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Short Communication

Effect of Firewood Energy Consumption of Households on Status of Soil Fertility in Debis Watershed, Ambo District, Oromia Regional State, Ethiopia

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Abstract

The increasing population of Ethiopia has resulted in excessive forest clearing for agricultural purpose, overgrazing and exploitation of the existing forests for fuel. The Environmental impact of over dependence on forest resources for energy source was not studied in sufficient detail in Debis watershed. Thus study was initiated to investigate the status of firewood consumption and its impact on soil fertility status. In order to investigate the impact of firewood consumption on soil fertility status, soil samples were collected from different land use types (deforested, grazing and natural forest) lands from soil of the upper (0-20cm) depth and analyzed for soil quality parameters (pH, organic carbon, total nitrogen, available phosphorus, CEC, and exchangeable bases). Data obtained were analyzed using PROC-GLM procedure of the Statistical Analysis System (SAS Institute, 2004). The results obtained from laboratory study of soil analysis, showed that, soil taken from natural forest had higher value of soil quality parameters such as: soil pH, organic carbon, CEC, total nitrogen and available phosphorus and potassium contents. The results clearly demonstrated that the different land use types had significant effects on soil quality, suggesting that a land cover change from forest land to the other land use types aggravated soil degradation, thereby resulting in soil fertility decline. Therefore, there is a need to develop sustainable and environmental friendly energy sources and practicing afforestation and forest management programs to overcome the deterioration of soil fertility of the study area in particular and other similar agro-ecological environments in the country.

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INTRODUCTION

Environmental resources are the foundation for social and economic development in Ethiopia. This development of a society finds expressions in its increasing capacity to meet certain need. Satisfying most of these needs would require the consumption of energy, albeit in varying degree. The development and the use of energy are thus vital to economic and social development. The increasing population of Ethiopia has resulted in excessive forest clearing for agricultural purpose, overgrazing and exploitation of the existing forests for fuel (EPA, 2003).

Ethiopian farmers and a significant number of urban dwellers depend solely on biomass energy for cooking and in some cases even for lighting purposes. So, firewood is one of the local energy sources, which is readily available to meet the energy needs of a significant proportion of the population particularly the poor in rural areas of the developing countries (Karekezi *et al*., 2004). In addition to climate change, soil degradation and deforestation are the key environmental challenges for the country because of devoid of its natural vegetation that emanated from large dependency on biomass energy (FAO, 2013). The highland regions in Ethiopia, soil loss by erosion is high and the basic nutrients are removed from the soil surface (Philor, 2011). Land degradation in Ethiopia is exacerbated by soil nutrient depletion arising from absence of adequate soil nutrient saving and recycling technologies (Bojo and Cassels, 1995; Sahlemedhin, 1999).

Reduction in vegetation cover increases soil erosion and loss of soil fertility causing land degradation. Changes in plant diversity especially those leading to loss in vegetation complexity affect the potential of soil to replenish its nutrients particularly soil organic matter (Maitima *et al.,* 2004). This soil nutrient depletion due to erosion and leaching of basic cations from the agro-ecosystem is also a very widespread crop production constraint in Ethiopia (Paulos, 2001; Taye, 2001). To overcome these problems, assessing the potential effect of firewood energy consumption on soil fertility status in the study area is prerequisite to design programs and projects to secure sustainable forest management and soil fertility. However; the environmental impact of over dependence on firewood is not studied in sufficient detail in the present study area. Therefore, the present study explored the status of firewood energy consumption of the households and its impact on status of soil fertility in Ambo District of Debis watershed.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted at Debis watershed, which is located in Ambo District of West Shoa Zone, Oromia Regional state, Ethiopia (Figure 1). Debis watershed is situated at about 125km from Addis Abeba and found at North part of Ambo town and includes Dobi, Abebe Doyo, Degele Gatira, Birbirsa fi kulit and Tule Administrations. Geographically, the study site lies at an altitude ranging from 2100 to 3044masl with area coverage of 4803ha. The area characterized by bimodal rain fall distribution with small amount of rain fall during Belg (autumn) and long rainfall during summer season. The main rainy season occurs between mid-June and mid-September, which is responsible for 70% of the annual average rainfall of 1,100 mm. It is characterized by Weyina Dega climatic condition and the lowest and highest mean annual temperature is13^{0}c and 27^{0}c respectively with average temperature of 18^{o}c. The agriculture is dominantly relied up on the seasonal rainfall and uses old traditional method of farming system and the farmers making their livelihood by producing food crops such as *Eragrostis teff* (Teff), *Hordium vulgare* (Barley), *Tritcum aesticum* (Wheat), *Phaseoulus vulgare* (Haricot Bean) *Zea mays* (Maize) and cattle rearing. The soil of the study area was classified into three main types when classified based on their colors: black soils, brown soils and red soils and highly dominated by soil clay minerals (AWADO, 2012). According to the sustainable land management project (2012) housing census the population of Debis watershed is 5561 with 1053 households (124 are female headed and 929 are male headed).

