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Soil Quality Variation between Prosopis juliflora Dominated Land and Adjacent Land Use Types: The Case of Dupti Sub-Watershed, Afar Regional State, Ethiopia

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Abstract
The study was conducted in Dupti sub-watershed, Afar Region, Ethiopia with the objective assessing soil quality variation between Prosopis juliflora land and adjacent land use types. A total of 18 soil samples (3 LUT x 2 soil depth layers x 3 replicates of sample plot) were collected and soil physico-chemical quality indicators were analyzed. Parameters such as SOC, Total N, available P, Electrical conductivity, Sand fraction, and exchangeable cations (Ca, Mg & K) content were found to be highest in the prosopis land than others, while pH, CEC and clay content were highest in the cultivated land; and pH was lowest under prosopis land while exchangeable Na and silt content were highest under the bare land. Exchangeable (Ca, Mg and K) were found to be lower under the bare land, while exchangeable Na was lower in prosopis land. Sand and clay, Bulk &Particle density, PWP and Exchangeable Na increased with soil depth while silt, FC, AWHC, Exchangeable Ca &Mg, pH, SOC, Total N, available P, CEC, and EC decreased with soil depth. Generally, most soil quality indicators show significant variation ($p \leq 0.05$) between prosopis dominated land and adjacent land use types. Thus, prosopis dominated land has better soil quality than adjacent land use types. Therefore, Control of prosopis will be the best option when it is acknowledged for its various economic and ecological values while eradication can be applied where it get out of control in highly valuable irrigable areas and grazing lands seems quite important to improve and sustain the soil quality and to maintain the sustainability of Ecology.
Keywords: Prosopis juliflora, Land use types, Soil depth, Soil Quality

INTRODUCTION

Changes in land use and land cover such as from forest to arable land and pasture land directly affects terrestrial ecosystems and biogeochemical cycles (Zewdu, 2000; Sahani and Behera, 2001; Mulugeta *et al.,* 2005a). Soil nutrient status has been found to have strong relation to land use (Zewdu, 2000; Mulugeta *et al*., 2005a).Thus land use type and subsequent land management practices have impacts on the magnitude of changes in soil quality.

Human-related activities play a major role in promoting soil degradation through deforestation, overgrazing, inappropriate tillage, nutrient mining, salinization and acidification (Barrios *et al*., 2006). Soil quality can be defined as "the capacity of a specific kind of soil to function within natural or managed ecosystem boundaries to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation" (Karlen *et al*., 1997; FAO, 2004). Soil quality is usually considered to have three main aspects such as physical, chemical, and biological soil properties and is important for the assessment of the extent of land degradation or amelioration, and for identifying management practices for sustainable land use (Schoenholtz *et al*., 2000; Dexter, 2004; Masto *et al*., 2008; Singh and Khera, 2009).

Since soil quality is a function of both static and dynamic soil physical and chemical properties for a given land use type, site-specific assessments of soil physical and chemical properties are required for proper understanding of the impact of present managements. Even though this paper is specifically dealing with soil physical and chemical qualities, it should be realized that land use changes can have similar, far-reaching effects on biological processes in the soil. Therefore, understanding of the soils' physical and chemical properties are of paramount importance for the utilization and proper management of the soil resources (Fantaw *et al*., 2006; Shukla *et al*., 2006; Bastida *et al*., 2008). In addition, knowledge of the variability in soil physical and chemical properties is a key for understanding the impact of land use on soil quality and for designing site-specific management practices (Shukla *et al*., 2006).

The main problem of the study area has been resource degradation and low productivity of the land, caused by lack of appropriate land management system. In the region; the area occupied by the *Prosopis juliflora* is around 1.2 Million ha and annually it invades around 50,000 ha of land (Media/02/03/2013).

Generally, the continuing or accelerating course of rangeland degradation in the Region shows changes in soil surface conditions, notably compaction through trampling by livestock, leading to deterioration in soil - plant - water relationships and reduced germination rate, particularly of the palatable species. The extent and rate of soil quality under *Prosopis juliflora* land with the adjacent land use types were not identified and quantified. Thus, the study focused on investigating the impact of *Prosopis juliflora* dominated land and adjacent land use types on soil quality and effect on sustainable NaRM and environmental protection.

The general objective of this study was to assess soil quality variations between *Prosopis juliflora* forest land and adjacent land use types with specific objectives evaluate and compare the effect of land use changes on the variability of soil properties and assessing the impact of *Prosopis juliflora* on soil properties.

METHODOLOGY

Description of study site

Geographically, the Afar Regional state is located in the northeastern part of Ethiopia. The total geographical area of the region is about 270,000 km^2 (CSA, 2008). It is geographically located between 39°34' and 42°28' East Longitude and 8°49'and 14°30'North Latitude. The region shares common international boundaries with the State of Eritrea in the north-east and Djibouti in the east, as well as regional boundaries with the Regional States of Tigray in the north-west, Amhara in the south-west, Oromia in the south and Somali in the south-east.

