doi:10.4149/ekol_2010_01_1

EFFECTS OF LAND USE TYPES ON SOIL CHEMICAL PROPERTIES IN SMALLHOLDER FARMERS OF CENTRAL HIGHLAND ETHIOPIA.

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Abstract

Duguma L.A., Hager H., Sieghardt M.: Effects of land use types on soil chemical properties in smallholder farmers of central highland Ethiopia. Ekológia (Bratislava), Vol. 29, No. 1, p. 1–14, 2010.

A study was conducted in Suba area, central highland Ethiopia to assess the variability in soil chemical properties between homesteads, small-scale woodlots, pasturelands, and cereal farms and see the relative soil improvement effects of the first three land uses under farmers' management compared to the dominantly practiced cereal farming. Soil samples collected from four land uses at two depth levels (0–15 cm and 15–30 cm) were analyzed. The results showed that pH (H_2O), organic C, total N, exchangeable K^+ and exchangeable Na^+ had significant differences across land uses ($p < 0.05$) while only organic C, total N and Mg^{2+} concentration showed significant difference across depth ($p < 0.05$). The soil organic C, total N, exchangeable K^+ followed a trend of homesteads > small-scale woodlots > pasturelands > cereal farms. The Relative Soil Improvement Index (RSII) computation showed that homesteads (RSII = 332.02%) and small-scale woodlots (RSII = 197.56%) are relatively very rich in soil organic C, total N, total P and exchangeable K^+, which may be due to the management effect through input of degradable materials. No difference exists between the cereals and pasturelands in RSII in Suba area which may be due to the effects of nutrient removal through cereal crops in the former and through grazing in the later. Thus, there is a need for proper land management approaches like crop remains management, pasture improvement by legumes and promotion of agroforestry interventions for the sustainable land management and optimal production of wood and food for the farm households.

Key words: soil, chemical properties, Relative Soil Improvement Index, farmers

Introduction

The dynamics of land uses in the tropical regions is of great global concern due to its direct impacts on one of the major ecosystems of the world, the tropical rainforest (Jepma, 1995).

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Land use types develop or vanish depending on the soil properties, the climate, the socio-political factors and the interest of the society or the landowner (which is often influenced by the social, ecological, and economic values attained from the land use). Though all these factors are important in general, soil properties and climatic factors are critically determinant for the existence of a given land use type, with the former being the major determinant in tropical regions as the latter is not as such a limiting factor. With the increment of human and livestock population, temporary extensification of arable farms and grazing areas has begun to influence the soil properties in turn, as the expansion is based on the conversion of the existing forestlands, which are rich in organic matter and other important soil nutrients. However, when the extensification limit is reached for example in countries like Ethiopia, where the forestland area dropped below 3% of the land cover (EARO, 2002) and the human population is growing sharply (MOFED, 2007) (almost doubling every 26.3 years), intensification (Lambin et al., 2001) i.e. the frequent and continuous utilization of the available land has continued. This resulted in severe land degradation in central highlands of Ethiopia (Grepperud, 1996).

Various studies have been conducted to assess the effect of land use changes on soil physical and chemical properties in Ethiopia (e.g. Yimer et al., 2007, 2008; Lemma et al., 2006; Lemenih et al., 2004). Lemma et al. (2006) showed that afforestation of farmland with exotic trees increased total N, exchangeable K^+, and exchangeable Ca^{2+} in surface soils while it had little effect on available P in Belete forest, which is part of government afforestation programme. Another study conducted by Lemenih et al. (2004) in Munessa Shashamene state forest area showed that soils under *Eucalyptus saligna* Sm. deteriorated more than those in traditional farming. Yimer et al. (2007) also compared croplands, forestlands and grazing lands and found that soil organic C and total N decreased in croplands as compared to forestlands. Another study conducted in India by Singh et al. (1995) showed that planting trees on alkaline soils increased organic C, available P and available K and reduced the pH more than in the open lands. On the other hand a study conducted by Tornquist et al. (1999) in Costa Rica showed that agroforestry systems composing trees did not have an effect on soil organic C and total N as compared to pasturelands.