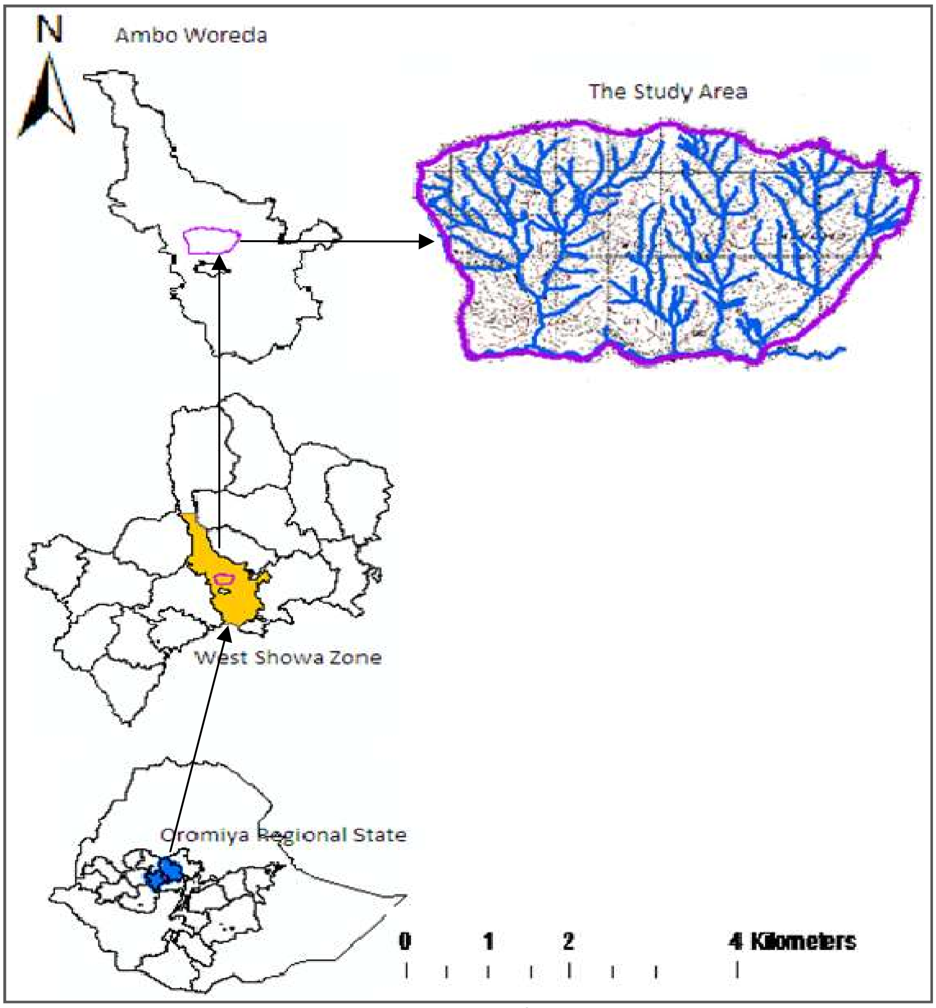

Figure 1: Location map of the study area

Methods of Soil Sample Collection

A necessary assumption made in this research approach was that soil conditions or parameters for all the study sites should be similar before changes in the land uses have been introduced and the observed differences in the present soil conditions can be assumed as being caused by the present land use changes due to cut-off trees for energy consumption. Based on field observation and soil survey, the soil samples were collected from the top (0-20cm) depth of soil surface from each land use (natural forest, grazing and deforested) lands by hand dang. Soil core samples from the 0-20 depth were taken with a sharp-edged steel cylinder forced manually into the soil for bulk density determination. The soil samples collected from representative fields' with three replications were then air-dried at room temperature for 15 days, homogenized, lightly grounded and passed through a 2mm sieve for the analysis of selected soil physical and chemical properties.

Laboratory Analysis of Soil Samples

Soil pH: was determined by digital pH meter method in the supernatant suspension of 1:2.5 soils to water ratio. Bulk Density (BD) was determined by undisturbed soil samples collected using a core sampler (which is weighted at field moisture) after drying pre-weighted soil core samples in an oven at 105^{o}c as described by Black (1965) procedure. Particle Density (PD) was estimated by the pycinometer method as described by (Devis and Freitans, 1984). The soil Particle size was determined by hydrometer or Bouyoucus method after dispersion in a mixer with hexametaphosphate (Martin, 1993). Organic Carbon (OC) was determined following the wet digestion method as described by Walkley and Black (1934). Organic Matter content (OM) content was derived from percent organic carbon computed as: OM % = C% X 1.724. Cation Exchange Capacity (CEC) was