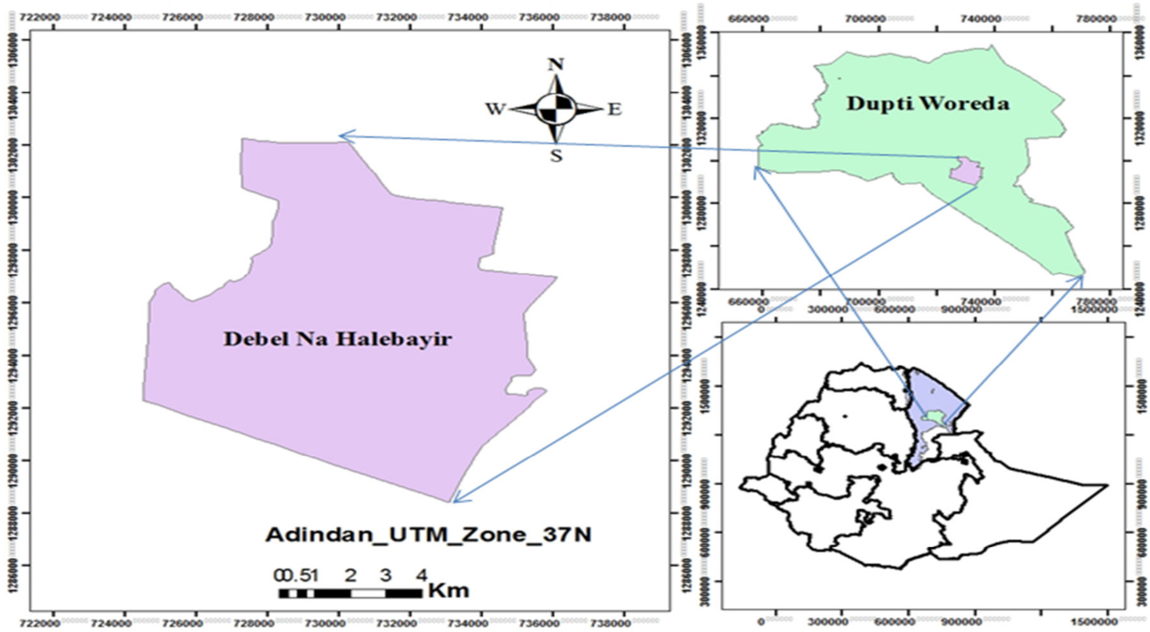

Figure 1: Map of the study area, Debel Na Halebayir study sub-watershed

Soil Sampling and Analysis

In Dupti watershed, there are three main land use types from which soil samples were collected; *Prosopis juliflora* dominated land, bare land and cultivated land. The major criteria to locate the sampling plots are closeness of the *Prosopis juliflora* land to adjacent land uses and to each other of the three land uses. Soil samples were taken from two depths, 0–15 and 15–30cm with sharp edged and closed, circular auger pushed manually down the soil profile. Collected soil samples were air-dried at room temperature, crushed, homogenized and passed through a 2mm sieve before laboratory analysis. A total of 18 soil samples (3 land use types x 2 soil depth layers x 3 replicates of sample plots) were collected for soil analysis. Moreover, undisturbed samples were taken with a core sampler for bulk density determination. The analysis was conducted at the Worer research center soil laboratory following standard laboratory procedures and methods.

Analysis of Soil Physical Properties

Soil particle size distribution was determined by the Boycouos hydrometric method (Bouyoucos, 1962; Van Reeuwijk, 1992) after destroying OM using hydrogen peroxide (H_2O_2) and dispersing the soils with sodium hexameta phosphate ($NaPO_3$). Soil bulk density was determined by the undisturbed core sampling method after drying the soil samples in an oven at 105 °C to constant weights, while particle density was measured by the pycnometer method (Black, 1965). Percentage pore space was computed from the values of bulk density (BD) and particle density (PD) (Brady and Weil, 2002) as:

Equation 1: Total pore space (%) = (1-(BD/PD)) x 100.

In order to determine the available water holding capacity (AWHC) of the soil, the field capacity (FC) and permanent wilting point (PWP) were measured using the pressure plate apparatus (Klute, 1965). The AWHC was obtained by subtracting PWP from FC.

Analysis of Soil Chemical Properties

The pH of the soil was measured in water and potassium chloride (1M KCl) suspension in a 1:2.5 (soil: liquid ratio) potentiometrically using a glass-calomel combination electrode (VanReeuwijk, 1992). The electrical conductivity (EC) of soils was measured from a soil water ratio of 1:2.5 socked for one hour by electrical conductivity method as described by Sahlemdhin and Taye (2000). The Walkley and Black (1934) wet digestion method was used to determine soil carbon content and percent soil OM. Total N was analyzed using the Kjeldahl digestion, distillation and titration method as described by Black (1965. Available soil P was analyzed according to the standard procedure of Olsen *et al.* (1954) extraction method.

Cation exchange capacity (CEC) and exchangeable bases (Ca, Mg, K and Na) were determined after extracting the soil samples by ammonium acetate. Exchangeable Ca and Mg in the extracts was analysed using atomic absorption spectrophotometer, while Na and K by flame photometer (Chapman, 1965;Rowell, 1994). Cation exchange capacity was thereafter estimated titrimetrically by distillation of ammonium that was displaced by sodium from NaCl solution (Chapman, 1965). Percentage base saturation (PBS) was calculated by dividing the sum of the charge equivalents of the base-forming cations (Ca, Mg, Na and K) by the CEC of the soil and multiplying by 100.

Method of Data Analysis /Statistical Analysis

The treatments consisted of factorial combinations of land use types and soil depths which were replicated three times. Land use types (*Prosopis juliflora* land, bare land and farmland) and soil depth were used as independent variables (factors) and the soil parameters as dependent variables. The significance difference of soil quality indicators with land use types and soil depth were tested using Analysis of variance (ANOVA) following general linear model (GLM) procedure at $P \leq 0.05$. The Tukey HSD (Honest Significant Difference) test has also been applied to separate the factors that are statistically different ($P \leq 0.05$) using SAS 9.1.3 (Portable) Statistics. Moreover, simple linear correlation analysis was applied to evaluate relationships among soil properties.

RESULTS AND DISCUSSION

Soil Physical Properties

Soil Texture

The sand, silt and clay fractions were significantly ($P \leq 0.05$) affected by land use but it was not significantly affected by soil depth and the interaction of land use and soil depth (Table 2). Except the bare land (loam), there were no textural class differences among the three land use type's and the two soil depths i.e. sandy clay loam. This result indicates that texture is relatively a permanent property which is less affected by management practices & it's in agreement with Sanchez *et al.* (1985).