Farmers have begun to plant trees as small-scale woodlot, boundary trees and in homesteads in response to severe scarcity of forest products (e.g. fuelwood, construction wood and animal feed) in Menagesha Suba area (Alemayehu, 2005; Duguma, Hager, 2009). These tree plantings are managed at a household level and cannot be compared with an enterprise or government plantations, which are cared for well and hence expected to have different effects on soil properties. Thus, there is a need to know what differences in soil chemical properties exist when all the land uses are under farm household management and little is done in this area. To contribute to this research gap, we assessed the following: 1) the variability in soil chemical properties (pH (H_20), organic C, total N, total P, basic cations concentrations, and cation exchange capacity) due to differences in land use types in Suba area, 2) the overall relationships of some selected soil chemical properties and, 3) the relative soil improvement effect among the major land uses in the same area.

Methods

Description of the study area

Suba, situated between 8°56'–9°00' N, and 38°31'–38°35' E, is located in Welmera district, Oromia regional state, Ethiopia. It has an average altitude of 2330 m a.s.l. receiving a mean annual rainfall of 1056 mm and has mean minimum and maximum monthly temperatures of 6 and 22 °C respectively. The monthly distribution of mean temperature and rainfall is shown in Fig. 1.

The mean family size in the area is 5.4. All farmers use the open fire cooking system where fuelwood (branches, twigs and split wood) and cattle dung are used for cooking and heating. Thus, there is a high wood and dung ash production from the process. According to a report by CSA (1996), 94.84% of the households in Welmera district do not have toilet. Agricultural production (crop production and small-scale animal rearing) is the basic livelihood activity of the community, implying the dominance of farmlands as the major land use types. However, very recently small-scale woodlots and homestead *Catha edulis* (Vahl) Forssk. ex Endl. productions are becoming very popular among the farmers. Livestock rearing is based on grazing in the communal pasturelands.

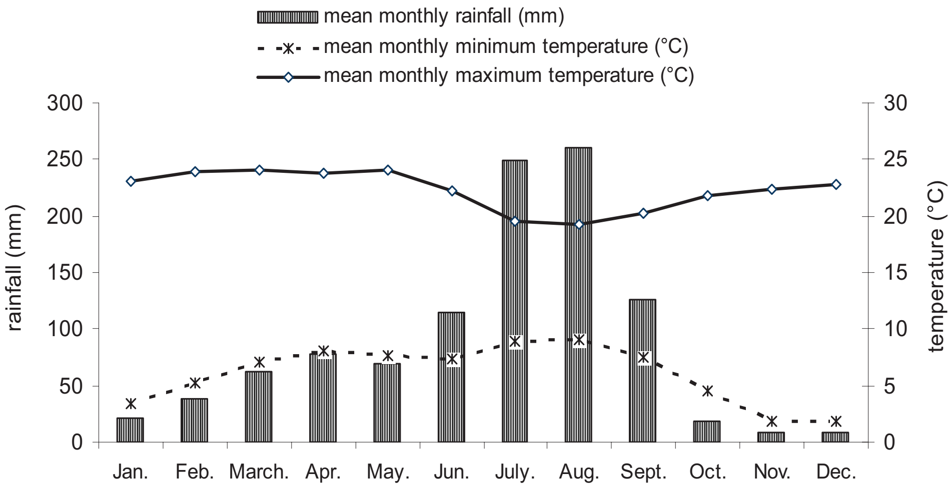

Fig. 1. Climatic condition in Suba area based on a long-term data (1963–2003) from a nearby weather station at Holleta.

Eshetu et al. (2004) showed that soil texture in the area varies from silt clay loam in the surface soils to clay or silt clay loams in the deeper horizons. They also found that rhodic nitosols dominate the depressions and gentle slopes of the area. During the dry season, the soil cracks into pieces of large soil aggregates. The soil is generally poor and cereal production is often reliant on supply of inorganic fertilizers. There is a severe soil erosion problem in the area to the extent of exposing the parent materials in some spots.

Description of the studied land uses

Ten cereal farms, nine homesteads, ten woodlots, and three communal pasturelands were selected based on the willingness of the owners and the representativeness of the land uses. In case of cereal farms and pasturelands, they should be used at least for five years to be selected for soil sampling. All land uses are located within the same topography and aspect. Cereal farms are dominantly used for growing wheat (*Triticum aestivum* L.) or teff

