INTERNATIONAL JOURNAL OF RESEARCH IN COMMERCE, ECONOMICS & MANAGEMENT

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   HYPOTHESES

   RESEARCH METHODOLOGY

   RESULTS & DISCUSSION

   FINDINGS

   RECOMMENDATIONS/SUGGESTIONS

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CONTRIBUTIONS TO BOOKS

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CONFERENCE PAPERS

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- Kumar S. (2011): "Customer Value: A Comparative Study of Rural and Urban Customers," Thesis, Kurukshetra University, Kurukshetra.

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- Garg, Bhavet (2011): Towards a New Natural Gas Policy, Political Weekly, Viewed on January 01, 2012 http://epw.in/user/viewabstract.jsp

IMPACTS OF LAND USE SYSTEM ON SOIL PROPERTIES AND FERTILITY STATUS IN THE MIZEWA WATERSHED OF LAKE TANA BASIN, NORTH WESTERN ETHIOPIA

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ABSTRACT

Like many other developing countries across the globe, agriculture in Ethiopia is expanding at the expense of natural forests to feed the increasing population. Areas which were under natural forest are being converted to cropland, grazing land and eucalyptus plantations. However, the general ecological effects of these changes have not been well investigated and documented. Therefore, this study was undertaken to investigate the effects of these land use changes on the physical and chemical properties of soils and the possible consequences on land productivity and the environment as a whole. Laboratory analysis was done for soil samples collected from the upper 0 - 20 cm depth from land utilized for crop cultivation, grazing, eucalyptus plantation and natural forest growth in order to compare moisture content, particle size (texture), Potential Hydrogen, Cataion Exchange Capacity, organic carbon, total nitrogen, available phosphorous, exchangeable potassium and exchangeable sodium. The study indicated as conversion of natural forest land to other land uses resulted in deleterious effects on soil moisture content, soil texture, pH, organic carbon, organic matter, total nitrogen and exchangeable potassium. Cataion Exchange Capacity, available Potasium and Carbon/Nitrogen ratio values were found less sensitive to changes in land use. Exchangeable sodium for all land use was nil. The results clearly indicate land use change aggravates soil degradation, thereby threatening agricultural development and environmental health. Therefore, there is a need to develop sustainable soil management options that will minimize or counteract the harmful effects of land use change.

KEYWORDS
Land use systems; land use change; natural forest; grazing land; cultivation; soil fertility.

INTRODUCTION

In countries like Ethiopia where agriculture is the basis of the national economy, agricultural production has been highly dependent on natural resources for centuries (Amsalu, 2007). As a result, agricultural lands have expanded at the expense of natural forests to meet the additional food demand for the increasing population (Tekle and Hedlund, 2000; Bewket, 2003; Kidanu, 2004). Besides the expansion of cultivated and grazing lands, forests have been heavily exploited for fuel wood and construction material in order to meet the needs of the rapidly expanding population (Zeleke and Hurni, 2000).

This excessive exploitation has led to the destruction of forest-lands and resulted in a massive environmental degradation, a serious threat to sustainable agriculture (Redhead and Hall, 1992). The consequences of this exploitation includes: shortage of biomass and ecological imbalances, which may lead to recurrent droughts, reduced water resources, deteriorated soil property, extinction of flora and fauna, and heavy soil erosion. Studies indicated as the expansion of cultivation on steep slopes at the expense of natural forests in the north-western highlands is causing serious trend of land degradation (Zeleke and Hurni, 2000).

Since most of the country is characterized by high mountains and erratic rainfall conditions, the land resource bases are sensitive to human interventions. With the ever-escalating population pressure on these high mountain ecosystems in conjunction with poor agricultural land management practices and tools, unregulated land use systems and farmers' inability to take measures to enhance soil fertility or conserve soil, degradation of land resources remain a common occurrence (Yitaferu et al., unpublished). For mentioned reasons, natural resource degradation threatens the staggering agricultural development and food security of the country (Taddese, 2001; Holden and Shiferaw, 2004).

In the study area, the mixed farming system, in which livestock production is as important as crop production, forces farmers to allocate land for intensive free grazing. Moreover, the increasing benefit from eucalyptus is an incentive for farmers to expand eucalyptus plantations at the expense of other land uses.