The highest average (surface and subsurface) sand content (57.4%) was observed under the prosopis dominated forest land and the lowest (51.07%) was recorded in the bare land, whereas the average clay fraction of the prosopis dominated forest land, cultivated land and bare lands were 22.43, 27.93 and 20.43%, respectively (Table 2). The higher clay content on cultivated land may be due to the intensive and continuous cultivation which might cause compaction on the surface that reduces translocation of clay particles within the different layers and due to mixing up by tillage activities in agreement with the findings reported by Wakene (2001) and Jaiyeoba (2001). On the other hand the highest amount of sand fraction observed in the prosopis dominated forest land is due to high infiltration that is happened in the forest i.e. the finer particles like colloidal clay move to the subsurface under the prosopis.

Considering the two soil depths, numerically the higher mean sand fraction (54.29%) was observed within the subsurface soils (Table 2). This is most probably due to low leaching effect of finer materials as a result of low rainfall observed in the study area. The result is not in agreement with Chesworth (2008) reported the reverse to this idea. Similar to sand, higher clay fraction (23.93%) was found in the subsurface soil layer. This is due to down ward movement of clay particles. The increase in clay fraction with increasing depth agrees with the results of others (Rezaei and Gilkes, 2005; Fantaw *et al.*, 2006; Sintayehu, 2006; (Chesworth, 2008; Khresat *et al.*, 2008). The silt content decreases with depth & numerically higher amount is found at the surface (0-15cm).Generally, the results showed that soil texture was significantly varied with land use types. However, management practices may contribute indirectly to the changes in soil texture particularly in the surface layers as a result of continuous breakdown of structures.

Sand was positively and significantly correlated with OM, total nitrogen, exchangeable Ca with correlation coefficient of r = 0.54*, 0.54*, 0.54, respectively. Whereas, it was negatively and significantly correlated with silt, bulk density, pH & exchangeable Na at correlation coefficients of r = -0.61**, -0.68**, -0.72** and -0.60**, respectively. Opposite to sand, the clay fraction was positively and significantly correlated with pH & available water holding capacity at correlation coefficients of r = 0.44* & 0.70**, respectively (Table 4).

Bulk and Particle densities

The mean bulk density show highly significant variation across all land use types and there was no significant difference with soil depths and with their interaction effects ($P \leq 0.05$; Table 2). The overall mean of soil bulk density under different land use types generally ranges from 1.36 g/cm^3 in the *prosopis* forest land; 1.51 g/cm^3 in cultivated land and 1.61g/cm^3 in the bare land i.e. the lowest bulk density under the *prosopis* forest land which is largely attributed to its largest soil OM content, less animal trampling effect and disturbance during plowing that makes soils loose, porous and well aggregated, and thereby lower bulk densities and the highest under bare land (Table 2). The result is in agreement with various studies (Mulugeta et al., 2005; Sintayehu, 2006; Celik, 2005; Awdenegest and Holden, 2008; Nega (2006)) found that bulk density was significantly varied with land use types. However, it was not in agreement with Fikadu (2006) and Gebeyaw (2007) that found land use types didn't significantly affect soil bulk density. This variation of results might be due to the difference in ecology, climate, land management, and land use histories.

Soil bulk density across soil depth was found to be lower in the surface soil layer than in the sub-surface soil layer, indicating the tendency of bulk density to increase with soil depth, due to the effects of weight of the overlying soil and the decrease in organic matter content (Brady and Weil, 2002; Shiferaw, 2004). According to Ameha (2006) and Getachew (1999) report no significant variation in bulk density with depth for Awash Valley and rift valley area.

The result of the analysis show that particle density was significantly ($P \leq 0.05$; Table 2) affected by land use types and it was not significantly affected by soil depth and their interaction effects. Particle density was not significant in between bare land and cultivated land. With respect to depth, the overall mean soil particle density increased from the surface (0-15 cm) to the lower subsurface soil layer (15-30 cm). The mean particle density of bare land (2.63 g/cm^3) is higher than cultivated land (2.61 g/cm^3) and the least in prosopis forest land (2.43 g/cm^3). The values were in agreement with Hillel (2004) reported in most mineral soils, the mean particle density is about 2.6 to 2.7 g cm^{-3} except in prosopis area.

Soil bulk density was positively and significantly correlated with pH, exchangeable Na, and the silt fractions with correlation coefficients of r = 0.54*, 0.64**, and 0.67**, respectively and negatively correlated with OM, total N, exchangeable calcium at correlation coefficients of -0.74**, -0.75** and -0.70**, respectively (Table 4).

Percentage Total Porosity

The result of the analysis show that the percentage total porosity of the site was significantly varied with land use types and it was not significantly affected by the soil depth and their interaction effects ($P \leq 0.05$; Table 2). The total porosity show no significant variation in between prosopis forest land and cultivated land and it is significantly different in between prosopis forest land and bare land and the highest total porosity was observed in the prosopis forest land due to the fact that high OM content and low bulk density. In general, it is a universal truth that fine textured soils have higher total porosity than coarse textured soils.

The mean total porosity at the surface (0-15 cm) soil was significantly higher than the subsurface soil layer. As a general trend, soil porosity decreased with depth because porosity had positive relation with OM and negative relation with bulk density. Thus, high total porosity was the reflection of high OM and low bulk density. The results of this study agreed with the findings of Mebit (2006) reported that the high total porosity was the reflection of high organic matter content along the toposequence of Woreta agricultural research farm. Similarly, Wakene (2001) reported that the low total porosity was the reflection of the low organic matter content and the high bulk density.