(*Eragrostis tef* Z u c c.). These two cereals are very small-sized and grow well in the climatic situation of the study area. Due to the poor soil condition, crops are grown by using inorganic fertilizers mainly Urea and DAP either by mixing or independently. During harvesting, the total crop stock (including the stems and seeds) is collected. Hence, small proportion of the plant biomass remains on the farmlands. Homesteads are small farm plots surrounding the residence areas used for the production of vegetables and fruits, spices, medicinal plants, trees and cash crops like *Catha edulis* and *Rhamnus prinoides*. There is an intense management activity done in homegardens due to its nearness to home and has great care from women as it provides consumable items, which the family frequently needs. The majority of the degradable household and animal wastes are thrown out to homesteads. In this study small-scale woodlots refer to small-size plantations of *Eucalyptus globulus* L a b i l l. or *Eucalyptus camaldulensis* D e h n h. established on degraded lands. The farmers stated that unproductive cereal lands are planted with trees (especially Eucalyptus) as trees demand less nutrients, which conceptually agrees with Bakker et al. (2004) finding of declining agricultural productivity due to soil erosion as a cause for land use change in Lesvos. It could also be because of the potential of trees to draw nutrients from the deeper soil horizons which are not accessible to shallow rooted crops. Currently, most woodlots are in the age range of 5–8 years and cover up to 0.5 ha in area. Pasturelands are abandoned lands which are seriously degraded and used only for grazing. Unlike the above three land uses, pasturelands are owned communally.

Soil sampling, sample preparation, and chemical analysis

Soil samples were collected from 0–15 cm and 15–30 cm depth levels from the four major land uses specified above in March 2008. At every sampling plot, soil samples were collected from five spots (north, south, east, west and centre of the plot) within the land use and composite samples were prepared by hand mixing depending on depth strata. Totally, we had 64 composite soil samples. The collected samples were weighed and air-dried for four days at 23 °C approximately. Soil samples were sifted through a 2-mm sieve and approximately 200 g of every composite sample was packed in a plastic bag and transported to Vienna, Austria for laboratory analysis at the laboratory of Institute of Forest Ecology, University of Natural Resources and Applied Life Sciences.

Soil pH was determined using a 1:2.5 (v/v) soil suspension in deionized water using a digital pH-meter (CG840, Ag/AgCl electrode, Schott Gerate, Hofheim, Germany) (Austrian Standards Institute, 2006). The pH was determined in both H_2O and 0.01 M $CaCl_2$ suspensions. Organic C was determined from over-dry weight using C/S-element Analyzer LECO S/C 444. The oven-dry samples were combusted at 1400 °C in pure O_2 and the evolved CO_2 was detected by infrared analyzer (Austrian Standards Institute, 2008a). Total nitrogen was determined from air-dry samples by Kjeldahl method. H_2SO_4 (98%) and a catalyst containing K_2SO_4 and $CuSO_4$ were used for the wet combustion of the air-dry soil samples at 400 °C (Austrian Standards Institute, 2008b). Automatic vapour distillation with saturated NaOH and titration of evolved NH_3 using Kjeltec Auto 2300, TECATOR was used (Mekonnen, 2007). Total P and S were determined using aqua regia extraction method (Austrian Standards Institute, 2008c). The exchangeable cations (Ca^{2+}, K^+, Mg^{2+}, Na^+, Mn^{2+} and Al^{3+}) were analyzed using 1M Ammonium acetate at pH of 7.0 (Grant, 1982). The cation exchange capacity, expressed in centimoles of charge per kilogram air-dry soil, was computed by summing up the charge concentrations of Ca^{2+}, K^+, Mg^{2+}, and Na^+.

Data analysis

The data was organized and entered into Statistical Package for Social Sciences (SPSS) software version 15.0.0 for Windows (SPSS, 2006). GLM with two-way-ANOVA was used to test the interaction effects of land use type and depth levels. Where significant mean differences exist, Tukey-HSD was used to test the differing means. Correlation test was conducted to assess the relationships between the different soil chemical properties. Pairwise comparison was also used to assess the mean differences of the land uses and depth levels depending on soil chemical properties. In the GLM procedure, simple contrast estimates of the soil chemical properties (dependent variables) were computed across the land use types (independent variables) for significant differences by comparing homestead, woodlot and pasturelands against cereal land use as a reference.

