IV. Soil properties under four homestead grown indigenous tree and shrub species in Galessa-Jeldu areas, Ethiopia

4.1. Introduction

High human and livestock population, a decline of forest resources and soil fertility depletion are some of the features of the highlands of central Ethiopia (ICRAF, 1990; GERMAN et al. 2005). The natural forests in the highlands of Ethiopia in general are heavily exploited to fulfill the cash and wood demand of the growing population. Similarly, the areas previously covered by forests have declined as a result of the expansion of farming with annual crops. Homesteads are one of the most important niches in which farmers feel confident to plant and maintain tree and shrub species.

Homesteads in the high altitude (> 2900 m.a.s.l) areas of central Ethiopia have a better tree and shrub species composition than farmlands (KINDU et al., 2006). The proportion and area coverage of indigenous species around the homesteads is also considerable as compared to exotic species. The increased proportion of indigenous species over the exotics is due to their adaptability to the local environmental conditions, resistance to pests and diseases, availability as sources of planting material and familiarity to the local farmers. Farmers grow tree and shrub species around homesteads to obtain various products (wood, food and feed) and services (live fence, shade and soil fertility improvement) (BERHANE et al. 2006).

Farmers in the high altitude areas highly recognize *Hagenia abyssinica*, *Dombeya torrida* and *Senecio gigas* as important indigenous soil improving tree and shrub species (KINDU et al. 2006). The contribution of some indigenous tree species for soil fertility improvement in farmlands has been investigated in the intermediate altitude (1500-2400 m.a.s.l) areas of Ethiopia by ABEBE et al. (2001), ASHAGRIE *et* al. (1999), HAILU et al. (1997), POSCHEN (1986) and GINDABA et al. (2005). Assessments of the soil properties under and away from the tree canopies were the focus of all of the studies. The report from most of the previous studies showed a higher soil organic matter, total N and other soil attributes under the tree canopies than in open areas.

Studies on soil properties under farmers' recognized indigenous tree and shrub species around homesteads are limited in the high altitude areas. Cognizant of the research gap, a study was conducted from 2004 to 2006 (a) to evaluate soil pH, organic C, total N, available P, exchangeable bases under four indigenous and an exotic tree species; and (b) to examine correlations between the different soil properties.

4.2. Materials and methods

4.2.1. Study site

The study was conducted from 2004 to 2006 in the upper plateaus of the Dendi and Jeldu districts, west Shewa zone, central Ethiopia (9^o 02' 47'' to 9^o 15' 00'' N and 38^o 05' 00'' to 38^o 12' 16'' E, and 2900 to 3200 m.a.s.l) (Appendix 1). The rainfall pattern is bimodal. The main rainy season is from June to September with a mean annual rainfall of 1399 mm. Barley is the most dominant crop followed by potato and enset (*Ensete ventricosum*). Cattle, sheep and horses are dominant livestock in the study area. The soil is characterized as Haplic Luvisols. The physical and chemical properties of the soil are presented in Appendix 2.

4.2.2. Selection of the tree and shrub species

A total of 150 households were interviewed to find out indigenous tree and shrub species that are traditionally considered by farmers as important soil fertilizers. Subsequently the farmers were asked to describe the type of tree and shrub species that they require best. The most important tree and shrub species for the farmers were species that regularly shed their leaves, have fast decomposing leaves, grow fast, propagate easily, produce high biomass, and protect soil erosion. Finally, farmers selected *Senecio gigas* Vatke, *Hagenia abyssinica* (Bruce) J.F. Gmel, *Dombeya torrida (*J.F. Gmel.) P. Bamps and *Buddleja polystachya* Fres. Three villages that had all the required indigenous species were identified. Tree and shrub species free from addition of farm weeded material; manure or house wastes and inorganic fertilizers were selected and demarcated in each village. The three villages were considered as replications. Most tree and shrub species in the village exist in hedges. A total of 12 trees from the four indigenous and three trees from an exotic species (*Chamaecytisus palmensis* (Christ) Bisby & K. Nicholls) were included in the present study. The exotic tree species was used for comparison purposes. Detailed description of the species is presented in Appendix 3.

4.2.3. Soil sampling and analysis

A transect approach was considered for soil sampling. Sampling locations were 75 cm (hereafter referred to as closest), 150 cm (hereafter referred to as midst), and 225 cm (hereafter referred to as distant) positions at both sides from the base of each marked tree (Power et al. 2003; WEZEL 2000; HAILU et al. 2000). Sampling depths were 0-15, 15-30 and

30-50 cm (KINDU et al. 1997). Soil samples collected from similar depths and positions were thoroughly mixed to obtain composite samples. Three replicated soil samples were collected under the four indigenous and an exotic tree and shrub species.