Table 1: Effects of land use and soil depth on selected soil physical properties

Trts (LUT)	Sand (%)	Silt (%)	Clay (%)	STC	BD g cm^{-3}	PD g cm^{-3}	TP (%)	FC (%)	PWP (%)	AWC (%)
PFL	57.4^a	20.17^b	22.43^b	SCL	1.36^c	2.43^b	43.7^a	28.16^b	12.66^a	15.50^b
CL	51.40^b	20.67^b	27.93^a	SCL	1.51^b	2.61^a	42.3^a	31.33^a	13.16^a	18.16^a
BL	51.07^b	28.50^a	20.43^b	Loam	1.61^a	2.63^a	38.4^b	28.00^b	13.50^a	14.50^b
LSD (0.05)	3.27	3.93	2.92		0.10	0.11	3.27	2.16	1.32	2.11
SEM (±)	1.503	1.805	1.34		0.05	0.05	1.50	0.99	0.60	0.97
Soil depth (cm)										
0-15	52.29^a	24.44^a	23.27^a	SCL	1.49^a	2.53^a	42.4^a	30.00^a	13.00^a	17.00^a
15-30	54.29^a	21.78^a	23.93^a	SCL	1.50^a	2.60^a	40.6^a	28.33^a	13.22^a	15.11^b
LSD (0.05)	2.67	3.21	2.38		0.087	0.09	2.67	1.76	1.08	1.73
SEM (±)	1.503	1.805	1.34		0.05	0.05	1.50	0.99	0.60	0.97
CV (%)	4.88	13.53	9.83		5.65	3.54	6.27	5.88	8.04	10.48

*CL= Cultivated land; BL= Bare land; PFL=Prosopis forest land. Different letters in a column indicate significant (P≤0.05) differences between the mean value in the different land use types and soil depth; STC = Soil texture class; SCL = Sandy clay loam; BD = bulk density; PD=Particle density; FC=Field capacity; PWP=Permanent wilting point; AWC=Available water holding capacity; %TP=Percentage total porosity; LSD = Least significant difference; SEM = Standard error of the mean; CV = Coefficient of variation.

Soil Water Characteristics

Soil water content at FC was significantly affected by land use types, but not significantly affected by soil depth and the interaction effects (P≤0.05; Table 2). The AWC was significantly (P≤0.05; Table 2) affected by soil depth and land use types but it was not affected by their interaction effects. The AWC and FC didn't show any significant variation within prosopis forest land and bare land. Moreover, PWP of the soils was not significantly (P≤0.05; Table 2) affected by soil depth, land use types and also their interaction effects (Table 2).

Water content at PWP was significantly increased from the surface (0-15 cm) to the subsurface (15-30 cm) soil layer, largely due to the increasing clay content with depth. The findings of this study was in line with the finding of Wakene (2001), who reported that soil water contents at PWP increased with depth due to the increasing trends of clay content along with the profile. The water content at FC was highest in the surface (0-15 cm) and decreased in the subsurface (15-30 cm) soil layer and the finding was not in agreement with the finding of Wakene (2001) who reported the opposite idea to this one. The AWC was the highest in the surface (0-15 cm) and decreased in the subsurface (15-30 cm) soil layer (Table 1). This was probably due to the reduction of OM from the surface to the subsurface soil layer (Table 1). According to Beernaert (1990) rating, the available water content of the soils in the study area was rated as medium.

Soil chemical properties

Soil Organic Carbon

Generally, the soil organic carbon content show highly significant variations with all land use types, and didn't show any significant variation with soil depths and their interaction effects (P ≤0.05; Table 3). The overall SOC content was significantly higher under prosopis forest land (0.14) than cultivated land (0.09) and the least under bare land (0.06); P ≤ 0.05; Table 3). As in Zelalem (2007), Total nitrogen (TN) and soil organic carbon (SOC) levels have shown increasing trend with increasing prosopis than the site without Prosopis.

The lower SOC content under cultivated land than in prosopis forest land could be due to the reduced amount of organic material being added to the soil system, and high rate of oxidation of soil organic matter as a result of continuous cultivation for long period of time without fallowing, loss of organic matter by water erosion, removal of green materials. The result is in agreement with the following various findings (Dalal and Chan, 2001; Jaiyeoba, 2003; Fantaw *et al*., 2007; Awdenegest and Holden, 2008) reported that the SOC content of the mineral soil was significantly lower in the croplands compared to the grazing and native forest land. Cultivation promotes SOC loss due to exposing micro-aggregate organic carbon to microbial decomposition by changing the moisture and temperature regimes (Reicosky and forcella, 1998). The higher overall SOC content in the forest land than farm lands may also be attributed to the higher accumulation of organic matter due to high inputs from root biomass and above ground biomass (Reicosky and Forcella, 1998; Saikh *et al*., 1998; Fantaw *et al*., 2007).

The lower content of SOC under bare land and cultivated land may be attributed to reduced organic matter input because of browsing due to uncontrolled grazing (Girmay *et al*., 2008). According to Landon (1991) ratings, soil organic carbon content was found to be very low in farm land (1.84%), and low (2.6 – 2.97%) in other land use types, indicating that soils under the forest land and adjacent land use types are threatened by the continuous animal encroachment, human interference and intensive agricultural production systems.

Considering the soil depth, the mean OM value observed in the surface (0-15 cm) soil was significantly higher than the mean values of OM in the subsurface (15-30 cm) (Table 3). The relatively higher OM content in the surface horizons could be attributed to the presence of remnant biomass in top layer whereas its decrease with depth of the profile could be due to decreasing root biomass with depth and the farming system. As in Berhanu (1980) rating, the OM content observed in the study area was within the range of low.

Soil OM was positively and significantly correlated with total nitrogen, available phosphorus, exchangeable Ca and Mg with correlation coefficients of r = 0.98**, 0.80**, 0.75** and 0.85**, respectively. On the other hand, it is negatively and significantly correlated with pH, exchangeable Na & bulk density of the soil (Table 4).