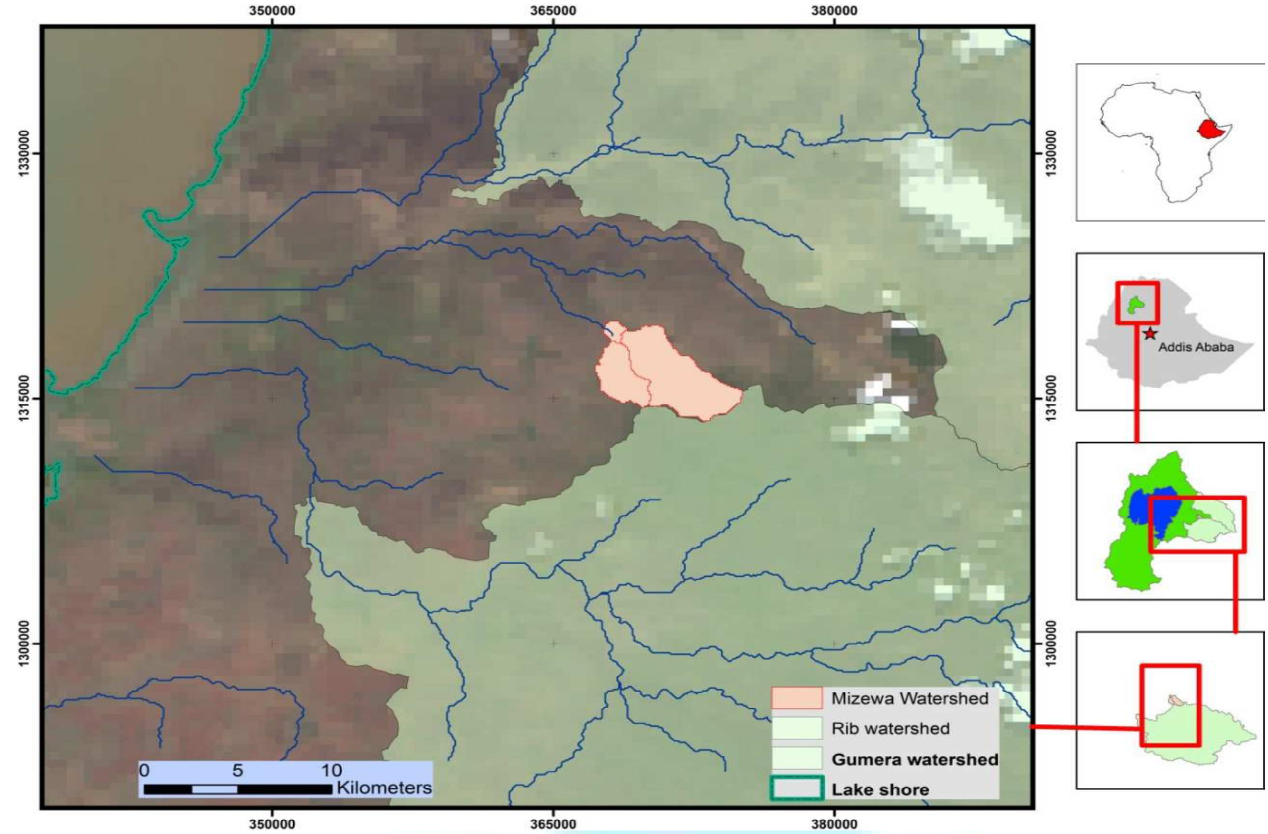
Regardless of the high conversion rate of land uses, the availability of studies on the possible consequences of land use changes is limited. Land use changes usually affect soils of an ecosystem and thus play an important role in the global soil nutrients cycle (Solomon, 1994).

Evaluating the effects of land use changes helps to identify the severity of the problems, to indicate where focus should be given to improve agricultural production and productivity, and to enhance sustainable land management systems. This study was conducted with the objective of identifying the possible effects of land use conversion on the soil environment, specifically the physical and chemical properties.

MATERIALS AND METHODS

STUDY AREA: The study was conducted in the Mizewa Watershed of Lake Tana basin, located between 11^0 55'N latitude and 33^0 47' E longitude in the North western Ethiopia. The altitude of the watershed ranges from 1480-2200m. Rainfall follows a unimodal distribution with an average annual of about 1800 mm. The average temperature is 21.7 ^oC with a maximum yearly variation of 4^oC. There are two temperature peaks: one around May to June at the start of the rainy season and the other at the beginning of the dry winter season from October to November. Subsistence agriculture is the major means of livelihood in the area with an average farm size of about one hectare (ha).The common crops growing in the cultivated/crop lands are maize (*Zea mays L.*), teff (*Ergarostis teff*) and beans (*Phaseolus vulgaris L.*).

