions from clay colloidal surfaces to the soil solution again reducing which finally reduce soil pH.

Organic matter

Deforestation of natural forests followed by conversion into managed agro ecosystems has induced a significant depletion in the stock of soil organic matter. Analysis of variance revealed soil OM contents under various land use types were significantly ($P \leq 0.01$) different from each other (Table-2). This implies that each land use type and corresponding soil management practices affected the direction and extent of its change. The least significance difference (LSD) test also demonstrated soil organic matter contents under grazing and cultivation were significantly lower ($P \leq 0.05$) than the OM content of corresponding soils under natural forests (Table-3). However soils under shrub lands did not do so.

The highest soil OM contents were observed in the surface soils of forest land while least Figures were from subsurface layers of the cultivated soils (Table-4). As can be seen, compared to the forest land, soils under shrub, grazing and cultivation in the 0-20 cm soil depth maintained 92.2, 71.4 and 58.4 percent, respectively, of the forest derived soil OM contents. Whereas only 65.7, 71.3 and 57.5 percent of the soil organic matter content of the forest lands were maintained in the subsoil, 20-40 cm depth. It can be concluded that, under the cultivated land uses, losses of forest derived soil organic matter were not fully compensated by organic matter input from the cereal crop residues. Such effects on these tropical soils are most likely to appear due to the effects of tillage practices coupled with reduced soil organic matter inputs and apparently complete removal of crop residues from cultivated fields. Use of crop residues as animal feed during dry season and source of fuel wood are two major reasons for massive removal of crop residues. In this regard, the well drained conditions of the soils of the study area have obviously enhanced the rate of organic matter decomposition.

A relatively lower level of disturbance in grazed soils has apparently led to an increase in organic matter content as compared to those cultivated soils. Though absence of such soil disturbance minimizes rapid loss of soil OM, export of nutrients and low biomass return after grazing have contributed much to its decline compared to observations made in the forest soils. In most of the instances, total organic matter content is higher in grazing land soils than those soils found under cultivated fields. However, measurements in grazing land soils, at both layers, were found lower than those under forest lands. This situation can be ascribed to the fact that continuously degraded and abandoned lands were only left for grazing purposes in the study area. Beside this, overstocking of livestock causes removal of grass and forage biomass which ultimately discourages organic matter accumulation and decomposition.

Concurrently, organic matter contents were profoundly affected by soil depth ($P \leq 0.01$) and the interaction ($P \leq 0.05$) of land use and soil depth factors. The mean value for level of soil OM in the 0-20 cm soil layer (6.7%) was much higher than that of the corresponding sub-surface (4.8%) soils (Table-3). This is attributed partly to the continuous accumulation of undecayed and partially decomposed plant and animal residues in the surface soils. In general, forest clearing followed by conversion into agricultural fields brought about a remarkable depletion of the soil OM stock. Hence findings of this study are in agreement with findings of similar and recent studies Weldeamlak and Stroosnijder (2003) and Genxu *et al*. (2004).

Total nitrogen and carbon to nitrogen ratio

Total nitrogen contents of soils demonstrated significant variation between land uses ($P \leq 0.01$), soil layers ($P \leq 0.01$) and interaction between the two factors ($P \leq 0.01$). Total nitrogen content declined with shift of land uses from natural forest into agricultural fields, and with increasing soil depth from 0-20 cm to 20-40 cm (Table-3). The variation paralleled that of change in soil organic matter contents. Mean values for total N increased from cultivated (0.24%) to grazing (0.31%) to shrub (0.38%) and forest land (0.39%) soils. This again declined with increasing depth from 0.41% in surface to 0.25% with subsurface soils. The LSD test also indicates that variation of total soil nitrogen content between subsurface soils of agricultural fields is significant ($P \leq 0.05$) as compared to that in forest soils though the soils under shrub lands maintained only numerical difference than statistical significance.

Table-4. Effects of land use and soil depth on soil OM, pH, total N, C: N ratio and available P contents.

Soil depth and land use type	**pH** (H_2O)	**Organic matter** (%)	**Total nitrogen** (%)	**C:N ratio**	**Available P** (mg kg^{-1} soil)
0-20 + FL*	6.6^{a}	7.7^{a}	0.50	8.9^{ab}	60.8^{a}
0-20 + SL	5.6^{b}	7.3^{a}	0.49	8.5^{b}	2.5^{b}
0-20 + GL	4.7^{c}	7.1^{a}	0.38	11.2^{ab}	3.8^{b}
0-20 + CL	4.8^{c}	4.7^{bcd}	0.26	10.8^{ab}	3.8^{b}
20-40 + FL	6.7^{a}	5.5^{b}	0.28	11.3^{a}	24.8^{b}
20-40 + SL	4.8^{c}	5.2^{bc}	0.27	11.2^{a}	1.8^{b}
20-40 + GL	4.6^{c}	4.5^{cd}	0.25	10.7^{ab}	2.0^{b}
20-40 + CL	4.9^{c}	4.2^{d}	0.21	11.6^{a}	2.6^{b}
LSD (0.05)	0.36	0.82	NS	2.649	23.2
SEM(±)	0.167	0.382	0.10	1.235	10.826
CV (%)	3.81	8.10	12.6	14.46	103.69

Means within a column followed by same letter are not significantly different from each other at $P > 0.05$;
*FL = Forest land; SL = Shrub land; GL = Grazing land; CL = Cultivated land

The remarkable losses of total nitrogen in the continuously cropped fields could be attributed to rapid mineralization of soil organic matter following cultivation. This disrupts soil aggregates, and thereby increases aeration and microbial accessibility to organic matter. Low input of plant residues in such cereal based farming systems has contributed to the depletion of soil OM thereby soil N in cultivated lands. As the study area receives high mean annual rainfall (1250mm) nitrogen leaching can be an additional factor for its decline in the cropped fields. Nitrate ions which are not adsorbed by the negatively charged colloids that dominate most soils, therefore move downward with drainage water and are thus readily leached from the soil.