Soil Reaction (pH)
In the site, pH show significant variation with all land use types and not significantly affected by soil depth and their interaction effects ($P \leq 0.05$; Table 3). The mean soil pH was significantly lower on the prosopis forest land (7.54) than on the bare land (8.06) and cultivated land (8.37) (Table 3).The result is in agreement with the finding of Zelalem (2007) that reported lowest pH in prosopis site when compared the area without *Prosopis* and it is not in agreement with the finding of Nega (2006) that reported highest pH under forest soils.

With regard to soil depth, the mean pH of the subsurface (15-30cm) soil layer was significantly lower than the pH values of the surface (0-15 cm) and it was in agreement with the finding of Chichester *et al.(*1970) reported the pH of the soil decrease with CEC associated with OM decrease. The finding of the study was not in agreement with that of Wakene (2001) and Ahmed (2002) who observed a relatively high pH value at the subsoil horizons of Bako area and Mount Chilalo, respectively.

The low soil pH in the lower soil layer than in the top surface soil layer (Table 3) may probably be due to the presence of relatively higher organic carbon in the surface layer of the soil and the reason also can be the decrease of basic cations such as Ca and Mg along soil depth (Table 3) which decrease soil pH from top to down the soil layers. This result indicates that pH was positively and significantly correlated with exchangeable Na (r = 0.64**), clay content (r = 0.44*), available water holding capacity (r = 0.48*), and bulk density (r = 0.54*). On the other hand, pH was negatively and significantly correlated with total nitrogen, organic matter & the sand fractions of the study area (Table 8). According to Tekalign (1991) rating, the pH values observed in the study area was within the range of moderately alkaline and strongly alkaline soil reactions.

Cation Exchangeable Capacity (CEC)
In the site, cation exchange capacity (CEC, cmol (+)/kg soil) didn't show any significant variation across all land uses, soil depth and also with their interaction effects ($P \leq 0.05$; Table 3). Though not statistically significant, the highest mean CEC was found to be in the cultivated land (53.06) followed by prosopis forest land (52.47) and least in bare land (51.72) (Table 3).

The mean CEC decreased with increasing soil depth i.e.it is higher in surface layer (54.25) and lower in subsurface (50.60) (Table 3). The occurrences of relatively higher value of CEC in the upper depth might be due to the presence of higher organic matter in surface layer. The finding is in agreement with (Foth, 1990; Voundi Nkana *et al*., 1998) reported the higher CEC under farm land followed by forest soils, indicating the relatively better soil fertility may probably as a result of the application of animal manure, house hold wastes and residues in the farm land as these are a good sources of soil nutrients such as Ca, K, P and Mg and relatively higher content of organic matter in protected forest and also the finding of Dawit and Reed (2002) agrees with the result. According to Landon (1991) rating scale, the CEC of the soils in the study area was with very high CEC.

Electrical Conductivity (ECe)
The Electrical conductivity of the site show very significant variation with all land use types and didn't show any significant variation with soil depth and with their interaction effects ($P \leq 0.05$; Table 3). The overall mean ECe of prosopis forest land is significantly lower than bare land and the highest under cultivated land and the finding is in agreement with the finding of Zelalem (2007) that reported the highest ECe under no prosopis site and not in agreement with Nega (2006) that reported the highest ECe under the forest soils. Higher value of ECe was in 0-15cm depth compared to 15-30cm depth and this could be attributed to the accumulation of higher salt because of removal of significant amount of water by evaporation.

Total Nitrogen

In the study site, the total nitrogen (%) show very highly significant variation with all land use types and soil depths but not with their interaction effects ($P \leq 0.05$; Table 3). The distribution of total nitrogen content followed a similar pattern to organic carbon distribution which was higher in the surface soil layer than in the subsurface layer (Table 3). Such result is expected since most soil nitrogen is bound in organic carbon. According to Zelalem (2007); TN and OC levels have shown increasing trend with increasing prosopis density. It was evident that there was gradual numerical increase in percent TN with increasing prosopis density. The increase in percent TN could be attributed to nitrogen fixation by prosopis trees. Prosopis belongs to mimosoideae sub-family. Though some authors could not readily accept the ability of prosopis to fix nitrogen Barth and Klemmendson, 1982; Geesing *et al.,* 2000) have found high levels of nitrogen fixation by prosopis during establishment decreasing as the tree aged. Individual *Prosopis juliflora* trees were estimated to fix up to 31g N/year (Diagne and Barker, 1994). Furthermore, Jarrel and Virginia (1984) have reported that numerous rhizobial strains can infect prosopis and the strains vary in their effectiveness. The idea is in agreement with the findings of Bhojvaid and Timmer (1997) that showed nitrogen accumulation following increasing pattern with increasing age of trees. A ten-fold increase in TN was observed after 30 years of tree growth.

The relatively higher TN in the *prosopis* forest and cultivated land than in the bare land could also be associated with the relatively higher organic carbon which was resulted from plant and root biomass as well as residues being returned to the soil system. The result is in agreement with Khresat *et al*.(2008) reported that total nitrogen showed significant difference between the forest and cultivated land due to differences in soil organic matter content, intensities of erosion and cultivation and also other studies reported that substantial N losses through process of cultivation and biomass transfer (Khresat *et al.,*2008;Weldeamlak and Stroosnijder,2003). The result is not in agreement with (Islam and Weil, 2000; Awdenegest and Holden, 2008) that reported total nitrogen was not significantly varied with land uses.

As in Birhanu (1980) rating, the TN of the soils of the study area was classified as very low except under prosopis forest which has low TN content (Appendix 5). As in Stocking and Murnagham (2001) cited in Tesfaye (2003) the principal cause for lower contents of total nitrogen comes from removal during harvest of crops and insufficient replenishment through manures or fertilizers.

