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Effects of scattered *Faidherbia albida* and *Cordia africana* Tree on Soil Properties under their Canopies in Fedis District, Easte Hararghe Zone, Oromia

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Authors' contributions

This work was carried out in collaboration between both authors. Author MA designed the study, performed the statistical analysis, wrote the protocol and wrote the manuscript. Author LN read and approved the final manuscript.

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ABSTRACT

The study was conducted to investigate the effect of scattered trees under their canopies on soil fertility status at Fedis district, East Hararghe Zone, oromia, Ethiopia. Accordingly, six isolated and nearly identical *Faidherbia albida* and *Cordia africana* trees were selected and the canopy coverage of each tree was divided into four radial transects. Soil samples from three horizontal distances levels: 2.5m, 5m and 25m with two soil depths levels (0–20cm and 20-40cm) were taken for analysis of soil physical and chemical properties and tree species with two levels with factorial arrangement in RCBD replicated six times were employed. The result revealed soil texture was not influenced significantly ($P>0.05$) by tree species. Soil bulk density was significantly ($p<0.05$) influenced by both tree species. Soil moisture was significantly ($p<0.05$) higher under canopy of trees than open field and in surface than in subsurface soils. Soil chemical properties;- electric

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conductivity, organic carbon, organic matter, soil carbon stock, total nitrogen, available phosphorus and exchangeable cation (Mg, Ca, Na and K) for surface and subsurface soil layers of under *F.albida* and *C. africana* trees were significantly ($p<0.05$) higher in canopy than open field and in surface than subsurface. Soil pH was not significantly ($p>0.05$) influenced by both tree species. It can be concluded that these tree species have the potential to improve soil fertility beneath its canopy. This may be important for the agricultural landscape health and demonstrated the scattered trees to retain on crop fields to improve soil fertility status under its canopy and on farm biodiversity conservation in agricultural landscapes conditions.

Keywords: Soil fertility status; scattered trees; under the tree canopy; soil properties; productivity.

1. INTRODUCTION

Growing scattered trees in farmlands is characterizing a large part of the Ethiopian agricultural landscape and it is the most dominant agroforestry practice in the semi-arid and sub humid zones of the country [1]. Scattered trees within crop fields are common features of smallholder agriculture, which dominates both economic and social activity for millions of farmers in Ethiopia. Scattered trees in farmlands characterize a large part of the Ethiopian agricultural landscape and it is the most dominant agroforestry practice in the semi-arid and sub humid zones of the country [1]. The major reason for practicing agroforestry land use systems like scattered trees is the domestication of soil improving trees for enhancing soil productivity through a combination of selected trees and food crops on the same farm field [2]. Scattered tree systems are defined as areas where scattered multipurpose trees characterized by the diversity of woody or often indigenous species occur on farmlands as a result of farmer selection and protection [3]. The landscapes in which mature trees occur scattered in cultivated or recently fallowed areas [4].

Scattered agroforestry practice which is a system practiced for many local populations is very important for food security, microclimate amelioration, income generation and environmental protection. It is found at different corners of the world, primarily in the semi-arid and sub-humid zones of Africa [3]. Poschen [5] reported that growing of *Acacia albida, Cordia africana* and *Corton macrostachyus*, on farmlands is very well practiced in the eastern parts of Ethiopia. A preliminary survey of seven coffee producing provinces in eastern Ethiopia also revealed that there is a traditional scattered tree-crop based agroforestry system being practiced by the farmers in the region [6].

The enhancement of soil fertility and yield improvement under tree canopies reported by different scholars .For example, *Faidherbia albida* parklands modify soil moisture availability through increased infiltration [7], *Cordia africana* has significantly more nutrients in the top soil underneath by 24% its canopy, improves soil fertility in southern Ethiopia [8], *Faidherbia albida* improve barley productivity increased by 1396 kg ha−1 in Ethiopia [9-10], improves maize productivity [11,5], 56% yield increment of Sorghum under *Faidherbia albida* in Ethiopia, sorghum grain yield under *Cordia africana* tree canopy was increased by 14% than those that were grown on farmlands without trees in Burkina Faso [3]. Abebe et al. [12] also reported that decreased in maize (*Zea mays* L.) yield from 1.575 kg/4 m^2 per plot at 15 m away from the scattered *Cordia africana* tree to 0.982 kg/4 m^2 per plot under the tree at Bako even though the soil properties are improved under the tree than the open field. Traditional scattered tree-crop based agroforestry system being practiced by the farmers in the eastern Ethiopia [6].