FIG. 1: MAP OF THE STUDY AREA



SOIL SAMPLING AND LABORATORY ANALYSIS

Soil samples were taken using auger from different points in a plot from six locations each from the four land use types at the depth of 0-20 cm. Then twenty four composite soil samples were prepared after thoroughly mixing the sub samples of each plot in a plastic bowl. The land use systems investigated were natural forest land, 4 to 9 years plantation fields (totally covered by *Eucalyptus camaldulensis*), communal grazing lands and cultivated (crop) fields. The common tree species covering the natural forest land includes: *Croton macrostachis*, *Cordia africana*, *Accacia abysinica* and different bushes and shrubs. Free grazing may be observed in the forest areas; therefore, forest samples were collected from more densely vegetated areas where animals did not obviously graze. To asses the variation of soil properties across locations, laboratory analysis was conducted to determine the major soil physical and chemical parameters.

Laboratory analysis was conducted at the Bahirdar Regional soil laboratory using the following standard methods. Moisture content, particle size, pH, cation exchange capacity (CEC), organic carbon, total nitrogen, available phosphorous and exchangeable potassium and sodium were analyzed in the laboratory. The soil samples were air dried at room temperature and sieved (<2 mm) prior to any laboratory analysis except for moisture content determination.

Moisture content was determined by initially weighing the field samples, drying the field samples at 105^{o}C for 24 hours, and weighing them again. The percentage of water held in the soil was calculated as the weight difference of field and oven dried soils divided by weight of oven dried soil alone multiplied by 100.

A hydrometer was used to determine the soil textural classes. After composition percentages of sand, clay and silt were identified, textural classes were determined using the USDA triangular guideline for classifying soil textures.

Soil pH was measured from a supernatant suspension of 1:2.5, soil to KCL liquid ratio. Soil organic matter was oxidized under standard conditions with potassium dichromate in a sulfuric acid solution. A measured amount of $K_2Cr_2O_7$ was used in excess of that needed to destroy the organic matter and the excess was determined by titration with ferrous ammonium sulfate solution, using a diphenylamine indicator to detect the first appearance of un-oxidized ferrous iron. Then, the percent organic carbon was determined using the following equation:

$$\%C = \frac{N(V1 - v2)}{S} 0.39mcf$$

---Equation 1

where N is the normality of ferrous sulfate solution (from blank titration), V1 and V2 are the volumes (ml) of ferrous sulfate solution for the blank and for the sample, respectively, S is the weight of air-dried sample (g), and mcf is a moisture correction factor.

The Kjeldahl procedure was used to determine total nitrogen in the soil. Organic matter was oxidized by treating soil with concentrated sulfuric acid, by which nitrogen in the organic nitrogenous compounds were converted to ammonium sulfate during oxidation. The acid traps ammonium ion (NH4+) ions liberated by distilling with Sodium Hydro-oxide (NaOH). The liberated NH4+ was absorbed in boric acid and back titrated with standard Sulfuric acid (H2SO4). Available phosphorous was measured using Olsen method. Cation exchange capacity (CEC) was determined by measuring the total amount of a given cation needed to replace all the cations from a soil exchange site. The exchangeable cations (Ca+, Mg+, Na+, K+, and Al+) and H+ of the adsorption complex were displaced with ammonium acetate 1 M pH 7.0 solutions. This helped to saturate the adsorption complex with this solution. The excess saturating cation not adsorbed on the exchange complex was eliminated by washing with alcohol. The saturating cation held on the exchange complex was then displaced with another cation, sodium chloride (10%), and the displaced cation measured. The saturating ammonium displaced by neutral salt was measured by distillation to determine CEC. Then the distillate leachate (NaCl percolate) was titrated with 0.1 N NaOH using the methyl red indicator until the color changed from purple to yellow. Exchangeable K and Na were measured by Flame-photometer from ammonium acetate leachate K and Na transmittances of the above solution.

STATISTICAL METHODS

Descriptive statistics was employed to asses the fertility status of the area. Analysis of Variance (ANOVA) was also performed to asses the significance of different soil parameters across different land use system using Social Science Statistical Package (SPSS).