The Soil pH was determined in 1:2.5 soil suspensions in deionised water for active acidity using potentiometric pH-Meter (ÖNORM L1083 2005). Organic carbon was determined by C/S-Element Analyzer LECO S/C 444 using oven-dry samples. Dry combustion at 1400 ^oC in pure O_2 atmosphere and infrared detection of evolved CO_2 was applied (ÖNORM L1080, 2005). Total nitrogen was determined by Semi-micro-Kjeldahl procedure using the air-dry samples. Wet combustion of air-dry soil samples was carried out with H_2SO_4 (98%) and a catalyst containing K_2SO_4 and $CuSO_4$ at 400 ^oC. Automatic vapour distillation with saturated NaOH and titration of evolved NH_3 using a Kjeltec Auto 2300, (TECATOR) with automatic calculation device was used (ÖNORM L1082 2005).

Available P was determined by Olsen method (OLSEN and SOMMERS 1982). Exchangeable element contents (K^+, Ca^{2+}, Mg^{2+}, Mn^{2+} and Al^{3+}) were determined by extraction of air-dried samples with 0.1M NH_4OAc at pH 7.0. Aqua regia and NH_4OAc were used while working on total and exchangeable element content, respectively. Determination of both the total and exchangeable elements was carried out using a simultaneous ICP-OES (Inductively Coupled Plasma – Optical Emission Spectroscopy) with an axial plasma (Perkin Elmer, OPTIMA 3000 XL). The determinations were made after calibration with matrix-adapted standard solutions (ÖNORM L1085 2004). Cation Exchange Capacity (CEC) and % base saturation (BS) were calculated as follows:

CEC ($mmol_c$ / 100 g) = K (ppm)/390 + Mg (ppm)/120 + Ca (ppm)/200 + Na (ppm)/230 + H (buffer pH)

BS = (Base (meq/100g)/CEC) *100

4.2.4. Statistical analysis

A one-way analysis of variance (ANOVA) was conducted on soil pH, OC, N and exchangeable bases using SAS (SAS institute 1999). The significance between means was tested using the least significance difference (LSD). The following model was considered while running the ANOVA:

$Y_{ij} = \mu + \alpha_i + \beta_j + e_{ij}$, where μ is the overall mean, α_i the i^{th} treatment (species) effect, β_j the j^{th} block (site) effect and e_{ij} is the random error associated with Y_{ij}.

Correlation analysis was performed to understand the relation between OC vs N; pH vs OC, N, Al, Mn, BS and CEC. Levels of P < 0.05, P < 0.01 and P < 0.001 were chosen to test significance differences.

4.3. Results

4.3.1. Soil pH, organic C, total N and available P

Soil pH at a depth of 0-15 cm varied horizontally from 6.01 to 6.8, 5.9 to 6.7 and 5.85 to 6.95 in the closest, midst and distant positions, respectively (Table 4.1). The soil pH values under *H. abyssinica* and *S. gigas* were above 6.34. The pH values under the five tree and shrub species varied significantly among the soil depths (Table 4.1 and 4.2). Higher pH values were found at the topsoil than that of lower depths. Similarly, the soil pH varied along the three horizontal positions. Higher pH values were noticed in the closest position than in the midst and the distant positions.

Table 4.1. Total N, organic C and pH at different depths and positions from five tree and shrub species.