measured by Ammonium Acetate method. Total nitrogen: was determined titrimetrically following the Kjeldahl method as described by Jackson (1958). Available Phosphorus was determined using Bray-II method. Exchangeable cations (Ca, Mg, K and Na) was determined as described by Black (1965), Exchangeable Ca and Mg in the extracts was analyzed using atomic absorption spectrophotometer, while Na and K were analyzed by flame photometer (Rowell, 1994).

Statistical Analysis

The quantitative data generated from soil laboratory test were analyzed using PROC-GLM procedure of the Statistical Analysis System (SAS Institute, 2004). Treatment means were compared according to Tukey test and for all analysis a significance level at α=0.05 was used.

RESULTS AND DISCUSSION

Effect of Land Use Types on Selected Physical and Chemical Properties of Experimental Soils

Soil moisture content was significantly influenced by land use types (P<0.05). Results revealed that soil mo varied from 5.73 to 6.7 for the different land use type (Table 1). The moisture content was significantly higher for soil taken from forest land than soils taken from grazing and deforested lands. The soil of forest land with highest moisture content might be due to accumulation of absorbent humus on the soil surface, the water infiltration capacity of undisturbed forest soils due to significantly reduction of volume, velocity, and erosive and leaching capacity of surface run-off by leaves and roots of trees. Soils from grazing land also have the second higher soil moisture content. Although the majority of the above ground biomass is removed by intensive free grazing on the land, the residual effects of underground grass biomass that facilitate infiltration and may account for the relatively high moisture content. The forest degraded land shows the lowest moisture content which is influenced by low organic matter content due to the removal of biomass and exposed to erosion.

