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WOODY SPECIES COMPOSITION AND SOIL PROPERTIES UNDER SOME SELECTED TREES IN PARKLAND AGROFORESTRY IN CENTRAL RIFT VALLEY OF ETHIOPIA

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ABSTRACT

Different parkland agroforestry practices conserve diverse woody species in different agroecologies. Despite variation in the extent most multipurpose agroforestry tree species have a positive influence on soil nutrient accumulation. A study was carried out in Shashemene district of central rift valley of Ethiopia to assess the status of woody species composition and topsoil properties beneath canopies of some selected tree species scattered on crop land and open fields, without any tree canopy effect. Woody species composition in the parkland agroforestry inventory was conducted by employing line transect survey method. A total of 36 sample plots/quadrates of 50m by 100m were laid along transect lines with 200m difference between consecutive plots and 1000 m distance between transect lines. On each plot all woody species were counted and recorded. Soil sample were collected from under canopy of *Ficus vasta* Forssk and *Albizia gummifera* (J.F.Gmel.) CA. Smith tree and in open field at 30m away from tree trunk. Soil texture, soil pH, available phosphorus, total nitrogen, organic carbon, CEC, and exchangeable base cations were analyzed following standard procedure in National Soil Laboratory and interpreted. Results showed that the presence of 24 woody species representing 15 families and 21 genera at the study site. At the family level, *Fabaceae* was the most dominant family represented by 5 woody species, followed by Moraceae represented by 4 species. The average density of 17 stems per ha was recorded from 18ha of land. Soil textural fractions, mainly sands generally decreased under tree canopies compared to open fields. Available P, organic carbon (OC) and total nitrogen contents (TN) of soils were significantly higher under tree canopies compared to the contents in open fields. Soil samples from under canopies of scattered *Ficus vasta* and *Albizia gummifera* trees, compared with open fields, generally had higher K and Mg. In general, the studied parkland agroforestry supports high biodiversity conservation and enhanced higher soil nutrient concentration under tree canopies than open fields without trees.

INTRODUCTION

There exist concert evidences on impact of deforestation particularly on loss of biodiversity and environmental degradation. To reduce/minimize deforestation problem farmers in different part of the glob integrate tree in the form of agroforestry on their farmland. Agroforestry is one of the options that helped them to obtain ecological, economic and social benefits that they used to acquire from natural forests and woodlands. Contribution of woody species in parkland agroforestry in conserving biodiversity is well recognized. According to Harvey and Haber (1999) the mechanism of such a role is due to better habitat improvement that otherwise absent from agricultural landscapes.

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The extent of woody species on parkland agroforestry is variable. Nikiema (2005) reported 41 woody species from 13.5 ha in Burkina Faso parkland agroforetry. Motuma Tolera *et al*. (2008) reported 32 woody species scattered on 50 ha of crop land in Ethiopia. Low soil productivity is a major constraint of crop production, most severe for smallholders in the tropics (Young, 1997). On-farm trees have been considered as an important means to positively influence on soil fertility (Rao *et al*., 1998; Zebene Asfaw and Agren, 2007). There is a general consensus that the improvement in soil fertility by trees is mainly a consequence of increased organic input (litter and root decay) and N-fixation by legume trees. Some studies on scattered tree species on crop fields show that there is a fertility gradient with fertility decreasing from a tree's base to the edge of its crown or beyond (Belsky *et al*., 1989; Kamara and Haque, 1992; Tadesse Hailu *et al*., 2000; Jiregna Gindaba *et al.,* 2005; Zebene Asfaw, 2008). At the study site, information based empirical data is lacking on status of woody species composition and effect of woody species on soil properties. Cognizant to the research gap, this study was conducted to assess the status of woody species composition and topsoil properties beneath canopies of some selected tree species and open field without tree canopy effect in Shashemene district central rift valley of Ethiopia.

MATERIALS AND METHODS

Study sites

The study site is located at 38°.32'E to 38°34′E and 7° 9.96′N to 7° 10.46′N with an elevation of 1940 m above sea level in Shashemene, central rift valley of Ethiopia. It receives an annual rainfall of 950 mm. The rainfall is bimodal with small intermittent rain from March to April and heavy rain from June to mid-September. It has an annual temperature range of 12–27°C. The highest monthly temperatures are recorded in the dry season between November and March. Soil at study site is an Umbric Andisols, a mineral soil formed from volcanic ash (Eylachew Zewde, 2004).