		pH (H_2O)			Organic C (mg g^{-1})			Total N (mg g^{-1})		
Species	Depth (cm)	75 cm position	150 cm position	225 cm position	75 cm position	150 cm position	225 cm position	75 cm position	150 cm position	225 cm position
Buddleja polystachya	15	6.07^{b}	5.90^{c}	5.86^{b}	51.31^{b}	40.33^{b}	39.73^{b}	4.75^{a}	3.99^{b}	3.83^{b}
Chamaecytisus palmensis		6.01^{b}	5.97^{bc}	6.09^{b}	61.37^{ba}	58.63^{ba}	56.36^{ba}	5.92^{a}	5.74^{ba}	5.19^{ba}
Dombeya torrida		6.14^{ba}	5.92^{bc}	5.85^{b}	63.50^{ba}	59.86^{ba}	57.59^{a}	4.92^{a}	5.36^{ba}	5.36^{ba}
Hagenia abyssinica		6.80^{a}	6.70^{a}	6.95^{a}	74.56^{a}	64.86^{a}	60.76^{a}	6.60^{a}	6.26^{a}	5.66^{a}
Senecio gigas		6.59^{ba}	6.47^{ba}	6.47^{ba}	58.93^{ba}	55.11^{ba}	53.00^{ba}	5.36^{a}	5.15^{ba}	5.04^{ba}
SEM		0.121	0.111	0.139	3.302	3.372	2.899	0.335	0.333	0.274
Buddleja polystachya	30	5.77^{b}	5.77^{b}	5.76^{b}	38.00^{a}	32.52^{a}	33.01^{a}	3.64^{a}	2.66^{a}	3.03^{a}
Chamaecytisus palmensis		5.89^{b}	5.83^{b}	6.11^{b}	50.84^{a}	44.82^{a}	39.34^{a}	4.94^{a}	3.98^{a}	3.82^{a}
Dombeya torrida		5.77^{b}	5.74^{b}	5.73^{b}	44.04^{a}	37.70^{a}	38.63^{a}	4.22^{a}	3.68^{a}	3.68^{a}
Hagenia abyssinica		6.72^{a}	6.59^{a}	6.86^{a}	56.29^{a}	43.92^{a}	44.42^{a}	5.21^{a}	4.13^{a}	4.14^{a}
Senecio gigas		6.39^{ba}	6.42^{a}	6.36^{ba}	43.76^{a}	36.95^{a}	33.84^{a}	4.07^{a}	3.28^{a}	2.89^{a}
SEM		0.128	0.118	0.141	3.199	2.654	2.279	0.280	0.284	0.227
Buddleja polystachya	50	5.71^{b}	5.74^{b}	5.77^{b}	32.41^{a}	24.96^{a}	21.12^{b}	2.92^{a}	2.14^{a}	1.96^{b}
Chamaecytisus palmensis		5.77^{b}	5.79^{b}	5.85^{b}	29.12^{a}	26.50^{a}	28.18^{ba}	2.67^{a}	2.45^{a}	2.51^{ba}
Dombeya torrida		5.67^{b}	5.64^{b}	5.71^{b}	31.25^{a}	28.24^{a}	28.49^{ba}	2.91^{a}	2.60^{a}	2.28^{ba}
Hagenia abyssinica		6.50^{a}	6.52^{a}	6.75^{a}	38.37^{a}	35.37^{a}	36.30^{a}	3.36^{a}	3.19^{a}	3.19^{a}
Senecio gigas		6.40^{a}	6.44^{a}	6.35^{a}	39.37^{a}	22.57^{a}	21.48^{b}	3.46^{a}	1.93^{a}	1.91^{b}
SEM		0.111	0.112	0.121	2.120	1.992	2.099	0.200	0.213	0.183

Means with different letters within a column at similar depth and position are significantly different (p <0.05).
SEM - Standard error of the means (n = 15).

The soil OC and N content under *H. abyssinica*, S*. gigas*, *C. palmensis* and *D. torrida* were comparable in the top 0-15 cm depth (Table 4.1). On the other hand, the soil OC content under *H. abyssinica* was higher by 23.25, 24.53 and 21.03 mg g^{-1} than under *B. polystachya* in the closest, midst and distant positions, respectively. The difference in soil N at the 0-15 cm depth was 1.85, 2.27 and 1.83 mg g^{-1}. The content of soil P has the following sequence in the top 0-15 cm soil depth of the closest and midst horizontal positions: *H. abyssinica* > *S. gigas* > *C. palmensis* > *D. torrida* > *B. polystachya* (Figure 4.1). Organic C, N and P showed significant differences among the soil depths, as well as horizontal positions (Table 4.1 and 4.2). The content of OC, N and P depicts a decreasing pattern from the 0-15 to the 30-50 cm soil depths and from the closest to the midst and distant positions.

Table 4.2. Effect of five tree and shrub species on soil attributes at three depths and three horizontal positions.

	Effect		
Soil attributes	Depth	Position	Depth x Position
pH (H_2O)	0.000	0.002	0.007
OC (mg g^{-1})	0.000	0.000	0.821
Tot. N (mg g-1)	0.000	0.000	0.040
Av. P (mg g-1)	0.000	0.000	0.043
Exch. K (µg g^{-1})	0.000	0.000	0.000
Exch. Ca (µg g^{-1})	0.000	0.003	0.757
Exch. Mg (µg g^{-1})	0.000	0.002	0.107
Exch. Na (µg g^{-1})	0.116	0.095	0.463
Exch. Mn (µg g^{-1})	0.000	0.013	0.002
Exch. Al (µg g^{-1})	0.000	0.000	0.079
BS (%)	0.000	0.000	0.000
CEC (mmolc kg^{-1})	0.000	0.000	0.014

Figures under the depth, position, and depth and position are P-values.

4.3.2. Exchangeable bases

The contents of soil K varied significantly under the five species specifically at the 0-15 cm soil depth of the horizontal positions (Table 4.3). The soil under *H. abyssinica, S. gigas* and *C. palmensis* had a high content of soil K at the 0-15 cm depth in the closest, midst and distant horizontal positions. The Ca content under *S. gigas*, *H. abyssinica* and *C. palmensis* was comparable at the 0-15 cm soil depth of the three positions (Table 4.3). The soil under *H. abyssinica* and *S. gigas* had a high Ca content in the lower 15-30 and 30-50 cm depths. The Mg content under *H. abyssinica* and *S. gigas* was high as compared to the Mg content under other species in all soil depths and horizontal positions. The Na content was significantly higher under *H. abyssinica* than under other species in almost all depths of the three positions. The content of K, Ca and Mg varied at the three soil depths of the closest, midst and distant horizontal positions, i.e. it decreased from the top to the lower soil depths and from the closest to the midst and distant positions (Table 4.2).