In such low-input agricultural systems, crop residues are continuously removed from fields for various reasons including their use as fuel wood and livestock feed. This makes the nutrient balance even more negative. In such a way the continuously declining soil N and P contents have rendered the soils infertile and difficult to sustain agricultural production. This can be exhibited in the continuous application of commercial nitrogen fertilizers (like $CO(NH_2)_2$) which in general were insufficient to replace nutrient off take.

The variation in C: N ratios between land uses did not reveal significant ($P > 0.05$) differences but varied across soil depth significantly ($P \leq 0.05$). Yet, the numerical values for land uses are highest for cultivated soils and lowest for forest soils which can be due to the rapid loss of N (the denominator) in the former. Thus, one can understand that the impact of land use and associated management was more pronounced in soil nitrogen than organic carbon.

Available phosphorus

Available P content of the surface soils of the study area varied from 42.8 mg kg^{-1} in forest soils to 2.1 mg kg^{-1} in soils under the shrub lands with significant differences between soil samples. In addition the vertical trend indicates that available P decreased from 17.7 mg kg^{-1} in surface soils to 7.8 mg kg^{-1} in sub-surface layers (Table-2) though not statistically significant. This implies available P content of soils drastically declined due to conversion of natural ecosystems into managed ones. The statistical analysis result has indicated that available P content was significantly affected by land uses ($P \leq 0.01$) while no significant differences were observed due to soil depth and the interaction between the two factors. In the LSD test, the average P contents of the soils under the different land uses were found to be significantly lower than the P content of the adjacent forest land soils. However, no statistically significant differences ($P > 0.05$) were observed among the remaining three major land use types and soil depths.

Far from expectation, available P contents for the cultivated soils were not low, rather found to be better than those soils under shrub and grazing land uses. Under such acidic conditions which limit P availability, application of organic materials such as animal manures might have increased P availability though not sufficient enough to maintain at the level seen in forest soils. During microbial breakdown of these materials, phosphorus is released slowly. Beside this, the residual effect of P containing fertilizers like Diammonim Phosphate (DAP) may also contribute to this increment. The unusual feature here is that available P contents of these tropical soils did not necessarily decrease with decreasing soil OM and vice versa. Thus, it can be concluded that, organic matter is not necessarily the primary P supplying source in these highly weathered and human managed tropical soils.

Rather it appears that inorganic sources from fertilizer application and mineral weathering have considerable importance in their contribution to soil available and total P pools. This is true as intensified human action increases rate of weathering and encourage decomposition in cultivated soils. This result is in agreement with findings made by Saikh *et al.* (1998) and Weldeamlak and Stroosnijder (2003) but contrasts with that made by Sanchez (2002).

In fact, some soils under the shrublands have lower P contents than their adjoining grazing land soils. This is possibly due to the fact that forest vegetation with their larger biomass utilizes P to a greater extent than pasture and grasses in grazing fields thereby causing P depletion. This may be one of the major reasons why the grassland soils have higher available P in their subsurface layer (which has direct contact with plant roots) compared their adjoining soils under shrub lands. More to importantly, the general decline in available P contents can be ascribed to (1) the remarkably high degree of phosphorus fixation which occurs at low pH levels and (2) losses through crop harvest and erosion which are characteristic features of agricultural soils in the tropics.

CONCLUSIONS

The findings of this study revealed that conversion of natural ecosystems into managed agro ecosystems resulted in significant changes in the quality of soil resources. These tropical soils significantly responded to changes in land use through salient soil features which constitute soil properties governing soil fertility and productivity. Such human-induced change is not limited to surface soils but also the subsurface soils and has remarkable implication for ecosystem quality and productivity of the traditional low-external-input agriculture in the study area. As agriculture is the pillar to the local economy, soil resources it depends on to grow crops and pasture must be ensured to sustainably support production. This means the nitrogen and phosphorus nutrients lost through agricultural uses should be replenished and get back into the system to keep the nutrient balance far from negative. However, the cost of replenishing these essential plant nutrients is considerable and has great significance for economic viability and sustainability of this smallholder agriculture. This implies that land use change is not only the main source of soil degradation, but also brings strains into the subsistent agricultural economy. Therefore, this study suggests that more detailed and expanded similar studies are required for better monitoring and improved understanding of the impact of such changes in land use.

ACKNOWLEDGEMENTS

The authors are grateful to the institutional support of the Oromiya Agricultural Research Institute and the financial assistance from the Agricultural Research and Training Project in Ethiopian Institute of Agricultural Research (EIAR). These two jointly made this study possible. Sincere thanks also go to the staff of the National

Soil Research Center, EIAR for the support they rendered in soil analytical services.

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