RESULTS AND DISCUSSION

SOIL MOISTURE CONTENT AND SOIL PH

Soil moisture content and pH were found statistically different for the different land use systems (table 1). The moisture content of forest and grazing land soils gave the highest values though that of grazing land is not significantly different from cultivated land. But the soils from eucalyptus plantation had the least value though not significantly different from grazing land. The pH values of bulk soils of the Natural forest land were also significantly higher ($P < 0.05$) than the soils of other land uses, i.e., cultivation, grazing and eucalyptus plantation land uses. Despite the fact that the pH from forest land is relatively higher, it lies in slightly acidic range (between 5.5 and 6.5) while values of other land uses are strongly acidic (<0.5.5).

Most of the land in the study area which was previously covered by natural forests was converted to cultivation fields to feed the increasing population. The crop-livestock mixed farming system of the area also caused the increase in livestock population, which triggered the conversion of some portion, though insignificant amount, of natural forest land to grazing land. Since the economical benefit from eucalyptus has also grown, many farmers are designating portions of their land for eucalyptus plantation. Different studies indicate that such abrupt transition from natural vegetation to a managed system has several effects such as ecological imbalance, soil erosion and soil nutrient (Zeleke and Hurni, 2000; Bewket, 2003).

In this study, forest soils had significantly higher soil moisture content. According to Jiang et al. (1996), water infiltration in undisturbed forest soils is enhanced by both preferential flow along trees roots and accumulation of absorbent humus on the soil surface, thereby significantly reducing the volume, velocity, and erosive and leaching capacity of surface runoff. The forest soils were well-structured (loam soil) compared to the clay soils of other land uses likely due to the addition of more organic matter from falling leaves and the greater shielding effect of the canopy formed by the mature shrubs and understory vegetation from the erosive energy of the falling raindrops improve the texture of the soil.

Soils from grazing land also have higher soil moisture content. Although the majority of the above ground biomass is removed by intensive free grazing on these lands, the residual effects of underground grass biomass that facilitate infiltration and undisturbed soil because of tillage which facilitates evaporation loss may account for the relatively high moisture content in the soils from grazing lands.

Eucalyptus is a fast growing voracious plant which absorbs high moisture and soil nutrients. According to Zewdie (2008), the soils found in the eucalyptus plantations in this study had the lowest moisture content. Eucalyptus plantations soils experience low infiltration due to the lack of understory vegetation, which often facilitate infiltration because of higher organic matter enhancing the soil structure. A significantly lower moisture content for soils of continuously cultivated and eucalyptus planted lands and better soil textural class for forest soils implied that poorly managed cultivation is primarily responsible for deterioration in soil quality in the study area.

The soil pH of all land uses lies in the acidic range. These may be because of the rainfall condition of the area which is sufficient enough to leach basic cations leaving the exchangeable complex dominated by $H+$ and $Al3+$. These two ions are mainly responsible for soil acidity. The pH range of most productive agricultural soils is between 5.5 and 7.5. Since the pH value for cultivated lands in this study is below this range, the productivity of soils is likely affected by soil acidity. From the analysis, only soils from forest land had pH values within the optimum range possibly because of the buffering effect of soil organic matter from decomposed litter of trees.

TABLE 1: SUMMARY OF PHYSICAL AND CHEMICAL ANALYSES OF SOILS FROM DIFFERENT LAND USE SYSTEMS INCLUDING THE ANOVA RESULTS

Land Use System	Moisture content (g)	PH KCL	CEC	% O.C	% T.N	Avai.P ppm	Exch. K	Exch. Na	C/N	Texture
Cultivated land	15.32^{a}	4.92^{a}	26.68^{a}	2.46^{a}	0.22^{a}	8.98^{a}	0.68^{a}	Nill	12.1	Clay
Grazing land	17.03^{ab}	4.40^{a}	51.34^{a}	2.94^{a}	0.26^{a}	2.31^{a}	0.69^{a}	Nill	12.1	Clay
Eucalyptus plantation	14.96^{ac}	4.57^{a}	44.28^{a}	2.66^{a}	0.24^{a}	6.99^{a}	0.73^{a}	Nill	11.8	Clay
Forest land	17.87^{b}	5.80^{b}	41.70^{a}	5.18^{b}	0.44^{b}	9.73^{a}	1.80^{b}	Nill	12	Loam

Similar small superscript letters indicate as there is no significant difference between values while different letters indicate the reverse.