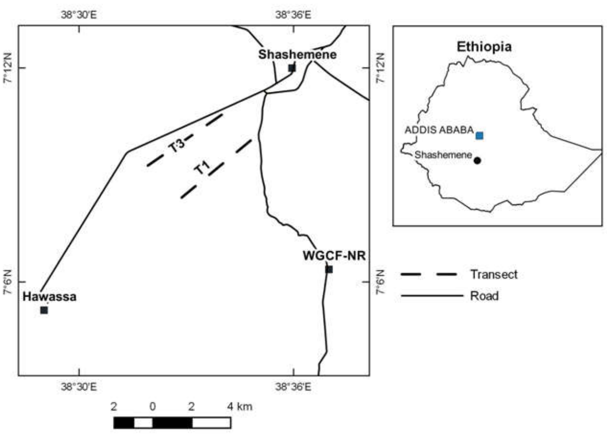


Figure 1. Map of study site at Shashemene in central rift valley, Ethiopia. T1-T3 represents three transects

The study site is characterized by mixed farming composed of annual crops, perennial crops, trees and livestock. Most farmers practice crop rotation with two harvests each year. This generally involves crops like potato (*Solamum tuberosum*), teff (*Eragrostis abyssinica)*, maize (*Zea mays*) and millet *(Eleusine coracana*) in the first crop season and potato, maize, or other cereals in the second season or rotation period. Maize is used both as staple food and income generating crop. Tef and potato is mainly produced for income generation. Before the area was converted to the existing agroforestry parkland, the study area was covered by forest (Chaffey DR. 1978; Gessesse and Christiansson 2007).

Sampling strategies

Woody species composition survey

In this study woody species survey was employed by using line transect survey method. A total of three transect lines with 1km distance between them and 200m distances between plots/quadrates were used. The first transect line and quadrate/plot was laid out randomly and the rest were sy stematically placed by using compass. A 50 m x 100 m plot size used as being more suitable for low density woody species (Nikiema, 2005). The vegetation survey was carried out at Buchna, Deneba and Kore peasant associations. In this survey woody species identification and recording in non-targeted agroforestry practices (e.g. boundaries, homegardens) were excluded. Nomenclature of woody species was carried out using book of Azene bekele *et al*. (1993).

Tree species selection and soil sampling

Soil samples from under scattered trees and outside the canopy effect were taken only at Buchna peasant association. From vegetation survey data, frequency distribution of the dominate woody species was in the order of C*roton macrostachyus* > *Cordial africana* > *Ficus vasta* > *Albizia gummifera* (Table 3). Since soil properties under canopy of *Croton macrostachyus* and *Cordial Africana* were studied by different scholars, (e.g, for *Croton Cacrostachyus* and *Cordia Africana* Jiregna Gindaba *et al*., 2005; for *Cordia Africana* also by Zebene Asfaw and Ågren, 2007), both are excluded from this study. Hence, *Albizia gummifera* and *Ficus vasta* tree species were selected to evaluate their effect on some selected top soil properties. In this study, four replicate trees of *Ficus vasta* and *Albizia gummifera* were sampled. Representative four trees of *Ficus vasta* as well as of *Albizia gummifera* with relatively similar variable dimensions were identified and measured Table 1.

Tree height was defined as the vertical distance from the base of tree to the upper- most tips. Stem diameter at breast height (1.3m) from the base of tree was measured for both trees species. The width of a crown, crown diameter, was measured by projecting the edges of the crown to the ground. The vertical projection was measured in four directions (roughly South-North and East-West) by clinometer and each spot was pegged. Then two distances, South-North and East-West were measured on the ground by meter-tape. The two diameter measurements are averaged to represent tree crown diameter.

Table 1. Height, diameter and crown diameter of sample *Ficus vasta* and *Albizia gummifera* trees in the central Rift valley, Ethiopia

Species name	Height (m)	[a)]Diameter (cm)	Crown diameter (m)
Ficus vasta	19.25±1.46	208±0.69	16.56±2.65
Albizia gumifera	11.18±1.27	24±0.23	5.48±1.25

Note: [a)] diameter at breast height

Before taking soil sample, an area under tree canopy was divided into eight compass directions away from tree trunks (Figure 2). On each line that represent individual direction from tree trunk, four transects were designated as 1 (from 0-0.5m, 2 (from 0.5m to mid crown) and 3 (from mid crown to crown edge), under tree canopy and 4 (open field 30m away from tree trunk). For under tree canopy, four soil samples (at 0-30 cm depth) were randomly taken from four compass directions lines at 1, 2 and 3. The soil sampled from these 12 cores of a single tree was mixed to make composite sample representing under crown. Similarly, following the same four compass directions lines, soil sample was again taken from four spot at 4 (open field) and mixed. From under canopy of each sampled tree transects and corresponding open field, 2 kg from was taken to National Soil Laboratory and Research Centre (NSLRC) in Addis Ababa (Ethiopia) for analyses. Table 2 shows methods employed for soil analysis.