Variation in soil chemical properties across land uses and soil depths were computed by taking the cereal land use and the 0–15 cm soil depth as reference groups respectively. Hence, for a given soil chemical property, the variation expresses how much it increased or decreased in percent in relation to the reference group. For example, variation (%) for homestead and for 15–30 cm soil depth for a given soil chemical property were computed as:

$$\text{var}\,iation_{\text{hom}\,estead}(\%) = \left(\frac{value_{\text{hom}\,estead} - value_{Cereal}}{value_{Cereal}}\right) * 100 \quad (1)$$

$$\text{var}\,iation_{15-30cm}(\%) = \left(\frac{value_{15-30cm} - value_{0-15cm}}{value_{0-15cm}}\right) * 100 \quad (2)$$

To assess the relative soil improvement effect of the land uses, a *Relative Soil Improvement Index* (RSII) was developed. Unlike the soil deterioration index, which assumes the adjacent natural forest or woodland or savannah as a reference land use (Islam, Weil, 2000); in RSII rather the comparison is made against the more prevalent land use type. Thus, the applicability of RSII is more imperative in cases where there are severe disturbances of the landscape structures because of human and livestock overpopulation, mechanized farming and other interfering investments, which challenge the existence of the adjacent "ideal" land use type to which we compare the others. In this study, RSII was computed only based on organic C, total N, total P, and exchangeable K^+. The homestead, woodlot, and pasturelands were compared against cereal farm to see how better the soils under the other land uses are as compared to the reference one. The cereal farm is the very dominant land use type in central highlands of Ethiopia. Then, the variation $_{\text{land use}}$ (%) of the four soil chemical properties computed using Equ. 1 above are summed together to get the RSII value of a given land use type.

$$RSII_{landuse}(\%) = \sum \text{var}\,iation_{landuse}(C, N, P, K) \quad (3)$$

Results

Soil pH (H_2O), organic C, total N and total P

Results of soil pH (H_2O), organic C, total N, and total P are presented in Table 1. Woodlot soils had the lowest pH value, while homestead soils had the highest pH level as compared to others (Table 1). Yimer et al. (2007) also reported high pH values for croplands as compared to grazing land and forestlands. There was a significant difference among the land uses in pH (H_2O) ($p = 0.001$). This result agrees with Abbasi, Rasool (2005) findings of significant effects of land use types on soil pH. The organic C content was lowest for cereal farms (15.51 mg.g^{-1}) and highest for homestead (22.85 mg.g^{-1}) with relatively higher values in woodlot and pastureland. It was observed that the organic C content was significantly affected by land use type ($p = 0.021$). Total N content was found to be the least in cereal farm (1.29 mg.g^{-1}), while woodlot (1.89 mg.g^{-1}) and pastureland (1.79 mg.g^{-1}) had a similar value. This result agrees with similar studies conducted in Nigeria and Ethiopia by Onweremadu (2007) and Yimer et al. (2008) respectively, where both found high total N content in pasturelands as compared to arable farms. Homestead had the highest N content (2.04 mg.g^{-1}). A significant difference ($p = 0.007$) was observed among the land uses in total N content. Soils from woodlot and homestead contained high total P while the least content was observed in pastureland and cereal farm. However, no significant difference was observed among all land uses for total P content. Similar results were reported by Lemenih et al. (2004) in which case the avail-

T a b l e 1. Mean ± S.E. of soil chemical properties across different land uses in 0–30 cm soil depth in Suba area.

Soil properties	Cereal farm	Homestead	Woodlot	Pastureland
pH (H_2O)	6.32 ± 0.11ab	6.57 ± 0.12b	5.90 ± 0.11a	6.08 ± 0.21ab
Organic C ($mg.g^{-1}$)	15.51 ± 1.69a	22.85 ± 1.78bc	21.57 ± 1.69ac	20.31 ± 3.08ac
Total N ($mg.g^{-1}$)	1.29 ± 0.15a	2.04 ± 0.16b	1.89 ± 0.15b	1.71 ± 0.28ab
Total P ($mg.g^{-1}$)	0.46 ± 0.12a	0.91 ± 0.13a	0.76 ± 0.12a	0.41 ± 0.22a
Ca^{2+} ($cmol_c.kg^{-1}$)	11.27 ± 0.76a	10.89 ± 0.80a	8.89 ± 0.76a	8.36 ± 1.38a
K^+ ($cmol_c.kg^{-1}$)	1.36 ± 0.27a	3.12 ± 0.28b	2.00 ± 0.27a	0.83 ± 0.49a
Mg^{2+} ($cmol_c.kg^{-1}$)	3.63 ± 0.19a	3.85 ± 0.20a	3.50 ± 0.19a	3.41 ± 0.34a
Na^+ ($cmol_c.kg^{-1}$)	0.16 ± 0.04a	0.13 ± 0.04a	0.20 ± 0.04a	0.44 ± 0.08b

Notes: Means across a row followed by the same letter are not significantly different at $p < 0.05$.

able P remained unaffected by land use variability. Lemma et al. (2006) also showed that afforestation of previous farmland did not show any effect on soil P.