Table 1: Mean value of selected soil physical properties of experimental soils

Land uses	Soil parameters						
	Mo (%)	**BD (g/cc)**	**PD (g/cc)**	**TP (%)**	**Clay (%)**	**Silt (%)**	**Sand (%)**
FL	6.79^{a}	1.04^{c}	1.11^{c}	6.30^{a}	60.13^{a}	27.29^{b}	12.47^{b}
GL	6.03^{b}	1.13^{b}	1.19^{b}	5.04^{b}	52.98^{b}	34.12^{a}	12.94^{b}
DFL	5.73^{b}	1.20^{a}	1.26^{a}	4.76^{c}	33.80^{c}	39.41^{a}	27.26^{a}

FL=Forest land; GL=grazing land; DFL=Deforested land; MO=moisture content; BD=bulk density; PD=particle density; TP=total porosity. *Data followed by the same letter in the same column are not significant different from each other at probability level of α =0.05 according to Tukey test.*

Bulk density (BD) of soils was significantly influenced by different land cover types (P<0.001). The mean values of BD obtained from the three land cover types were 1.054, 1.136 and 1.20(gm/cm^{3}) for forest, grazing, and deforested lands, respectively (Table 1). Results showed that the BD of deforested land was significantly higher as compared to that of grazing and forest lands. In line with the present finding, Islam and Weil (2000) reported lowest BD for soil taken from natural forest compared to other land uses like cultivated land and grazing land. The lower BD observed in soils of forest land might be due to undisturbed soil and high organic content. The removal of biomass like leaves, branches and wood bio mass from forest land and the removal of above ground biomass by free grazing might have resulted in the soil compaction (higher bulk density). Organic matter decreases BD in that, organic matter is much lighter in weight than a corresponding volume of mineral matter and gives increased aggregate stability to soil (Troeh and Thompson, 1993). Soil with higher organic matter content has less degree of compaction. Thus soil compaction determines soil BD according to Arshad *et al*. (1996).

Soil particle density varied with land cover type and recorded the highest and lowest in soils of deforested and forested land, respectively. The lower particle density of forest land compared to grazing and deforested land is due to higher content of organic matter and trapped air in soils of forest land.

Textural classes of soils taken from different land use types were significantly influenced (P<0.05). The compositions percent clay content of the three land use types were, 60.13, 52.98 and 33.8 for forest, grazing, and deforest lands respectively. The composition percent of silt were 27.29, 34.12 and 39.41 for soils taken from forest, grazing, and deforested lands respectively whereas the percent composition of sand content were 12.48, 12.94 and 27.26 for forest land, grazing land, and deforested land, respectively. For soils of forest and grazing lands, the percent clay content was significantly higher than that of silt and sand contents. Percent clay content was significantly higher in soil collected from forest land than from grazing and deforested lands and Percent silt content was also higher than percent sand content in all land use types.

Soil pH was significantly influenced by land cover changes (P<0.001). Results revealed that soil pH varied from 6.34 to 5.25 for the different land use type (Table 2). Soil obtained from the forest land showed significantly higher soil pH value as compared to that of grazing and deforested lands. The lowest value of pH recorded in soil of deforested land might be due to the low organic carbon content and drainage of cations to streams by run-off.

This result is the same to the study reported by Gebeyaw (2007) that the highest pH recorded in forest land than cultivated and grazing lands due to cation drainage to streams in run- off generated from accelerated erosion. Based on classification of soil reaction by Tan (1996) the pH value of soil from forest land was slightly acidic, grazing land was moderately acidic whereas for that of the deforested land was strong acidic.

Table 2: Mean value of selected soil chemical properties of experimental soils

Land Uses	Soil parameters								
	pH (H_2O)	OC %	TN %	Av.P (ppm)	Ca (meq/100g)	Mg (meq/100g)	K (meq/100g)	Na (meq/100g)	CEC (meq/100g)
FL	6.34[a]	2.70[a]	0.28[a]	8.93[a]	27.12[a]	7.13[a]	2.86[a]	4.49[a]	48.08[a]
GL	5.71[b]	1.88[b]	0.20[b]	8.47[a]	20.32[b]	7.01[a]	0.95[b]	1.52[b]	37.87[b]
DFL	5.25[c]	1.76[b]	0.13[c]	5.95[b]	14.47[c]	6.82[b]	0.66[b]	1.16[b]	31.48[c]