Table 2: Effects of land use and soil depth on selected soil chemical properties

Trts (LUT)	pH(H_2O)	SOC	TN	Av.P	CEC	OM(%)	ECe
PFL	7.54^{c}	0.14^{a}	0.013^{a}	19.53^{a}	52.47^{a}	0.24^{a}	1.15^{c}
CL	8.37^{a}	0.09^{b}	0.007^{b}	18.60^{b}	53.06^{a}	0.15^{b}	4.64^{a}
BL	8.06^{b}	0.06^{c}	0.006^{c}	16.99^{c}	51.72^{a}	0.11^{c}	3.25^{b}
LSD (0.05)	0.12	0.02	0.001	0.60	5.79	0.03	1.23
SEM (±)	0.05	0.001	0.0007	0.27	2.66	0.017	0.0007
Soil depth (cm)							
0-15	8.03^{a}	0.105^{a}	0.009^{a}	18.83^{a}	54.25^{a}	0.18^{a}	3.39^{a}
15-30	7.95^{a}	0.095^{a}	0.008^{b}	17.92^{b}	50.60^{a}	0.16^{a}	2.64^{a}
LSD (0.05)	0.097	0.02	0.001	0.48	4.73	0.03	1.006
SEM (±)	0.05	0.001	0.0007	0.27	2.66	0.02	0.0007
CV (%)	1.187	17.06	13.96	2.57	8.78	17.12	13.96

* CL= cultivated land; BL= bare land; PFL=Prosofis forest land. Different letters in a column indicate significant ($p \leq 0.05$) differences between the mean value in the different land use types & soil depth; LSD = Least significant difference; SEM = Standard error of the mean; CV = Coefficient of variation; OM=Organic matter; SOC=Soil organic carbon; TN=Total nitrogen; Av.P=Available Posporous; CEC=Cation exchange capacity; ECe=Electrical conductivity

Available Phosphorus

Available phosphorus was significantly varied with all land use types and soil depth but not with their interaction effects ($P \leq 0.05$; Table 3). The mean available phosphorus (Av. P) was significantly higher in the prosopis forest land than in other land use types ($P \leq 0.05$; Table 3) and the result is in agreement with Zelalem (2007) reported higher value under prosopis forest site than the site without prosopis and Nega (2006) also reported higher available P under forest land.

With regard to soil depth, the available P was higher on surface soils than lower part. It is generally accepted that available P is high in surface soil due to the addition of fertilizers and or easily mineralized organic phosphorous compounds. The result is in agreement with Berhane and Sahlemedhin (2003) and the findings of Tekalign *et al.* (1988) who reported that topsoil P is usually greater than the subsoil due to sorption of the added P, greater biological activity and accumulation of organic material on the surface. The low level of available P in subsurface layer may be due to constant removal of soluble P from this zone by plant roots or eluviations (Smeck, 1973. The result disagrees with (Fantaw *et al*., 2006) reported lower available P content in the protected forests.

In Olsen *et al*. (1954) rating, the available Olsen P of the soils of the study area was classified as significantly high. The high contents of available Olsen P observed in the site was in agreement with the finding of Mebit (2006) who reported that the available P extracted by the Olsen method showed extremely high value (86.40 mg kg^{-1}) in the Mollic Leptosols of the summit area and this could be due to the relatively high OM content or low clay content. Furthermore, available Olsen's P is higher at the upper most horizons of the pedons and decreased with depth persistently in all the landforms at Woreta ATVET College, Ethiopia. Other studies (Wakene and Heluf, 2003; Sintayehu, 2006; Gebeyaw, 2007) reported that the availability of P in most soils of Ethiopia decline by the impacts of fixation, crop harvest and erosion by water.

Available P was positively and significantly correlated with OM (r = 0.80**), TN (r = 0.83**), exchangeable Ca (r = 0.81**) & Mg (r = 0.83**). On the other hand it was negatively and significantly correlated with bulk density and exchangeable sodium (Table 8).

Exchangeable Sodium and Potassium

The content of exchangeable Na was significantly affected by land use ($P \leq 0.05$; Table 4). On the other hand, it was not significantly ($P \leq 0.05$) affected by soil depth and the interaction effects of land use by soil depth. Considering the main effects of land use, exchangeable Na content was highest (3.65 cmol(+)/kg) under the bare land and lowest (1.58 cmol(+)/kg) in the prosopis dominated land use (Table 4). This indicates that prosopis dominated land has the ability to detoxify the concentration of exchangeable Na i.e. the highest content is found under the bare land. The finding of this study was supported by the finding of Zelalem (2007) who reported that the content of exchangeable Na was decreased when the density of prosopis increases. Exchangeable Na was positively and significantly correlated with bulk density (r = 0.64**), pH (r = 0.64**), and negatively correlated with sand fractions (r = -0.60**), available phosphorus (r = -0.80**), OM (r = -0.76**) & total nitrogen of the soil (Table 4).

The overall concentration of exchangeable Na increased with soil depth (Table 4) and the result was in agreement with Fantaw *et al*., (2008). According to FAO (2006a) rating, the site has very high concentration of exchangeable Na except under prosopis forest land which has high concentration.

The result indicated that the concentration of exchangeable K was significantly varied with land use types and not significantly varied with soil depth and their interaction effects ($P \leq 0.05$; Table 4). The overall mean exchangeable K was significantly higher in the prosopis forest land than cultivated land and the least in bare land (Table 4). The highest content in the prosopis dominated forest land was related with the contribution of prosopis to increase exchangeable K. The finding of this study is agreed with the finding of Zelalem (2007) who reported that the content of exchangeable K was increased when the density of prosopis increased & the lowest content is recorded in the bare lands.