Across land uses, we found that organic C, total N, and total P declined with depth for cereal farm, homestead and woodlot (Table 2). The highest decline with depth was observed in woodlots. The reverse was observed in pastureland i.e. the organic C, total N, and total P increased by 48.48%, 63.64% and 20.42% respectively across depth. The pH decreased with depth for cereal farms, woodlots and pastureland while it increased for the homesteads. When all soil samples are pooled, the soil pH (H_2O), organic C, total N, and total P decreased with increasing soil depth up to 30 cm depth. However, only organic C and total N differed significantly with depth ($p = 0.034$ and 0.042 respectively). The organic C declined 19% within the upper 30 cm soil depth while the total N and total P decreased by 26 and 20% respectively.

T a b l e 2. Variation (%) in soil chemical properties between 15–30 cm and 0–15 cm soil depth compared to values of 0–15 cm soil depth in Suba area.

Soil properties	Cereal farm	Homestead	Woodlot	Pastureland
pH (H_2O)	-1.26	1.19	-1.35	-5.85
Organic C ($mg.g^{-1}$)	-17.65	-22.48	-29.92	48.48
Total N ($mg.g^{-1}$)	-22.38	-22.57	-29.13	63.64
Total P ($mg.g^{-1}$)	-25.97	1.87	-41.86	20.42
Exch. Calcium ($cmol_c.kg^{-1}$)	-0.10	-11.26	9.96	-19.74
Exch. Potassium ($cmol_c.kg^{-1}$)	-25.43	2.10	-26.02	-3.66
Exch. Magnesium ($cmol_c.kg^{-1}$)	-10.32	-12.38	-8.91	-16.32
Exch. Sodium ($cmol_c.kg^{-1}$)	81.87	-17.03	-26.58	-51.36
Cation exchange capacity ($cmol_c.kg^{-1}$)	-4.23	-9.36	-0.97	-19.22

Exchangeable cations

The exchangeable Ca^{2+} was highest in cereal farm and homestead as compared to woodlot and pastureland in 0–30 cm soil depth (Table 1). The values ranged from 8.36 $cmol_c.kg^{-1}$ in pastureland to 11.27 $cmol_c.kg^{-1}$ in cereal farm. The highest exchangeable K^+ content was observed in homestead (3.12 $cmol_c.kg^{-1}$) followed by woodlot (2.00 $cmol_c.kg^{-1}$) and cereals (1.36 $cmol_c.kg^{-1}$). The pasturelands had the lowest exchangeable K^+ content (0.83 $cmol_c.kg^{-1}$). The exchangeable Mg^{2+} followed the trend of homestead > cereal > woodlot > pastureland, though there is no significant difference among the land uses (Table 1). The exchangeable Na^+ content was highest in the pastureland (0.88 $cmol_c.kg^{-1}$) compared to woodlot (0.20 $cmol_c.kg^{-1}$), cereal farm (0.16 $cmol_c.kg^{-1}$), and homestead (0.13 $cmol_c.kg^{-1}$).

All the exchangeable cations decreased with depth except exchangeable Ca^{2+} in woodlots, exchangeable K^+ in homesteads, and exchangeable Na^+ in cereal farms that showed the reverse trend (Table 2).

Cation exchange capacity (CEC)

The cation exchange capacity did not show any significant difference among the land uses. However, the homestead has the highest CEC value (18.00 $cmol_c.kg^{-1}$) followed by cereal farm (16.41 $cmol_c.kg^{-1}$), woodlot (14.59 $cmol_c.kg^{-1}$) and pastureland (13.04 $cmol_c.kg^{-1}$). The CEC decreased with depth in all the land uses with a 19% sharp decline across depth in pasturelands.

Correlation between soil chemical properties

The correlations between the different soil chemical properties are presented in Table 3 and Fig. 2. The pH (H_2O) had strong correlation with exchangeable cations and CEC, which is directly affected by the exchangeable cations. The CEC significantly influences most of

T a b l e 3. The correlation matrix for soil chemical properties in 0–30 cm soil depth in Suba area.

	pH (H_2O)	C	N	P	Ca^{2+}	K^+	Mg^{2+}	Na^+
C	0.17							
N	0.15	0.97**						
P	0.38**	0.77**	0.76**					
Ca^{2+}	0.64**	0.22	0.11	0.29*				
K^+	0.58**	0.70**	0.70**	0.70**	0.40**			
Mg^{2+}	0.55**	0.37**	0.28*	0.28*	0.77**	0.49**		
Na^+	0.22	0.03	-0.04	-0.06	0.26*	-0.06	0.32**	
CEC	0.71**	0.42**	0.32**	0.45**	0.95**	0.64**	0.86**	0.26*

Notes: * significant at 5%, ** significant at 1%.