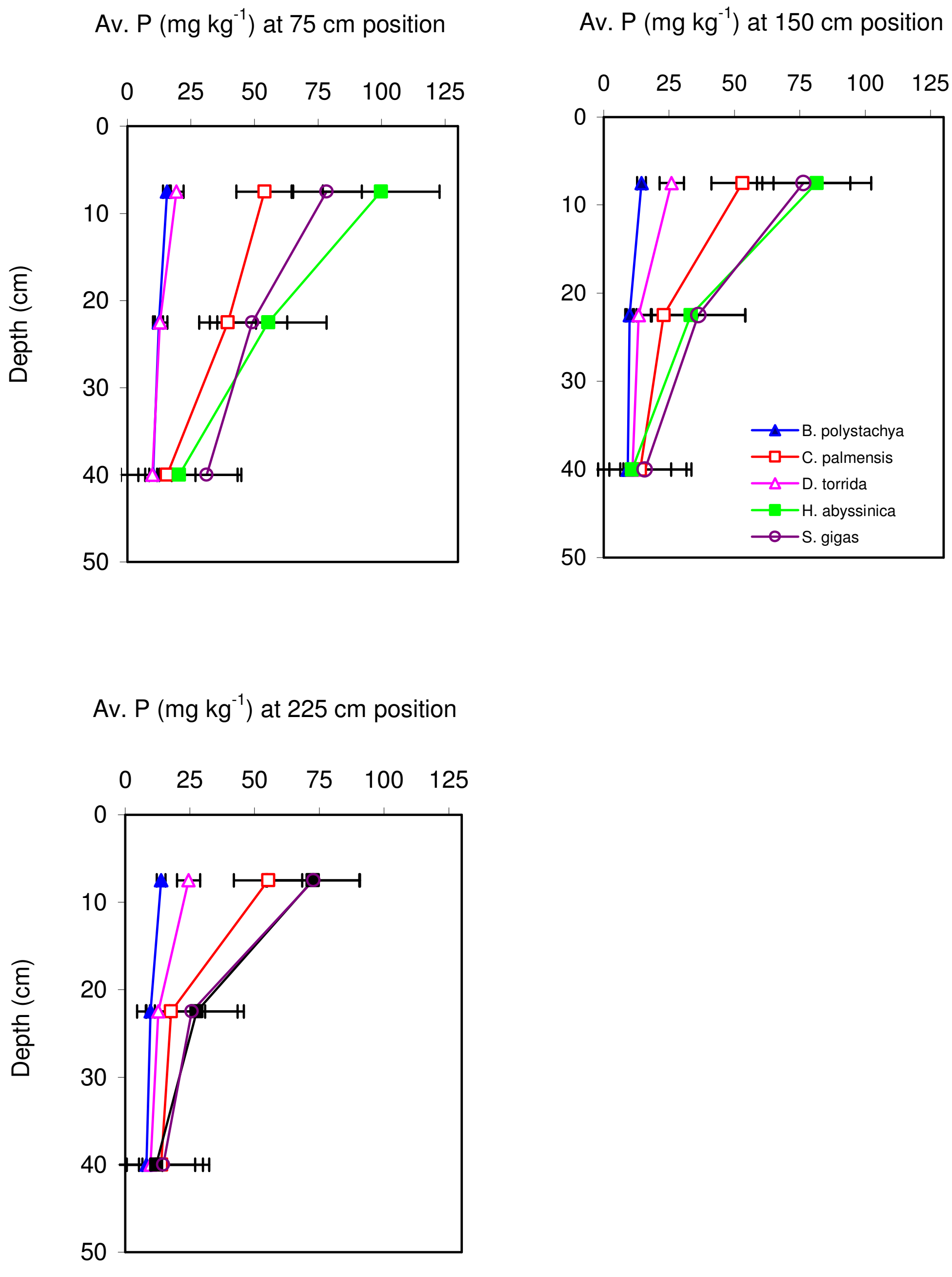

Figure 4.1. Trends of available P under five tree and shrub species at different soil depth and horizontal positions. Horizontal bars show standard errors of the mean.

Table 4.3. Excangeable cations at different depths and positions from five tree and shrub species.