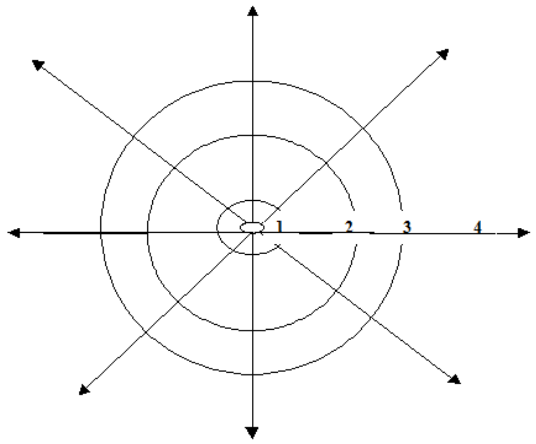


Figure 2. Design for soil sampling the interior circles (1-3) represents under tree crown. Under tree canopy 1= distance from 0-0.5m, 2= from 0.5m to mid crown, 3= from mid crown to crown edge and outside the tree canopy 4= distance from tree trunk to open field 30m away from tree trunk

Table 2. Method employed for physical and chemical parameters analysis in laboratory of National Soil Laboratory and Research Centre (NSLRC), Addis Ababa

Parameters	Methods used
pH and EC	1:2.5 soil water mixture (Jackson, 1973)
Texture	Hydrometer (Bouyoucos)
Ex. Ca, Mg, K, and Na	Exchangeable base cations were extracted with 1N ammonium acetate at pH 7. Calcium and magnesium were determined by atomic absorption spectrophotometer while sodium and potassium were determined by flame emission spectrophotometer, respectively (Black *et al*., 1965)
CEC	Chapman (1965).
Organic carbon	Wet oxidation of Walkley and Black (Schnitzer 1982)
Total Nitrogen	Kjeldahl method (Bremner & Mulvaney, 1982)
Available P	Olsen *et al*., (1954)

Statistical analysis

T test analysis was employed to identify status of soil parameters under tree canopy and at open field.

Data was analyzed by using Statistical package for Social Sciences (SPSS) version 16 software and with Microsoft Excel 2010 for frequency analysis.

RESULTS AND DISCUSSION

Species composition

A total of 311 individuals representing 15 families and 24 woody species were identified in all plots (N=36). At the family level, *Fabaceae* was the most dominant family represented by 5 woody species, followed by Moraceae represented by 4 species (Table 3).

Table 3. List of woody species families, number of species, abundance and stem number per ha of each family in parkland agroforestry, Shashemene, Ethiopia

Family name	No. of species per family	Abundance of all plots	Stem per ha per family
Balanitaceae	1	22	1.22
Boraginaceae	1	43	2.39
Celastraceae	2	28	1.56
Cupressaceae	2	7	0.39
Euphorbiaceae	2	85	4.72
Fabaceae	5	30	1.67
Icacinaceae	1	1	0.06
Meliaceae	1	4	0.22
Melianthaceae	1	3	0.17
Moraceae	3	39	2.17
Myrtaceae	1	9	0.50
Podocarpaceae	1	6	0.33
Proteaceae	1	14	0.78
Rutaceae	1	2	0.11
Ulmaceae	1	18	1.00
Total	24	311	17.28

Three families Celastraceae, Cupressaceae, and Euphorbiaceae were represented by 2 woody species while the remaining 10 families represented by one species. The average number of woody species per sample plot was 0.67 with an average of 5 trees. This study showed that cropland in the rift valley of Ethiopia conserves high woody species diversity (richness) though the 24 woody species recorded from 18 ha is a bit low as compared to some other studies.