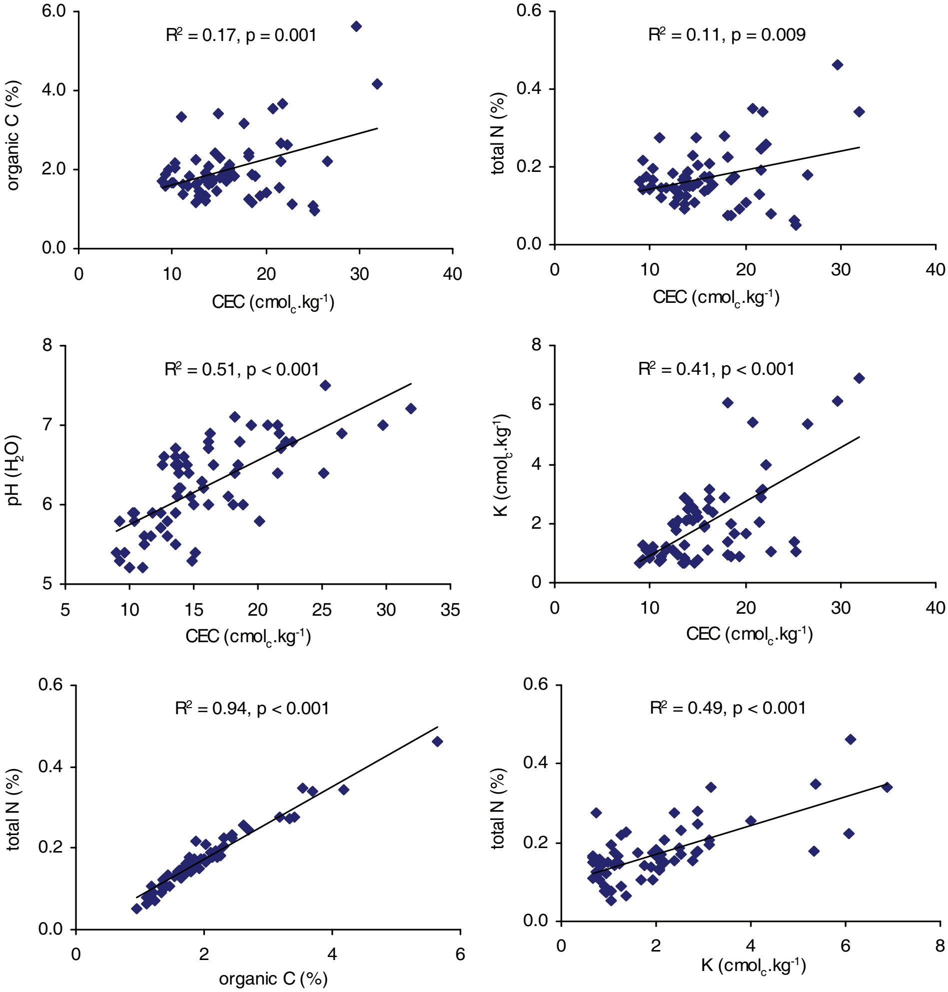

Fig. 2. The relationship between the different soil chemical properties in 0–30 cm soil depth in Suba area.

the soil chemical properties in Suba area (Table 3 and Fig. 2). Generally, there is a strong association between the different soil chemical properties.

Comparison of the homestead, woodlot, and pastureland based on soil chemical properties using the cereal land use as a reference land use

The homestead had a RSII value of 332.02% followed by woodlot (197.56%) and lastly pastureland (14.64%). These values indicate that homestead soils are very rich relative to the

Table 4. Variation (%) in soil chemical properties within 0–30 cm soil depth between homestead, woodlot, and pastureland as compared to cereal farm in Suba area..