Species	Depth (cm)	Exchangeable K (µg g^{-1})			Exchangeable Ca (µg g^{-1})			Exchangeable Mg (µg g^{-1})			Exchangeable Na (µg g-1)		
		75 cm position	150 cm position	225 cm position	75 cm position	150 cm position	225 cm position	75 cm position	150 cm position	225 cm position	75 cm position	150 cm position	225 cm position
Buddleja polystachya	15	826^{b}	568^{a}	455^{c}	845^{b}	736^{b}	707^{b}	169^{b}	155^{b}	146^{b}	43.01^{b}	43.06^{b}	40.36^{b}
Chamaecytisus palmensis		1428^{ba}	1409^{a}	1291^{bac}	1106^{ba}	1056^{ba}	1100^{ba}	189^{b}	181^{b}	211^{ba}	37.98^{b}	39.93^{b}	39.66^{b}
Dombeya torrida		927^{b}	771^{a}	639^{bc}	982^{ba}	853^{b}	782^{b}	203^{b}	183^{b}	143^{b}	44.17^{b}	41.65^{b}	42.64^{b}
Hagenia abyssinica		1929^{ba}	1592^{a}	1642^{a}	1637^{a}	1476^{a}	1869^{a}	369^{a}	339^{a}	327^{a}	60.15^{a}	72.83^{a}	60.31^{a}
Senecio gigas		2306^{a}	1518^{a}	1507^{ba}	1580^{a}	1529^{a}	1527^{ba}	305^{ba}	251^{ba}	251^{ba}	41.69^{b}	40.47^{b}	46.50^{ba}
SEM		215.11	175.62	167.27	120.27	110.68	160.04	27.47	25.14	24.72	2.65	4.74	2.88
Buddleja polystachya	30	489^{a}	444^{a}	424^{a}	686^{a}	592^{c}	621^{c}	145^{a}	147^{a}	147^{ba}	48.15^{ba}	42.42^{bc}	39.42^{b}
Chamaecytisus palmensis		1171^{a}	1154^{a}	1389^{a}	994^{a}	747^{bc}	783^{bc}	181^{a}	139^{a}	157^{ba}	38.70^{b}	38.38^{c}	36.84^{b}
Dombeya torrida		539^{a}	531^{a}	482^{a}	738^{a}	682^{bc}	689^{c}	136^{a}	133^{a}	125^{b}	47.57^{ba}	50.72^{a}	41.25^{ba}
Hagenia abyssinica		1483^{a}	1205^{a}	1324^{a}	1364^{a}	1110^{ba}	1266^{a}	268^{a}	249^{a}	272^{a}	52.38^{a}	47.48^{ba}	50.83^{a}
Senecio gigas		1544^{a}	1259^{a}	1222^{a}	1368^{a}	1277^{a}	1201^{ba}	242^{a}	242^{a}	235^{ba}	44.09^{ba}	44.58^{bac}	43.11^{ba}
SEM		183.33	178.74	183.44	115.19	89.44	88.80	23.18	20.26	22.53	1.86	1.42	1.75
Buddleja polystachya	50	339^{a}	480^{a}	470^{a}	640^{b}	556^{a}	666^{a}	148^{ba}	130^{b}	148^{b}	42.89^{b}	50.97^{a}	41.58^{b}
Chamaecytisus palmensis		840^{a}	876^{a}	915^{a}	631^{b}	622^{a}	652^{a}	127^{b}	121^{b}	137^{b}	33.54^{b}	37.49^{a}	38.14^{b}
Dombeya torrida		343^{a}	325^{a}	344^{a}	667^{b}	596^{a}	659^{a}	136^{ba}	131^{b}	137^{b}	42.50^{b}	44.93^{a}	40.56^{b}
Hagenia abyssinica		1048^{a}	938^{a}	1141^{a}	982^{ba}	1024^{a}	1138^{a}	228^{ba}	195^{ba}	200^{ba}	58.74^{a}	49.61^{a}	55.41^{a}
Senecio gigas		1372^{a}	1232^{a}	1197^{a}	1363^{a}	1055^{a}	991^{a}	268^{a}	265^{a}	277^{a}	41.82^{b}	46.46^{a}	38.39^{b}
SEM		166.41	158.13	157.64	89.72	85.50	82.91	22.49	21.31	18.50	2.46	2.17	2.19

Means with different letters within a column at similar depth and position are significantly different ($p < 0.05$).

SEM - Standard error of the means (n = 15).

4.3.3. Cation exchange capacity and base saturation

The CEC and BS values under *H. abyssinica* and *S. gigas* were higher at the three soil depths of all the horizontal positions (Figure 4.2 and 4.3). The soil under *C. palmensis* had higher CEC and BS values than under *B. polystachya* and *D. torrida*. The lowest CEC and BS values were recorded under *B. polystachya* at the 0-15 and 15-30 cm soil depths of all the three horizontal positions.