Generally, the lower exchangeable K contents in the cultivated and bare lands than in the forest land might be due to its continuous losses in the harvested parts of the plants from the cultivated and bare lands. Previous findings have also considered these factors and the application of acid forming fertilizers as major factors affecting the distribution of K in soil systems mainly enhancing its depletion especially in tropical soils (Baker *et al*., 1997; Wakene, 2001).

The ranges of mean exchangeable K values observed in this study show that K was above the critical levels (0.38 cmol(+)/kg) for the production of most crop plants as indicated by Barber (1984) and as in FAO (2006a) rating, the site has high exchangeable K concentaration.

In line with this, Gebeyaw (2007) and Fantaw *et al*. (2008) reported that the concentration of exchangeable K was lower in the farm land than in grazing and native forest. In contrast, Mulugeta *et al*.(2005) reported that the concentrations of exchangeable K remained higher in the soils of the farmlands compared to the soil under the adjacent natural forest. The concentration of exchangeable K was found to be higher in the top surface layer than in the lower soil layer (Table 4) suggested that vegetation pumps bases such as K, Ca and Mg from the subsoil to the topsoil (Fantaw *et al.,* 2008). According to Landon (1991) ratings the studied soil has sufficient amount of exchangeable K.

Exchangeable Calcium and Magnesium

Under all land use types and soil depth classes, the overall mean concentration of exchangeable cations (cmol (+)/kg soil) present was in the order of $Mg^{2+} > Ca^{2+} > Na^{+} > K^{+}$, that a beat contradicts with the report of Bohn *et al*., (2001) that cations in productive agricultural soils with their energy of adsorption sequence are present in the order $Ca^{2+} > Mg^{2+} > K^{+} > Na^{+}$.

The content of exchangeable calcium (Ca) was significantly affected by land use types but soil depth and the interaction effect of land use by soil depth were not significant ($P \leq 0.05$;Table 4). Accordingly, the mean exchangeable Ca content of the prosopis dominated land use was significantly higher than that of the cultivated and bare lands. It holds true for the mean exchangeable Ca content of the cultivated land was significantly greater than that of the bare land.

In the surface soil layer, the concentration of exchangeable Ca (cmol/kg soil) was significantly higher than the subsurface soil layer (P $\leq$0.05; Table 4) and the result was in agreement with other findings that reported in all land use types, exchangeable Ca was higher in the surface soil layer than the lower soil layer, that probably indicate the application of household wastes (ash) on the farmers' field because ash is a good source of Ca, K, P and Mg (Voundi Nkana *et al*., 1998) and vegetation pumps bases from the subsoil to the topsoil (Fantaw *et al*., 2008). According to FAO (2006a) rating, the soil of the site has high concentration of Ca except under bare land which has medium concentration.

The exchangeable Mg (cmol (+)/Kg soil) show highly significant difference across all land use types and soil depth but not with their interaction effects (P$\leq$0.05; Table 4). Considering the main effects of land use types, the mean exchangeable Mg content of prosopis dominated forest land was highly significantly higher than that of the cultivated and bare land use types. This is because of the highest content of organic matter recorded in prosopis forest land. The overall mean content of Mg was significantly higher in the prosopis forest land (21.68) and cultivated land (19.27) than bare land (17.06); P $\leq$ 0.05; Table 4). Organic matter and basic cations have positive correlations.

The finding of this study regarding to exchangeable Ca & exchangeable Mg showed that their concentration is highest at the prosopis dominated forest land. On the contrary their lowest amount is recorded at the bare land. The finding of this study was supported by the findings of Zelalem (2007) who indicated that the concentration of Ca and Mg were increased when the density of prosopis was increased. The highest content of these two cations has also been reported in high prosopis density (Zelalem, 2007) and the lowest is recorded in non prosopis land uses.

Considering soil depth, the mean exchangeable Ca content was not significantly (P $\leq$ 0.05) affected by soil depth. But, the mean exchangeable Mg content of the surface (0-15 cm) soil found to be significantly higher than that of the subsurface (15-30 cm) soil layer. Exchangeable Mg followed by Ca was the predominant cation in the exchange sites of the soils in the study area. The exchangeable Mg decreased with soil depth in exactly the same pattern as observed in soil pH. These indicate that the downward leaching of most of the basic cations in the study area is very low because of the low rain fall occurrence in the study area. The highest value obtained on the surface soil could also be related to the higher content of organic matter. According to FAO (2006a) rating, the soil of the site has very high concentration of Mg.

According to Landon (1991), the response to Ca fertilizer is expected from most crops when the exchangeable Ca is less than 0.2 $cmol_{(+)}\ kg^{-1}$ of soil, while 0.5 $cmol_{(+)}\ kg^{-1}$ of soil is the deficiency threshold level in the tropics for Mg. Accordingly, the exchangeable Ca and Mg contents of the soils are above the critical values. Exchangeable Ca was positively and significantly correlated with exchangeable Mg, sand, available phosphorus, and OM with correlation coefficients of r = 0.96**, 0.54*, 0.83**, and 0.75**, respectively (Table 8). However, it was negatively and significantly correlated with exchangeable Na and pH. On the other hand, Exchangeable Mg was positively and significantly correlated with the sand fraction, available phosphorus, OM, and TN (Table 4).