Soil properties	Homestead	Woodlot	Pastureland
pH (H_2O)	3.99	-6.65*	-3.75
Organic C ($mg.g^{-1}$)	47.29**	39.05**	30.90
Total N ($mg.g^{-1}$)	58.06**	46.59**	32.56
Total P ($mg.g^{-1}$)	96.74*	64.35	-10.22
Exch. Ca ($cmol_c.kg^{-1}$)	-3.39	-21.12*	-25.81
Exch. K ($cmol_c.kg^{-1}$)	129.93**	47.57	-38.60
Exch. Mg ($cmol_c.kg^{-1}$)	6.16	-3.45	-5.99
Exch. Na ($cmol_c.kg^{-1}$)	-15.00	23.13	176.88*
CEC ($cmol_c.kg^{-1}$)	9.66	-11.10	-20.53

Notes: * significant at 5%, ** significant at 1%.

cereal farm soils in organic C, total N, total P, and exchangeable K^+, which all together are very important for plant growth and productivity. Woodlot soils were the next richer soils in Suba area. There is no significant difference between the pastureland and cereal farm, which indicates either the improvement of the abandoned pastureland through time due to animal wastes, or the declining quality of the cereal farms due to intensive cultivation. The continuous nutrient removal through annual crops harvesting in cereal land use and through livestock grazing by free grazing practice in pasturelands also contribute to the lack of difference between the two land uses in the study area. It is not so surprising if the cereals had the lowest values in soil properties because they are exposed to wind and water erosion (Onweremadu, 2007) as they are only covered for few months in a year and hence even the available nutrients are easily washed or blown away with the topsoil. On the other hand, the exposure to higher irradiance increases the soil temperature, which in turn may facilitate faster mineralization of the available organic matter (Onweremadu, 2007; Kirschbaum, 1995) so that the released mineral nutrients may be consumed by the annual crops.

When all the soil chemical properties are taken into account (Table 4), the homestead is the most preferred land use type in its soil quality in Suba area while cereal farm is the least. The woodlot, though not as rich as the homestead in its soil, is still considerably better than the pastureland and the cereal farm.

Discussion

Effects of land use types on organic C, total N and total P

The high organic C, total N, and total P content of homesteads can be attributed to its management and location. The household wastes, livestock waste, wood and dung ash and other decomposable materials are often thrown to the homesteads which in aggregate increase the availability of the above nutrients through time. Livestock urine and dung are good sources of N (Richards, Wolton, 1976). Thus, the addition of these components to the homesteads promotes the concentration of total N and organic C. In addition, as different types of plants (fruits, vegetables, spices, medicinal herbs and shrubs and other tree species) are grown in the homesteads, the leaf and other plant remains all add up to the high C content. The high P concentration in the homestead soils can be attributed to waste from chickens and birds and to the wood and dung ash, which are cleaned from the kitchen daily and thrown out to the homesteads. Bone remains from slaughtered animals can also be important source of P in the homesteads. Wood ash is an important source of P and K^+ (Pitman, 2006).

Unlike in other studies (e.g. Lemenih et al., 2004; Zerfu, 2002) the woodlots, though established on poor soils which are inappropriate for agricultural use, had better organic C, total N, and total P. This may be because these woodlots established nearby residence areas also serve as "toilets" too, as more than 95% of the community does not have toilet (see section 2.1). Every family member and neighbors go to these plots to leave their wastes (feces and urine). Assuming a 0.3 kg person^{-1} day^{-1} human dung production (dry weight) (Amoo-Gottfried, Hall, 1999) and a 5.38 average family size, the annual human dung input to the woodlots is 589 kg yr^{-1} household^{-1}. The other reason for better nutrient content of woodlots could be the absence of leaf litter raking from Eucalyptus woodlots in Suba area unlike in other parts of the country. In addition, the shrubby and herbaceous undergrowths that frequently die and decompose add to the nutrient contents of the woodlots. Litterfall from trees are also important sources of nutrients, though Eucalyptus litter has low decomposition rate generally (Louzada et al., 1997). Furthermore, the frequency of nutrient removal through the wood harvest is less as compared to the cereals and pasturelands because the trees need some years to grow.

The pasturelands had relatively high organic C and total N mainly due to the growing habit of the grasses i.e. the grasses frequently develop juvenile leaves and stocks, which add to the N and C content of the soil. The dense root biomass of grasses is also an important contributor for higher C content (Rhodes et al., 2000) from fine root turnover and decay. Livestock waste is another important nutrient input for the pasturelands as the animals stay the whole day in the grazing area and their waste remains out there especially in the rainy season when it becomes solubilized by rain water and mixes with the soil. In dry seasons most of the dung is collected for fuel purpose.