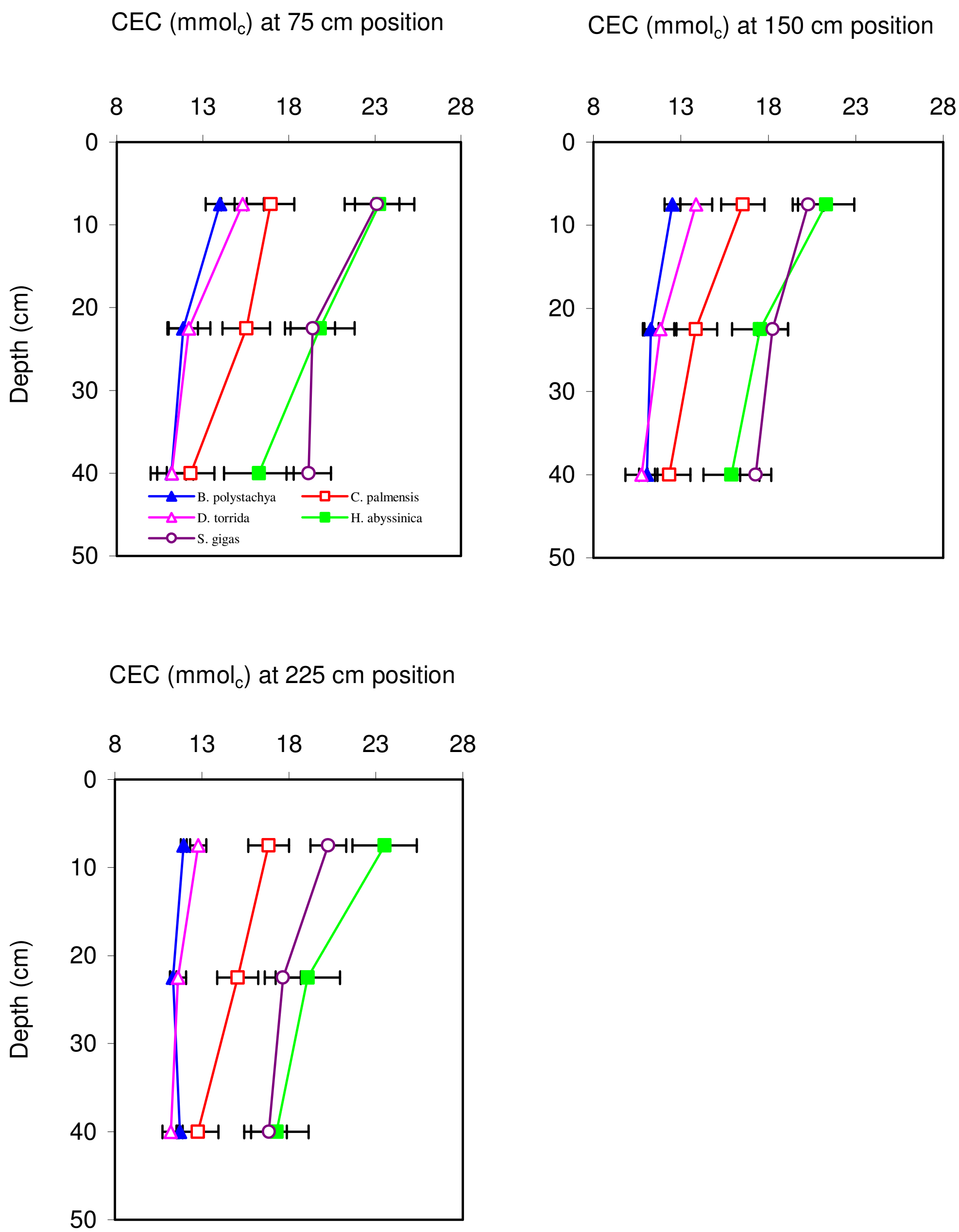

Figure 4.2. Trends of CEC of the soil under five tree and shrub species at different soil depths and horizontal positions. Horizontal bars show standard errors of the mean.