Table 4. Woody species, frequency and abundance in parkland agroforestry at a Shashemene, Ethiopia

Species Name	Family Name	Frequency no. and	(%)	abundance	Density ha
Acacia abyssinica Hochst. ex Benth.	Fabaceae	5	13.89	11	0.61
Acacia Senegal	Fabaceae	4	11.11	7	0.39
Acacia seyal	Fabaceae	4	11.11	7	0.39
Acacia tortilis (Forsk)	Fabaceae	3	8.33	3	0.17
Albizia gummifera (J.F.Gmel.) CA. Smith	Celastraceae	15	41.67	25	1.39
Apodytes didimiata E. May. ex Arn	Icacinaceae	1	2.78	1	0.06
Balanites aegyptiaca	Balanitaceae	11	38.89	22	1.22
Bersama abyssinica Fres	Melianthaceae	3	8.33	3	0.17
Junipures procera	Cupressaceae	1	2.78	3	0.17
Casimiroa edulis La Llave & Lex.	Rutaceae	1	2.78	2	0.11
Celtis Africana Burm. F.	Ulmaceae	6	16.67	18	1.00
Cordia Africana Lam.	Boraginaceae	28	77.78	43	2.39
Croton macrostachyus Hochst. ex Del.	Euphorbiaceae	30	83.33	70	3.89
Ekebergia capensis Sparrm	Meliaceae	4	11.11	4	0.22
Maytenus senegalensis (Lam) Exell	Celastraceae	3	8.33	3	0.17
Euphorbia abyssinica	Euphorbiaceae	6	16.67	15	0.83
Faidherbia albida Del. A. Chev	Fabaceae	2	5.56	2	0.11
Ficus sur Forssk.	Moraceae	12	33.33	16	0.89
Ficus sycomorus Forssk.	Moraceae	2	5.56	1	0.06
Ficus vasta Forssk.	Moraceae	18	50.00	22	1.22
Grevillea robusta A. Cunn. Ex. R. Br.	Proteaceae	8	22.22	14	0.78
Podocarpus falcatus (Thunb) Mirb.	Podocarpaceae	6	16.67	6	0.33
Prunus africanus (Hook.f.) Kalkm	Cupressaceae	2	5.56	4	0.22
Psidium guajava L.	Myrtaceae	4	11.11	9	0.50
Total				311	

Motuma Tolera *et al*. (2008) reported 32 woody species scattered on 50 ha crop land in Beseko area, relatively at higher altitude than the current this study area. Nikiema (2005) reported 41 woody species from 13.5 ha in Burkina Faso. Like elsewhere tree density in the studied parkland agroforestry is low, 17 stem ha^{-1}. This is within the range reported frm other studies. For example, Rao, *et al*. (1998) reported five to ten *Vitellaria paradoxa* of trees ha^{-1}, 5-50 *Faidherbia albida* trees ha^{-1} and 10-45 Prosopis trees ha^{-1}. At the study site, farmers manage both native (92%) and exotic (8%) woody species for ecological and socioeconomic benefits. From study made in Kigezi highlands, south-western Uganda, Boffa *et al*. (2005) reported low occurrence indigenous trees (31%) as compared to exotic (69%). Frequency is the number of sample plots in which a given woody occurred in the study area. Out of the total woody species recorded from the sample plots, species with top ranking frequency were in the order of: *Croton macrostachyus* (83.33%) *Cordia africana* (77.78%) *Ficus vasta (*50%) *Albizia gummifera (*41.67%) (Table 4). *Apodytes didimiata*, *Junipures procera* and *Casimiroa edulis* species were recorded on only one single plot. The high frequency of *Croton macrostachyus* and *Cordia Africana* on crop land suggest that those species have better socioeconomic and ecological importance in the area.

Soil property

Soil texture

Under the canopy of both *Ficus vasta* and *Albizia gummifera* trees the sand fractions of the soil was slightly lower than soil from the open fields (Fig 3). Conversely higher silt content was observed under tree canopies than in open fields. However, the influence of *Ficus vasta* and *Albizia gummifera* trees on topsoil texture was not significant, may be due to being from similar parent material. This is in line with earlier works for other parkland agroforestry tree (for *Faidherbia albida* by Kamara and Haque, 1992; for *Millettia ferruginea* by Tadesse Hailu *et al*., 2000; for *Croton Cacrostachyus* and *Cordia Africana* Jiregna Gindaba *et al.,* 2005). However, Pandey *et al*. (2000) reported a significant influence of *Acacia nilotica* on sand and clay fractions laterally as a function of distance from trunks.