In cereal land use, the low organic C, total N, and total P content may be due to the frequent harvesting in which case the crops perpetually remove the nutrients from the soil (Fermont et al., 2008; Haileslassie et al., 2005). The removal of the crop remains (Haileslassie et al., 2005) for house wall making and animal feed almost leaves no biomass to be returned to the soil. The small-sized nature of the major crops grown (teff and wheat) in the study area is another constraint for the nutrient return to the soil through plant remains, a determinant source for labile C (Hooker, Stark, 2008). Cultivation also exposes the available organic matter to moisture (Reicosky, Forcella, 1998), aeration and other decomposing agents, facilitating the fast degradation and mineralization (Wild, 2003) of the available organic matter thereby reducing the soil C and N. The frequent (Shisanya et al., 2008) i.e. intense utilization of farmlands (Murage et al., 2000) due to land shortage is another factor for the diminishing quality of the farmlands as the crops remove substantial amount of nutrients (Fermont et al., 2008) with minimal return rate every year. The cereal land use does not have other substantial sources of P except inorganic fertilizers, which the crops consume during their temporary growing time. Nevertheless, a small amount of P may be deposited through dirt in the rainy season.

Organic C, total N, and total P decreased with depth except for pastureland. The high content of these elements in deeper layers of the pastureland soils is mostly due to the dense root biomass in the deeper soil layers, which when dead and decomposed increase the organic C, total N, and total P. In the other three land uses the external inputs like human and animal wastes and inorganic fertilizers temporarily remain in the top surface soil rather than going deeper. Cultivation in homesteads and cereal farms mixes up the soil in the upper and lower depths especially in the upper 30 cm depth.

Effects of land use types on exchangeable cations, CEC and pH (H_20)

The high exchangeable Ca^{2+}, Mg^{2+}, and K^+ of the homesteads is still associated with the effect of external inputs (wood and dung ash) to the land use because of its proximity to living quarters. Wood ash provides considerable amount of Ca^{2+}, K^+, Mg^{2+}, and other trace elements (Pitman, 2006; Misra et al., 1993). Thus, the throwing out of wood ash to homesteads significantly influences the exchangeable Ca^{2+}, K^+, and Mg^{2+}. The household and animal wastes also contribute to the increase in these cations in homesteads. The lack of significant differences among the cereal farm, homestead and woodlot in Mg^{2+} may be due to the little impact of tree planting (afforestation) on soil Mg^{2+} concentrations (Lemma et al., 2006). The relatively high pH in pastureland may be due to burning of the grass biomass during the dry season producing ash which at least temporarily increases the concentration of the base cations (Islam, Weil, 2000). The highest concentration of the exchangeable Na^+ in pasturelands may be due to the effects of livestock urine, which is added daily to this land use type through free grazing. Similarly, the human urine disposed often at the woodlots is another factor for the high Na^+ concentration as human urine contains high concentration of NaCl (Lind et al., 2000). The high concentration of the exchangeable Na^+ in pastureland is also accountable for its high pH.

The decrease in the exchangeable cations with depth in most of the land uses may be due to cation leaching. Furthermore, in cereals and homesteads, hoeing (Habarurema, Steiner, 1997) and cultivation also play a vital role because they mix up the upper layer, where inorganic fertilizers, wood and dung ash, and household wastes are added, with the lower soil layers. Thus, in addition to the cations leaching, farm management is also critically important in translocating the cations.

Conclusion

Land use type has a significant impact on soil chemical properties in Suba area. Homesteads, due to their composition and proximity to living quarters, were found to be better in organic C, total N, total P and exchangeable K^+. The poor infrastructural development in the study area, i.e. lack of toilet for most of the households and usage of open cooking were opportunities for the high nutrient inputs to woodlots and homesteads. This calls to attention the consideration of the holistic view of the area when assessing its soil properties because some important nutrient input sources may be ignored unintentionally. The cereal farms were found to be even poorer than the pasturelands, which the farmers abandon because of poor productivity. This signals the great need for soil amelioration activities, for example through agroforestry practice and incorporation of N-fixing trees into the farming systems so that the soil organic C, N, P and exchangeable bases concentration will be improved and enable production of sufficient food and wood for the farm households at the same time minimizing soil degradation.

Translated by the authors

Acknowledgements

We are very grateful for all assistances we have got from the community around Menagesha Suba area. We also thank the Austrian Exchange Service for financially supporting this study. Our special thanks also goes to G. Mistlberger, K. Wriessnig and A. Gruber for their support during the soil analysis. We appreciate the assistance of Alemayehu Negassa, Ayantu Tadesse and Getachew Negesse during the soil sample collection in the field. We are also very grateful to the two anonymous reviewers and the editorial team for the valuable comments.

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