Soil fertility depletion and low crop yields are widespread in the Hararghe highland [10]. The use of supplementary inorganic fertilizers has become more difficult for many Ethiopian farmers, due to the increase in cost following the removal of fertilizer subsidies. Consequently, retaining nitrogen fixing trees like *Fedhirbia albida* and *Cordia africana* trees has been used to address low fertility problems on small holders' fields in the region [13]. Additionally, it is important to combine plant biomass with inorganic fertilizers so as to increase fertilizer use efficiency and add organic matter that improves soil structure [14]. Few studies have examined soil fertility along a gradient from the tree base to nearby open areas in different under tree canopies. As such, the objective of this study was to determine the effects of *Fedhirbia albida* and *Cordia africana* trees on soil fertility along a gradient from the tree base to nearby open areas in different distances so as to assess the vertical and horizontal soil fertility gradients.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

2.1.1 Location

The study was conducted in Fedis district of the East Hararghe Zone of Oromia Regional State. Fedis district is one of the nineteen districts in East Hararghe zone, which is located at 550 km east of Addis Ababa and about 24 km from Harar town in the southern direction. The district comprises 19 peasant associations (PAs), which are associated with two different agro-ecological zones. The geographical location of the district is 8^0 22' 0" and 9^0 14' 0" N and 42^0 62' 0" and 42^0 19' 0" E. The altitude of the area ranges between 1200 to 2118 m.a.s.l.

Land use of the study area cultivable land/cropland (21.02%), pasture (2.80%), forest (11.2%),grass land (38.01%),communal land (10.5%) and remaining (14.04%) is considered as mountainous, valley and otherwise unusable (FWANRDO,2018).The district has two basic agro-climatic conditions, namely Midland (39%), and lowland (61%).The mean annual maximum and minimum rainfall, mean annual maximum and minimum temperature in the area were 850 to 650 mm, 30.4°C, and 10.0°C, respectively. The soil of the study area Precambrian quartz; calcareous sandstones, and calcareous limestone form the parent rock in the Eastern parts of the Hararghe highlands [5]. Fedis district has few patches of natural vegetation cover and some of the area is occupied by plantation forests and farmers incorporating trees on farmlands, boundary plantings, trees in croplands and woodlots agroforestry etc. The most dominant tree species found in the area include; acacia species, *Croton macrostachyus*, *Cordia africana, Fedhrbia albida, Eucalyptus camaldulences,* and many others [15].

X –axis represent for rainfall and Y-axis represent for temperature.

The district consists of 19 rural PAs and two rural towns and the total human population of the area 149,664 of which 76,182 (50.9%) are males and 73,482 (49.09%) are females [16]. The average family size is estimated to be 6 and 4 per household in rural and urban areas respectively. The average landholding per farm family is 0.73 hectare and has a total area of 110,502 hectares [15]. Crop production is mainly rain-fed, practically all annual crops produced by this way for household consumption. Cereal crops including maize (Z*ea mays* L.), sorghum (S*orghum biocolar*), and haricot beans (*Phaseolus vulgaris*) are grown on the study area. Haricot bean (*Phaseolus vulgaris*) is growing as an intercrop with maize and sorghum crops in the study area. A cash crop such as *Chat* (*Cata edulis*) is also grown predominantly in the study area. In addition to these different fruits, vegetables, cereal crops, and tuber crops are the most common agricultural products of the study area [15].

2.2 Methodology

2.2.1 Tree selection

The study was carried out on farmers' farm land in Fedis District, East Hararghe Zone of Oromia Regional State to compare the soil fertility status under traditionally retained scattered *F.albida and C.africana* trees against the open farmland outside the canopy cover. *F.albida and C.africana trees being the most abundant scattered tree species on crop fields were selected for this study.* Relatively homogenous site conditions in terms of slope, aspect and topography and growth of the trees were also considered in the selection of the trees of each species *and the where sorghum are stapled food crops of the area. The farmer's used manual land preparation methods like hand hoeing and oxen to cultivate the sampled farm fields. The sampled trees had also more or less similar management history* **.**On the selected field, individual trees of *F.albida and C.* a*fricana* having approximately similar height, diameter at breast height (DBH), crown diameter and from uniform site condition were marked to make other soil forming factors nearly constant. Of all the marked trees, six individual *F.albid* a*and C. africana* trees were randomly selected for this study, their DBH, height and crown diameter was measured by using caliper, hypsometer and meter tape, respectively. Each tree species was replicated six times. The dimension of each replication was almost uniform with the average DBH, height, and crown radius of 27.5cm, 10.67 m& 4.65mfor *F. albida*, respectively. Similarly, for *C.africana* the average DBH, height and crown radius were 31.83 cm, 12m & 5.49 m respectively.