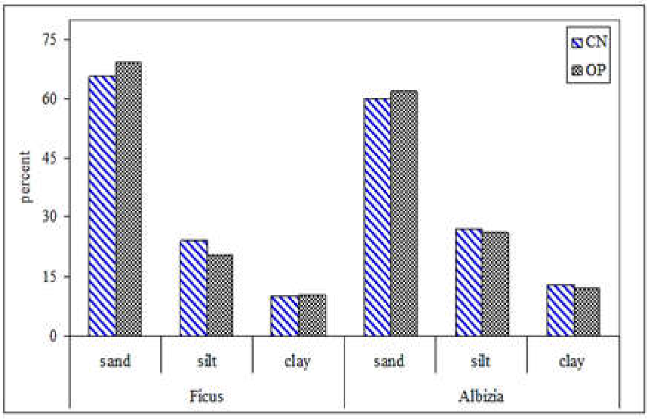
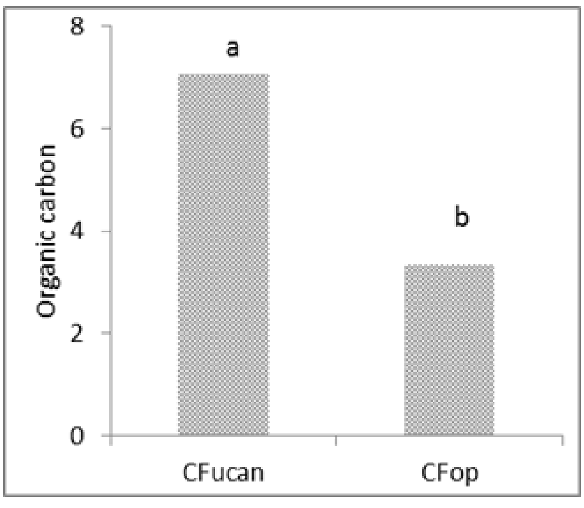


Figure 3. Bar chart chowing t*extural fractions of soil beneath Ficus vasta and Albizia gummifera in the parkland agroforestry of central Rift valley, Ethiopia*

Chemical properties

Organic C, Total N and Available P

The result of this study indicated significantly increased concentrations of soil organic C under both *Ficus vasta* ($p<0.002$) and *Albizia gummifera* ($p<0.03$) canopies, respectively, as compared to open fields outside the influence of trees (Figure 4). This finding is in line with other studies on scattered tree species (Nyberg and Högberg, 1995; Tadesse Hailu *et al*., 2000; Jiregna Gindaba *et al*., 2005; Zebene Asfaw, 2008). The major mechanisms by which scattered trees increase or maintain organic carbon status in the soil under their crown canopy zone can be through leave and root decomposition, reduced leaching, and nutrient recycling to the soil surface (Young 1997). The high proportion of organic carbon implies high soil organic matter (SOM) under canopy of the two studied trees. Large *Ficus vasta* trees often have extensive lateral root spread and can take up nutrients from a large surrounding area and eventually concentrate them under their crowns. Similarly fruits on long branches of Ficus are commonly consumed by birds and unused part fruits drop on the soil, and excreta during nesting in canopies could contribute to higher soil organic carbon concentration. Moreover, it is common to see livestock resting and their



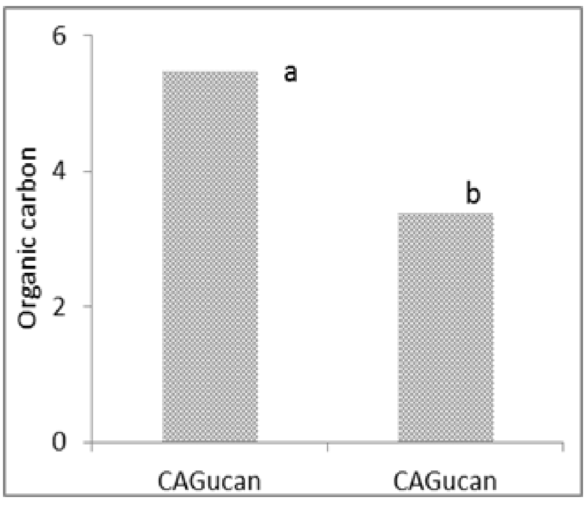


Figure 4. Bar chart chowing *organic carbon content of soil under canopy of Ficus vasta (left) and Albizia gummifera (right) trees and corresponding open field in the parkland agroforestry of central Rift valley, Ethiopia. Mean value on bar with different letter are* significantly different at P < 0.5.