FL=Forest land; GL=grazing land; DFL=Deforested land; OC=organic carbon; TN=total nitrogen; Av.P=available Phosphorus; CEC=cation exchange capacity. D*ata followed by the same letter with in a column are not significant different from each other at probability level of* α *=0.05 according to Tukey test.*

Percent soil organic carbon (OC) content of the soil was significantly influenced by different land use types (P<0.05). When comparison between land cover type are made, the experimental data showed that the mean value of percent soil organic carbon was 2.71, 1.88 and 1.76 for soil taken from forest, grazing and deforested land, respectively (Table 2). This result revealed that percent organic carbon in soil from forest land was significantly higher as compared to that of deforested and grazing lands. However, Percent organic carbon content in soil of grazing land and deforested land were at same level. Previous studies showed that total organic carbon, the principal component of OM, in forest ecosystem was greater than both the grassland ecosystem and agro ecosystem whereas in turn grazing land ecosystem was greater than agro ecosystems in general (Eshetu, 2010).

Cation exchange capacity (CEC) of the soil was significantly affected by land use types (*P*<0.001). The Mean value of CEC in soil of the three land cover types were 48.08, 37.87 and 31.48 (meq/100 gm) for forest, grazing and deforested land, respectively (Table 2). The CEC in soil of forest land was significantly highest as compared to in soil of grazing and deforested lands whereas the CEC in soil of grazing land was in turn higher than soils of deforested land. This high value of CEC in soils of forest land might be due to the high clay content and colloidal organic matter which have the ability to absorb and hold positively charged ions. According to Charman and Murphy 2000, the CEC is highly strongly-minded by the level of organic matter and the soil texture. The reason of low level CEC observed in deforested land might be attributed to the decline in soil OM content through erosion and nutrient cycling materials.

In line with the present findings, Gebeyaw (2007) reported that the high CEC obtained from forest land soil was directly related to the high content of clay and organic matter of the forest land. Moreover, it is in agreement with the results of Wolde and Edzo (2005) who observed CEC as significantly higher in closed areas than in free grazing lands.

The present finding indicate the significant difference of available phosphorus (P) between land covers (*P*<0.01). The mean value of available P for the three land use types were 8.94, 8.48 and 5.95(ppm) for forest, grazing and deforested lands respectively (Table 2). The present result of the study showed that available P content of soils from forest and grazing lands were significantly higher as compared to soil of deforested land. This is may be because of the forest vegetation with their larger biomass (higher quantity of litter fall), absorb larger amount of available P and the lower available P in deforested land may be because of lower SOM status, soil erosion and leaching. Result of the present study is consistent with Achalu *et al*. (2012) and Dawit *et al.* (2002b) who reported SOM as the main source of available P in most soils of Ethiopia and declined by the impacts of P fixation, abundant crop harvest and erosion.

Total nitrogen (TN) was considerably influenced by land use types (*P*<0.001). The mean values of percent TN were 0.28, 0.20, and 0.14 for soil of forest, grazing and deforested lands, respectively (Table 2). Data presented in (Table 2) revealed that the TN content of soils obtained from forest land was significantly higher than the TN content in soil taken from deforested and grazing lands. The TN content in soil of grazing land was in turn significantly higher than that of deforested land. Soil of forest land showed a medium TN content based on the classification of TN content as rated by Barber (1984) whereas soils of both deforested and grazing lands were low in TN content. The higher TN content in soil from forest land might be due to the fact that the forest ecosystem was dominated by nitrogen fixing trees which might have resulted in biological nitrogen fixation. Moreover, the high litters in the forest ecosystem might have led to mineralization of organic nitrogen, which in turn has enhanced the soil N content. The low level of TN in deforested land in contrast, could be attributed to the reduction in SOM content, soil erosion and removal of the nitrogen fixing trees. On the other hand, the lower N content of soil taken from grazing land could be due to the adverse effects of overstocking of livestock, which might have caused soil degradation. In support of the present finding, Wolde and Edzo (2005) also observed higher N content in closed areas as compared to free grazing lands.