TEXTURE COMPOSITION

The texture composition of the soil samples from each land use type is indicated in table 2. Forest soils were classified as loam, while soils from other land uses had greater clay contents, ranging from silty clay loam to heavy clay. Grazing land had the highest clay content (averaging 53%) followed by eucalyptus plantations (46%), cultivated land (40%), and the least in forest samples (22%).The composition percentage of sand was the highest for soils taken from forests followed by cultivation land. The composition of silt was relatively similar in samples from all land uses.

TABLE2: TEXTURAL COMPOSITION PERCENTAGE FOR SOILS OF DIFFERENT LAND USES

Land use system	Textural Composition			Textural Class
	Sand %	Silt %	Clay %	
Cultivated Land 1	25	36	39	Clay loam
Cultivated Land 2	23	34	43	Clay
Cultivated Land 3	20	41	39	Silty clay loam
Average Value	**23**	**37**	**40**	**Clay**
Grazing Land 1	11	34	55	Clay
Grazing Land 2	13	26	61	Heavy Clay
Grazing Land 3	18	38	44	Clay
Average Value	**14**	**33**	**53**	**Clay**
Eucalyptus Plantation 1	10	26	64	Heavy Clay
Eucalyptus Plantation 2	23	44	33	Clay loam
Eucalyptus Plantation 3	17	42	41	Silty clay loam
Average Value	**17**	**37**	**46**	**Clay**
Forest Land 1	38	36	26	loam
Forest Land 2	42	34	24	Loam
Forest Land 3	42	42	16	loam
Average Value	**41**	**37**	**22**	**Loam**

ORGANIC MATTER, ORGANIC CARBON AND TOTAL NITROGEN

Soil organic matter and total nitrogen values of forest land were significantly higher ($p < 0.05$) than soils from other land uses. The highest organic carbon content resulted in higher organic matter content for soils of forest land while other land uses only rated medium levels.

Even though there is no statistical difference among the total nitrogen contents of soils, it was high for grazing soils and medium for cultivation and eucalyptus plantations (table3)

Significantly higher organic carbon, total nitrogen and soil organic matter was found in soils from forest. On the contrary, soils from cultivated lands and eucalyptus plantations had lower values of carbon, nitrogen and soil organic matter suggests that the changing of land uses from natural forest growth to cultivation depletes specific nutrients and organic matter.

Cultivation of native soils reduces soil organic matter by facilitating interactions of physical, chemical and biological soil processes that increases decomposition rate of soil organic matter (Amsalu et al., 2007). This reduction was also noted in Kosmas et al. (2000) in which a deterioration of soil fertility in continuously cultivated soils compared to soils under natural vegetation. In addition to low biomass input, facilitated decomposition rate and continuous mining of soil nutrients, erosion also decreases soil carbon, organic matter and nitrogen from cultivated soils (Willet, 1994). Tillage practices enhance the oxidation of soil organic matter and loss by erosion.

The significantly lower values of soil organic matter in grazing land compared to forest land is related to the low biomass return back to the soil because the majority of above ground biomass is lost due to intensive free grazing (Harvey et al., 1985). Therefore, the input to the soil is restricted to the underground biomass of forage species (Kosmas et al., 2000).

Higher soil organic carbon oxidation due to higher soil surface temperatures in arable soils as compared to soils under forest decreases carbon contents of cultivated land. Veldkamp (1994) found the conversion of forest land to pasture and grasslands causes a decline in soil organic carbon. Loss of organic matter results in the release of carbon dioxide to the atmosphere. The increment of CO2 concentration in the atmosphere will increase the global temperature. Therefore, the conversion of forest lands to other human managed land uses will aggravate green house effect, i.e., global warming. The relative high range of nitrogen in grass lands may be caused by inhibited nitrification leading to nitrogen preservation in low mobility form.

Regardless of the significant difference of soil organic matter, carbon and nitrogen contents, the C/N ratio of soils of all land uses is almost similar. This result agrees with Solomon (1994) in which the C/N ratio of a soil should be considered as less informative indicator of soil organic matter quality than the carbon and nitrogen contents alone.