excreta under the large canopy of Ficus tree during the dry season. So the unique features of Ficus branches and animal excreta can increase SOM under its canopy. Higher SOM under tree canopy may increase mineralization and greater availability of plant available nutrients under trees than in the open areas during the cropping season (Rhoades, 1995). SOM can also contribute to nutrient retention capability of the soil through increasing cation exchange capacity. Increases in organic matter and improved microclimatic conditions under parkland trees enhance soil microbial and enzymatic activity, decomposition and physical characteristics (Rao *et al*., 1998). Gindaba *et al*. (2005) for *Croton Cacrostachyus* and *Cordia Africana* in eastern Ethiopia. Values of N and organic carbon recorded in the open fields are comparable to findings of Eylachew Zewde (2004). The high total nitrogen under *Ficus vasta* could be associated with high soil organic carbon under its canopy. The mechanisms by which *Albizia gummifera* trees increased total N under their canopy is attributable to addition of nitrogen input into the system through biological nitrogen fixation as it is N_2-fixing species (Azene Bekele, *et al*.,1993; Zebene Asfaw and Agren, 2007).

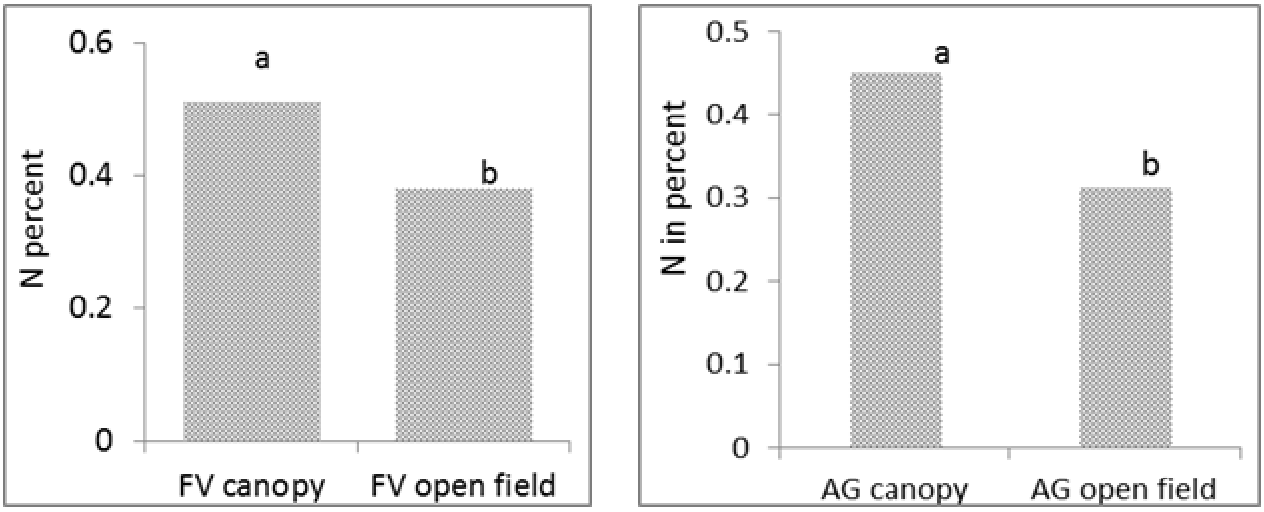


Figure 5. Bar chart chowing total nitrogen (%) content of soil under canopy of Ficus vasta (left) and Albizia gummifera (right) trees and corresponding open field in the parkland agroforestry of central Rift valley, Ethiopia. Mean value on bar with different letter are significantly different at P < 0.5