Available potassium (k) was significantly influenced by land use types (*P*<0.01). Available K in soil obtained from forest land was significantly higher than in soils of both deforested and grazing land (Table 2.), whereas available K of grazing land was higher than deforested land. The relative low amount of K in deforested and grazing lands was the result of the removal of vegetation. The highest level of K in forest land might be due to the contribution from an undisturbed ecosystem where there is a natural balance and no removal of biomass that removes K. In agreement to this finding Eshetu (2010) reported that available K in soil forest land significantly higher than both grazing and cultivated lands. Additionally, the lower exchangeable K contents in different land uses like grazing and cultivated lands than forest lands resulted from continuous losses of harvested biomass (Gebeyaw, 2007).

The calcium (Ca) content of soil significantly varied among the land use types (*P*<0.01). The mean values of all land use types were 27.12, 20.32 and 14.47 (meq/100g) for forest, grazing and deforested land, respectively (Table 2). Compared to forest land, the relatively lower concentration of exchangeable Ca ion content recorded in soils of deforested land could be due to leaching and the higher exchangeable Ca^{2+} in forest land was attributed to higher organic soil colloids. The result of the present study revealed that the organic matter content of forest land was higher than that of grazing and cultivated land (Table 2) and hence forest soil has more a strong affinity to adsorb Ca than others soil types. Study by Achalu (2012) revealed that, deforestation contributed to depletion of basic cations and CEC.

Sodium content (Na) of soil taken from different land cover type was highly differentiated by land cover types (*P*<0.05). The concentration of Na content in the soils of three land cover types were 4.49, 1.52 and 1.16 (meq/100g) for forest, grazing and deforested land soils respectively (Table 2). An examination of data presented on Table 2, showed that the Na content of soil from forest land was significantly the highest as compared to that of grazing and deforest lands whereas Na content in soil of deforested land was the lowest of all land cover types. The relative highly significant concentration of Na^{+} ion observed in forest land than both grazing and deforested lands might be due to the percent clay content of forest land and leaching of basic nutrient by erosion from deforested land.

Exchangeable Magnesium (Mg) content was significantly (*P*<0.01) affected by land cover type (Table 2) considering the mean effects of land use the mean exchangeable Mg value was highest (7.13 meq/100g)) under the forest land and lowest (6.80 meq/100g)) on deforested land. Results obtained from soil extraction for Mg showed that exchangeable Mg^{2+} content in soil of forest land was the highest followed by grazing land. Exchangeable Mg^{2+} content in soil of grazing land, in turn was significantly higher as compared to that of deforested land. The lower Mg content in soil of deforested land might be attributed to losses in the harvested parts of plants and leaching from top soil. According to Gebeyaw (2007), deforestation, leaching, limited recycling of dung and biomass in the soil and soil erosion have contributed to depletion of basic cations and CEC from other land uses compared to forest land soil.

CONCLUSION

All of the households of the study area have been using firewood as energy source for cooking, heating, baking and lighting which have been collected more from natural forest which accompanied by high level of deforestation which aggravated soil erosion. The result of the present study is evidenced of significant changes in the quality attributes of the soils of the study area following the removal of vegetation cover there by declining soil fertility status. The study revealed the significantly declined of selected soil physicochemical properties such as (pH, OC, TN, CEC, PD, available P, exchangeable bases and soil texture). So, the process of prolonged use of firewood as source of energy with no re-plantation and conservation has exacerbated deforestation and deterioration of soil fertility status. Major declines were observed for organic matter which is the principal source of plant nutrients and helps to sustain soil fertility by mineralization and nutrient retention. This decline in organic matter and other soil quality attributes also affects the status of soil basic nutrients. Therefore, there is a need to develop sustainable modern and environmental friendly energy sources and practicing afforestation and forest management programs to overcome the deterioration of soil fertility of the present study area and other similar agro-ecology.

Conflict of Interest

All the authors declared no conflict of interest regarding publishing this paper.

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