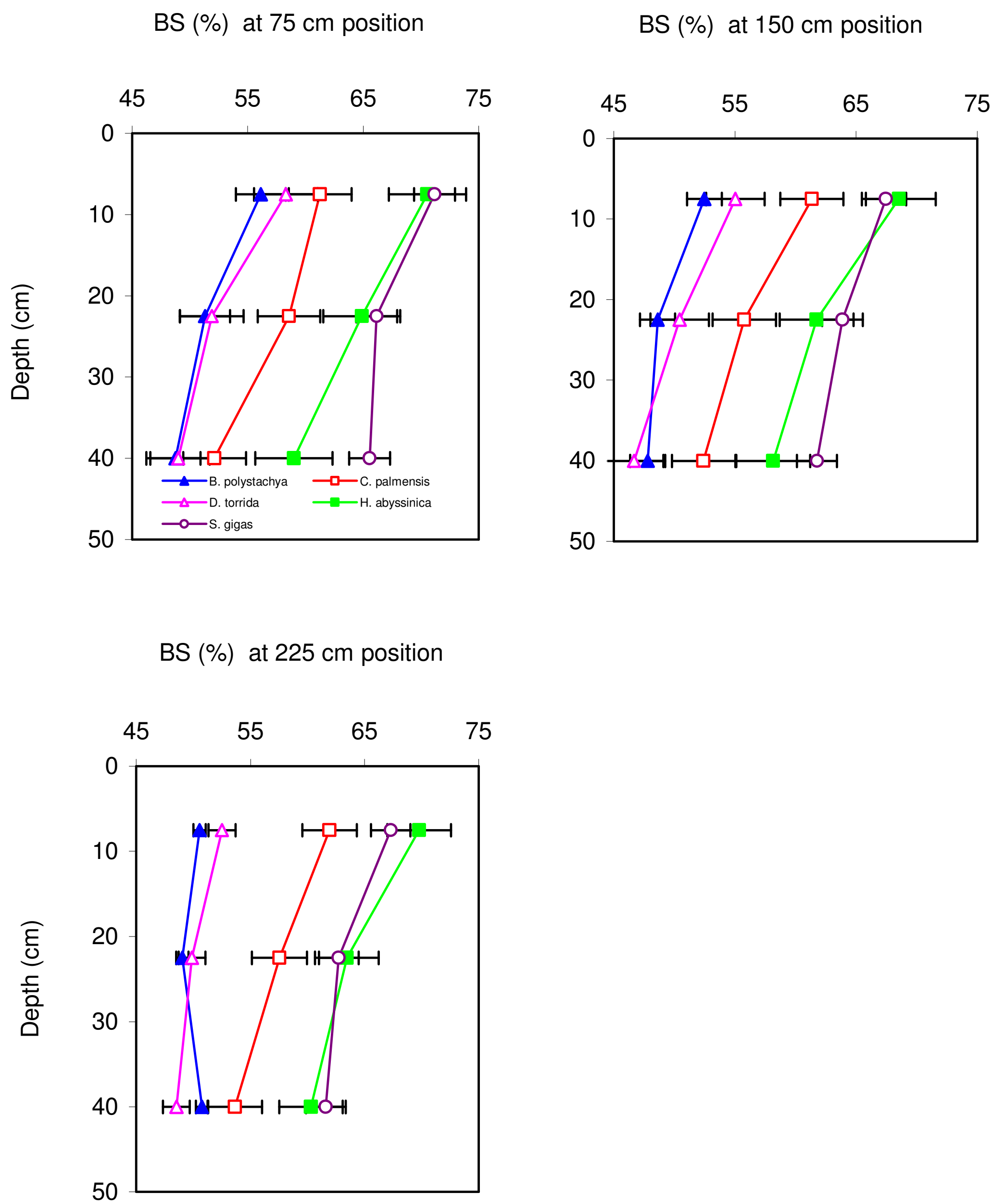

Figure 4.3. Trends of base saturation of the soil under five tree and shrub species at different soil depths and horizontal positions. Horizontal bars show standard errors of the mean.

4.3.4. Correlation between soil properties

The correlation between OC and N was positive and statistically significant at all the soil depths of the three horizontal positions (Table 4.4). Soil pH was positively and significantly correlated with CEC and BS, and negatively and significantly correlated with Mn. The correlation between soil pH and N as well as pH and OC was positive in almost all the cases. No significant correlation was found between pH and Al; pH and OC; pH and N, except at the 0-15 cm soil depth and in the closest position of the five tree species.

Table 4.4. Correlations between selected soil attributes for the five tree and shrub species.

Depths and positions (cm)	Tot. N vs OC	pH vs Tot. N	pH vs OC	pH vs Exch. Al	pH vs Exch. Mn	pH vs BS	pH vs CEC
0 to15 and 75	0.841***	0.640**	0.630**	-0.510*	-0.768***	0.918***	0.944***
0 to 15 and 150	0.954***	0.512*	0.449	-0.450	-0.706***	0.897***	0.929***
0 to 15 and 225	0.974***	0.410	0.407	-0.468	-0.8089***	0.897***	0.964***
15 to 30 and 75	0.984***	0.357	0.447	-0.415	-0.706***	0.880***	0.921***
15 to 30 and 150	0.937***	0.031	0.043	-0.243	-0.726***	0.888***	0.924***
15 to 30 and 225	0.968***	-0.032	0.002	-0.313	-0.703***	0.838***	0.921***
30 to 50 and 75	0.972***	0.256	0.315	-0.185	-0.607*	0.811***	0.883***
30 to 50 and 150	0.969***	0.067	0.072	-0.212	-0.654***	0.848***	0.907***
30 to 50 and 225	0.940***	0.322	0.252	-0.229	-0.695***	0.815***	0.925***

Tot. N - total N, OC - organic C, Exch. Al - exchangeable Al, Exch. Mn - exchangeable Mn, BS - base saturation, CEC - cation exchange capacity

*P<0.05, **P<0.01 and ***P<0.001 (level of significances)

4.4. Discussion

Tree and shrub species can differ in their effect on soil properties through various mechanisms, including rates of nutrient inputs, outputs, and cycling. The high content of OC and N under *H. abyssinica* as compared to *B. polystachya* could be due to the addition of higher organic resources of the former than the later. *Hagenia abyssinica* constantly sheds high amount of leaves and provide mulch and green manure to the soil within its vicinity. KINDU et al. (2006) reported the presence of high amount of litter deposition under 64 months old *H. abyssinica* and *Grevillea robusta* on Nitisols of central Ethiopia. *Dombeya torrida, S. gigas* and *C. palmensis* shed substantial amount of leaves even though their leaf shedding pattern is not as regular as that of *H. abyssinica*.