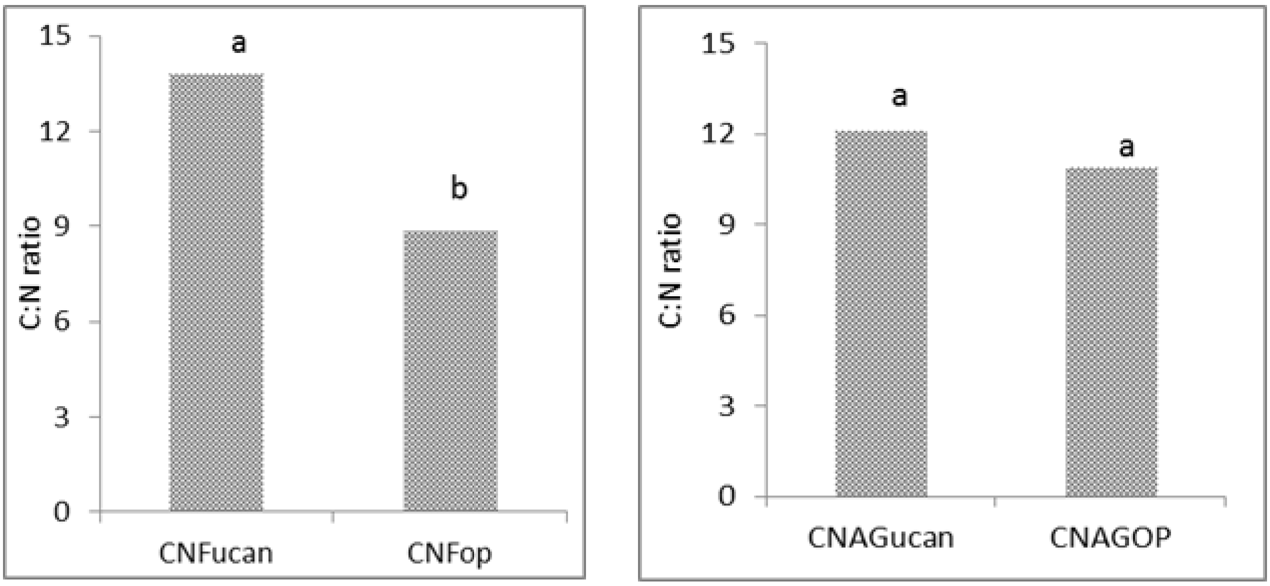


Figure 6. Bar chart chowing c*arbon: nitrogen ratio of soil under canopy of Ficus vasta (left) and Albizia gummifera (right) trees and corresponding open field in the parkland agroforestry of central Rift valley, Ethiopia. Mean value on bar with commonletter are not* significantly different at P < 0.5

The total nitrogen (N) of soil under the canopy of *Ficus vasta* and *Albizia gummifera* is significantly ($p< 0.009$; $p<0.001$), respectively, higher than soil from open fields (Figure 5). Similar findings were reported from other studies (For example, Nyberg and Högberg (1995) for *Cordia africana* in Kenya; Tadesse Hailu *et al*. (2000) and Zebene Asafw (2008) for *Millettia ferruginea*, southern Ethiopia and Jiregna The C:N ratios were significantly greater ($p<0.007$) under *Ficus vasta* canopies as compared to open fields (Figure 6). Available P was markedly higher under both *Ficus vasta* ($p<0.023$) and *Albizia gummifera* ($p<0.008$) tree canopy than open field (Figure 7). This is in accordance with several reports on different tree species (Kamara and Haque, 1992; Nyberg and Högberg, 1995; Pandey *et al*., 2000; Tadesse

Hailu *et al*., 2000; Jiregna Gindaba *et al*., 2005; Zebene Asfaw, 2008). The high concentration available P under the canopy of trees may be attributed to the tree litter, the excreta of livestock resting under their shade during the dry season (Rao *et al*., 1998). The symbiotic association trees with endomycorrhizae can help to explore a large soil volume and this might enhance high phosphorus accumulation under the canopy of those trees (Young, 1997).

pH and ECE

In general, there is a tendency towards high pH under *Ficus vasta* canopy (Table 5). Under the canopy of *Ficus vasta* pH were significantly higher ($p < 0.004$) than soils from open field. The increase in soil pH might be attributable to higher litter deposition from the trees, which upon decomposition and subsequent mineralization, releases cations to the soil systems (Young, 1997). If conditions allow the exchangeable bases to remain in the soil, the soil is likely to exhibit high pH values (Brady and Weil, 2000). It is possible that the high levels of Ca, Mg, K, Na and CEC under tree canopy might contribute for relatively high value of pH than the open fields outside the influence of trees. The values of CEC in soil from under *Ficus vasta* canopies were significantly ($P < 0.013$) higher than values of soil at open from fields (Table 5). The high accumulation of litter under the tree canopy may result in increased amounts of organic matter in the soil, which may increase the CEC.