Table 3: Effects of land use and soil depth on exchangeable bases

Treatment	Exchangeable basic cations ($cmol_{(+)}kg^{-1}$)			
(LUT)	Ex. Ca	Ex. Mg	Ex. K	Ex. Na
PFL	11.96^{a}	21.68^{a}	1.33^{a}	1.58^{c}
CL	10.75^{b}	19.27^{b}	0.83^{b}	2.76^{b}
BL	9.12^{c}	17.06^{c}	0.66^{b}	3.65^{a}
LSD (0.05)	0.78	1.06	2.17	0.72
SEM(±)	0.34	0.49	0.096	0.33
Soil depth (cm)				
0-15	10.88^{a}	19.87^{a}	0.94^{a}	2.63^{a}
15-30	10.33a	18.80^{b}	0.94^{a}	2.70^{a}
LSD (0.05)	0.63	0.87	0.17	0.58
SEM (±)	0.34	0.49	0.096	0.33
CV (%)	5.85	4.38	17.75	21.48

* CL= Cultivated land; BL= Bare land; PFL= Prosopis forest land. Different letters in a column indicate significant (P$\leq$0.05) differences between the mean value in the different land use types & soil depth; LSD= Least significant difference; SEM= Standard error of the mean; CV= Coefficient of variation

In general, the pattern of exchangeable cations supported the conclusion that there is an increasing loss of basic cations due to export in crops (grains and residues), vertical/lateral movement of finer material within the soil profile and removal in drainage waters which ultimately join down streams. As one traces from forest to agricultural soils, it readily decreases demonstrating the declining dominance of basic cations in the exchange complex of the soil colloids. Therefore, this result is in agreement with the findings of Allen (1985), Saikh *et al* (1998) and Jaiyeoba (2003).

Table 4: Pearson's correlation matrix for various soil physicochemical parameters

	Sand	Silt	Clay	BD	Av. P	AWHC	pH	OM	TN	Ca	Mg	Na	CEC
Sand	1.0												
Silt	-0.61**	1.0											
Clay	-0.16	-0.68**	1.0										
BD	-0.68**	0.67**	- 0.22	1.0									
Av. P	0.40	-0.54*	0.30	-0.70**	1.0								
AWHC	-0.24	-0.38	0.70**	-0.22	0.36	1.0							
pH	-0.72**	0.17	0.44*	0.54*	-0.37	0.48*	1.0						
OM	0.54*	-0.42	0.03	-0.74**	0.80**	0.11	-0.63**	1.0					
TN	0.54*	-0.42	0.03	-0.75**	0.83**	0.15	-0.67**	0.98**	1.0				
Ca	0.54*	-0.55**	0.19	-0.70**	0.81**	0.32	-0.45*	0.75**	0.75**	1.0			
Mg	0.52*	-0.46*	0.10	-0.76**	0.83**	0.31	-0.52*	0.85**	0.84**	0.96**	1.0		
Na	-0.60**	0.42	0.02	0.64**	-0.80**	0.07	0.64**	-0.76**	-0.78**	-0.76*	-0.77*	1.0	
CEC	-0.37	0.25	0.03	-0.08	0.23	0.40	0.07	0.26	0.27	0.26	0.33	-0.1	1.0

Conclusions

This study provides a comparative study on soil quality variations between *Prosopis* area and adjacent land use types in the Dupti sub-watershed. The results showed that most of the soil physical and chemical properties show highly significant variation with land use types. Most soil textural fractions (sand, silt, clay) also significantly varied with land use types. Moreover, the soil textural class of the studied soil was found to be sandy clay loam except in bare land which is loam. Among the soil physical properties bulk and particle density, total porosity, and FC were significantly varied with land use types but not with soil depth and their interaction effects. AWC was significantly affected by both land use types and soil depth, but not with their interaction effects.

The results show that soil chemical properties such as pH, SOC, TN, available P, ECe, and Ex. bases (Ca, Mg,K &Na) were significantly varied with land use types and TN and available P were significantly varied with the soil depth. The SOC, TN, available P and ECe content were found to be higher in the prosopis forest land than in the other land use types, while pH and CEC were higher in the cultivated land; pH and ECe were lowest under prosopis forest land. Exchangeable Ca, Mg and K were found to be highest under prosopis area, while exchangeable Na was highest under the bare land. Exchangeable Mg was significantly varied with soil depths. Accordingly, SOC, exchangeable Ca and Mg decreased with depth. Generally, most soil quality indicators show significant variations between prosopis forest area and the adjacent land use types. Human interference, livestock grazing and intensive agricultural production in the cultivated and bare land use types might have lead soil quality deterioration.

Generally, when we observe the impact of prosopis on the soil parameters, we can conclude that prosopis is of higher value to increase soil fertility and alleviates problems related to salinity and sodicity (i.e. increased soil fertility and reclamation of salt affected soil). Because it has the ability to restore the fertility of the soil & it has the capacity to detoxify saline soils specifically sodic soil.

Recommendations

In order to improve and reverse soil quality deterioration and to maintain long-term productivity of the agricultural land, while contributing to sustainability of Natural resources in the watershed the following recommendations can be forwarded:

- Control of prosopis will be the best option when it is acknowledged for its various economic and ecological values while eradication can be applied where it get out of control in highly valuable irrigable areas and grazing lands.
- Integrating the cultural NRM practices with modern SWC practices suited for the area;
- Strengthening and expanding the fertility management practices such as organic fertilizer (household wastes, manure, composts) is decisive to sustain agricultural production;
- Provision of technical support to the concerned cultural leaders through the government and concerned non-governmental organizations.
- Extension work needs to be given priority by concerned body in order to enhance the extremely low level of exploiting prosopis as a source of income by pastoral households. Besides, the Office should consider organizing the pastoralists into cooperatives to provide firewood and charcoal from prosopis to the market; and supporting the cooperatives both technically and financially.
- Further studies about the socio-economic impacts of prosopis and management techniques which are cost effective and practical to the Afar pastoralists need to be conducted. In addition, the allopathic effect on other plant species needs investigation.

Generally, the site and its surrounding lack scientific evidence on forest resources like species composition, structure and diversity, soil description and soil biological properties are among the untouched research gaps in the area.

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