Farmers in the highlands of central Ethiopia rake the excess foliage litter under *H. abyssinica*, *D. torrida* and *S. gigas* trees and use them as organic fertilizer source for the nearby crop fields. However, *Hagenia abyssinica*, *D. torida* and *S. gigas* as none N-fixing tree species only cycling the N present in the soil, not adding N inputs to the system, as happens through biological nitrogen fixation (BNF) in *C. palmensis*. None N-fixing tree and shrubs species in general obtain their N and other nutrients through effective retrieval from the soil (JAMA et al. 2000).

The contents of P, K, Ca and Mg in the soil beneath *H. abyssinica*, *S. gigas* and *C. palmensis* were relatively high as compared to the other species considered for the present study (Table 4.3 and Figure 4.1). Enrichment of these nutrients beneath the three species could be associated to the rooting system and efficient nutrient cycling power of the trees. Deep-rooted trees and shrubs often act as ‘nutrient pumps’, taking nutrients from deep subsoil horizons into their root systems, translocating it to their leaves, and recycling it back to the surface of the soil via leaf fall and leaching (KINDU et al. 1997, 1999). Hence, cycling of essential nutrients maintains an abundant supply of nutrients for incorporation into new biomass while at the same time limiting nutrient losses from the soil profile.

The soil under *B. polystachya* had the lowest nutrient content as compared to all other indigenous and exotic species included in the present study. The low soil nutrient content under *B. polystachya* can be related to the very low leaf shedding characteristics of the species. As a result of low leaf shedding, the nutrient gain of the soil system under *B. polystachya* through litter fall can be inadequate. It is likely to notice the positive impact of the *B. polystachya* through chopping and incorporating the green biomass of the tree into the soil system. *Buddleja polystachya* readily coppice and provide substantial amount of green biomass.

Organic C, N, P, K, Ca and Mg progressively declined with depth and horizontal distance from the base of the tree and shrub species. The presence of the tree and shrub species and associated soil enrichment would therefore seem to be restricted to the near surface layers. The effect of the trees on the bulk of the soil in the lower depths was very minimal (Table 4.1 and Figure 4.1). The minimal effect for the five tree and shrub species on the soil properties in the lower as compared to the topsoil depths could be related to young age of the trees. The age of the tree and shrub species included in the present study was between four and nine years (Appendix 3). Trees can positively influence soil properties in lower soil depths during many years of their below and aboveground growth (PANDEY et al. 2000; CHANG et al. 2002). Improvement of soil nutrients in the upper soil depths and close to the tree stems has been reported to various tree and shrub species (ABEBE et al. 2001; ASHAGRIE et al. 1999; GINDABA et al. 2005; HAILU et al. 2000).

The soil pH under *H. abyssinica* and *S. gigas* was slightly high as compared to other species (Table 4.1). The elevated soil pH under the two species could be resulted from increased base cation cycling and subsequent enrichment of the base status of the underneath soil. The presences of higher level of exchangeable base forming cations contribute to the amelioration of soil acidity (BRADY 1990). Our findings on the levels of K, Ca, Mg and Na under *H. abyssinica* and *S. gigas* are in accordance with the investigation of HAILU et al. (2000) and SAE-LEE et al. (1992).

The level of CEC under the five species was slightly higher in the top 0-15 cm soil depth than in the lower 15-30 and 30-50 cm soil depths (Figure 4.2). Likewise, the soil under *H. abyssinica* and *S. gigas* depicted relatively more CEC than under other species. Like the contents of base cations, higher level of CEC under the two species could be due to greater amount of litter deposition. The level of CEC varies with changes in soil pH, organic matter, and clay content. Cation exchange capacity provides a reservoir of nutrients to replenish nutrients that can be removed from the soil water by plant uptake and leaching (CAMBERATO 2001).

Total soil N was positively and strongly correlated with OC under the five tree and shrub species. Such a correlation of N with OC was expected as the amount of the former parallels with soil organic matter (SCHLESINGER 1997; BRADY and WEIL 2002). Similarly, soil pH was positively related with BS and CEC while negatively related with Al and Mn. Soil pH drops as acidic H and Al cation in the exchange sites increases and basic Ca, Mg and K cation decreases (DAVID *undated;* Hodges *undated*).

4.5. Conclusions

The soil under *H. abysinica, S. gigas* and *C. palmensis* retained a substantial amount of plant nutrients. This is an indication of the species potential for improving soil fertility and contributing to long-term ecosystem sustainability. Hence, further research is urgently needed to evaluate the performance of the three tree and shrub species in farmlands and other land-use types of the high altitude areas where soil erosion and soil depletion are critical problems.