Exchangeable bases

Although the extent of differences varied for individual nutrient, the concentrations of Na, and Ca were slightly higher under tree canopies than in open fields (Table 6). On the other hand, concentrations of K under the canopy of *Ficus vasta* tree was significant ($p<0.024$) than values of open field. Similar trend of differences ($p<0.04$) in concentrations of K under canopy of *Albizia gummifera* and corresponding open fields were observed. From other study, Jiregna Gindaba *et al*. (2005) reported significantly higher concentration of K under canopy of scattered trees on crop fields. According to Schroth *et al*. (2003) trees promote potassium and calcium through

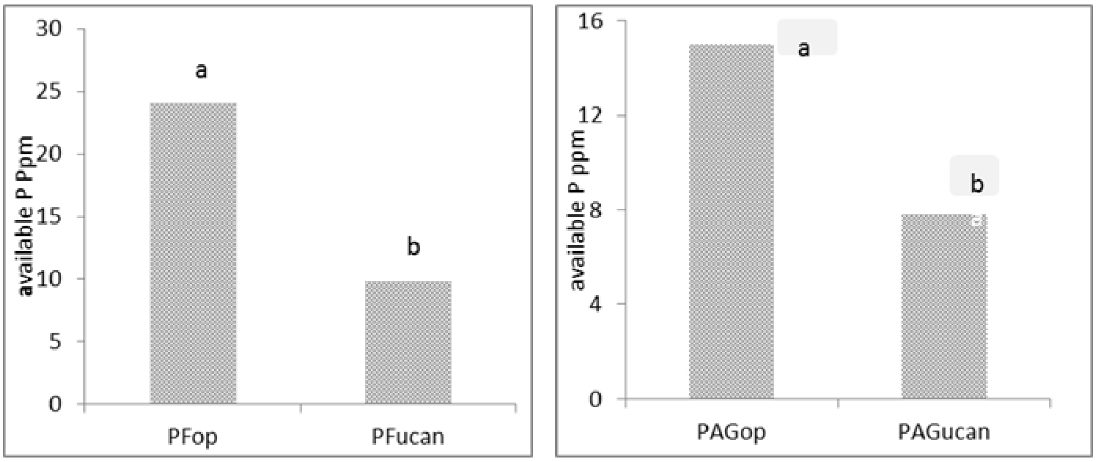


Figure 7. Bar chart chowing a*vailable phosphorous concentration in soil under canopy of Ficus vasta (left) and Albizia gummifera (right) trees and corresponding open field in the parkland agroforestry of central Rift valley, Ethiopia. Mean value on bar with different letter are* significantly different at P < 0.5

Table 5. Mean value (Mean±SD) of pH and CEC of soil under canopy of *Ficus vasta* and *Albizia gummifera* trees and open crop fields in the central Rift valley of Ethiopia

Species	Sample plot[1)]	pH	CEC Meq/100g
Ficus vasta	CN	8.03±0.21^a	22.30±2.18^a
	OP	7.33±0.31^b	19.19±1.7 6^b
Albizia gummifera	CN	6.97±0.55^a	23.25±4.07^a
	OP	6.73±0.29^a	21.20±4.08^a

CN= under canopy, OP= open field. Within column, means of individual species and open field followed by the same letter are not significantly different at P < 0.5.

Table 6. Exchangeable bases of soil samples from under canopy of *Ficus vasta* and *Albizia gumifera* trees and open crop fields in the central Rift valley of Ethiopia. (Mean± SD)

species	Sample plot[1)]	Exchangeable base Meq/100 g soil			
		Na	K	Ca	Mg
Ficus vasta	CN	0.55±0.21^a	2.64±1.75^a	7.87±1.84^a	2.81±0.76^a
	OP	0.43±0.23^a	1.47±0.221^b	6.21±1.48^a	2.44±0.32^a
Albizia gumifera	CN	0.69±0.11^a	4.42±1.65^a	12.41±3.24^a	3.39±1.76^a
	OP	0.60±0.28^a	1.86±0.89^b	12.15±2.45^a	3.27±0.92^a

[1)] CN= under canopy, OP= open field. Within column, means of individual species and open field followed by the same letter are not significantly different at P < 0.5.

efficient uptake by a large root system and subsequent release from litter. The higher K value under tree canopy might be also due to the efficient capturing of nutrients by tree roots below the root zone of crops. Concentrations of Mg were slightly higher under *Ficus vasta* canopy than open fields.

Conclusion

A total of 24 woody species representing 15 families and 21 genera was recorded at the study area. At the family level, *Fabaceae* was the most dominant family represented by 5 woody species, followed by Moraceae represented by 4 species. Out of 24 woody species, 92% were native. In general, this parkland agroforestry has high potential in biodiversity conservation. Concentrations of total nitrogen, organic carbon and available P under tree canopies were significantly higher than open fields. Naturally, *Ficus vasta* has higher foliar biomass than *Albizia gummifera* may better enhance organic C, or soil organic matter. The overall differences in assessed soil variables between the open fields and under tree canopies can be due cumulative effects of nutrient recycling by litter from trees and various animals.

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