TABLE 3: ORGANIC MATTER, ORGANIC CARBON AND TOTAL NITROGEN RATES IN DIFFERENT LAND USE SOILS

Land Use System	% O.M	Rating	% O.C	Rating	% T.N	Rating
Cultivated land	2.5	medium	1.45	medium	0.12	medium
Grazing land	3.33	medium	1.93	medium	0.16	high
Eucalyptus plantation	2.84	medium	1.65	medium	0.14	medium
Forest land	7.03	very high	4.08	very high	0.34	very high

CEC, AVAILABLE P, EXCHANGEABLE K AND NA

Cation Exchange Capacity and available phosphorous didn't show significant difference among the different land uses. But exchangeable potassium of bulk soils of the natural forest land (very high range) was significantly higher ($p < 0.05$) than the soils of other land uses (table 1). Except for forest soils, the exchangeable potassium contents were not significantly different regardless of its range from high (for eucalyptus plantation) to medium for the other two land uses.

The exchangeable Na content of soils from all land uses was nil. The available P in the different land uses varied from low to very low and was not significantly different (table 4). Soils from grazing land had the lowest available phosphorous. CEC varied from very high (grazing land) to high (eucalyptus plantation and forest) and to medium (cultivated lands).

The similar results for CEC and available P in the soils from all the land uses indicate that these parameters are less prone to changes in land use and cover. Despite the very high organic matter content and relatively high pH value in forest soils, its CEC values were found to be lower than grazing and eucalyptus plantation land uses. This may be because of high percentage composition of clay colloids of grazing land use (53%) followed by eucalyptus plantation (46%) compared to forest land (22%) use which has the least clay composition.

Acidic soils fix phosphorous resulting in low to very low available phosphorous in all land uses sampled in this study. Moreover, phosphorous compounds commonly found in soils are unavailable to plants because they are highly insoluble. Plant uptake, erosion, leaching and fixation usually cause losses of phosphorous from the soil system. Crop production is highly influenced by phosphorous, which is a critical element for the production of healthy plants and profitable yield. The available P values from this study indicate there is insufficient available P for optimal crop production in the soils tested.

Regardless of the long-held belief that soils in Ethiopia are rich in potassium, the values of potassium found in this study for cultivated and grazing land use systems indicate a decrease due to the conversion of land use systems. Being the third element next to nitrogen and phosphorous to limit plant productivity, deficiency of soil potassium can significantly affect land productivity. The recycling of nutrients from crop and grass residues is poor because freely roaming animals intensively graze any residues remaining on the land. Therefore, the relative low amount of potassium in cultivated and grazing land uses is likely the result of the removal of vegetation. The highest level of potassium in forest land uses may be because of the contribution from an undisturbed ecosystem where there is a natural balance and no removal of residues that removes potassium.

Sodium is usually abundant in sodic soils. However, the soils of all land uses in the study area were found to be acidic; therefore, resulting in the absence of sodium in soils from all the land uses examined.

TABLE 4: CEC, AVAILABLE P EXCHANGEABLE K AND THEIR EXCHANGEABLE RATES IN DIFFERENT LAND USE SOILS

Land Use System	CEC	Rating	Avai.P ppm	Rating	Exch. K	Rating
Cultivated land	24.56	medium	7.62	low	0.56	medium
Grazing land	41.43	very high	1.21	very low	0.57	medium
Eucalyptus plantation	36.36	high	5.67	low	0.64	high
Forest land	32.61	high	8.54	low	1.81	very high

SUMMARY AND CONCLUSIONS

This study showed that conversion of natural forest into human-managed land uses (crop land, grazing land and eucalyptus plantation) had more deleterious effects on soil moisture content, soil texture, pH, soil organic carbon, soil organic matter, total nitrogen, and exchangeable potassium. In general, forest ecosystems were found to retain soil nutrients very efficiently.

Since the pH value of most land uses is below the range of productive soils, it may be highly affecting the yield of cultivated soils in addition to controlling nutrients availability including phosphorous. If organic matter also continues depleting following land use changes, release of CO_2 to the atmosphere will aggravate global warming problem. The study also indicated as the existing thought of soils of Ethiopia is rich in potassium is being challenged because of land use changes and needs to be well studied.

As there is a need to increase agricultural production to meet food demand for the growing population, it is more likely as change of natural forest lands to other land uses will continue. But, as the study clearly indicated, these changes will be accompanied by soil degradation which is a major concern for food production and sustainable management of land resources. Therefore, conservation and improvement of the natural resources on which agricultural production depends will improve productivity so that the pressure on conversion of forests to other land uses will decrease. Moreover, better soil management helps to decrease degradation problem including serving as carbon sink.

ACKNOWLEDGEMENTS
I indebted to Bahir Dar Regional Soil Laboratory staffs for their hearty support during laboratory works. I also thank the people of Mizewa watershed who gave me valuable information during the data collection.

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