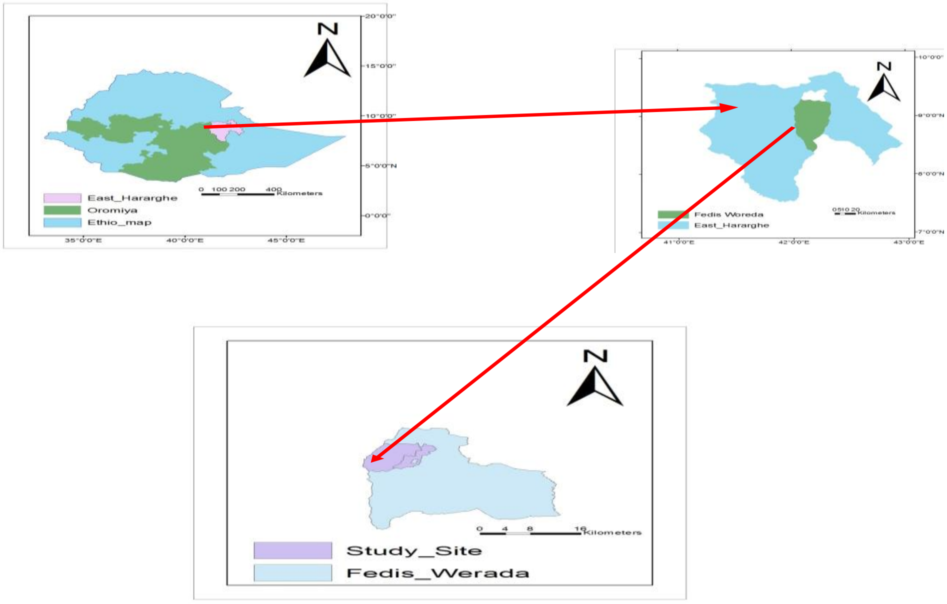

Fig. 1. Location map of the study area

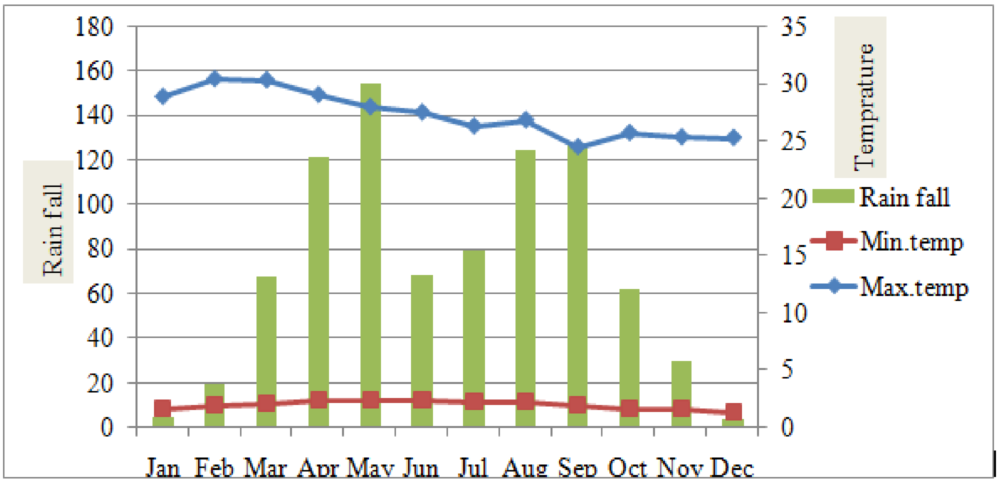

Fig. 2. Rainfall fall and temperature data of study area, 2018 GC

2.2.2 Treatments and experimental design

For the experiments, three factors; distance from tree trunk, soil depth and tree species were involved. Two tree species namely; *Cordia africana and F.albida trees* that are traditionally grown commonly on croplands were selected independently in the study area. Six isolated and nearly identical trees of each species growing on similar site conditions were selected and the canopy coverage of each tree was divided into four radial transects as shown in Fig. 3. Three plots (quadrates) of 1m by 1m were established on each radial transect at the distance of 2.5, 5, and 25 m away from the tree trunk [17]. The control plot was established at a distance of 24 m away from the trunk as per the suggestion made by [18]. *Two soil depth: levels (0-20 cm) depth representing surface and level (20-40 cm) the subsurface soil layer. The two tree species involved; Cordia africana and F.albida trees.* Experimental design*: the factorial arrangement of treatments in a randomized complete block design replicated six times, three distance levels *two soil depth levels*two tree species levees * six replication =72* total treatment combinations were used in this study.

2.2.3 Soil sampling and analysis

Three transect were made under each tree crown at 2.5 m crown radius as transect one, edge crown radius as transect two and third sample was taken as a control from open field which was third transects Fig. 3.For representativeness of the soil samples, three sub-composite soil samples were taken from surface (0–20 cm) and subsurface (20–40 cm) soil layers at each distance from three compass directions (North, South, East and West) of each tree trunk for all replication. Soil samples within the same radial distance and depth were composited. The composited samples of 2 kg were properly labeled, and air-dried, ground and sieved through 2 mm sieve. Besides, separate soil samples were collected by using core sampler for soil bulk density. Soil texture was determined by modified Bouyoucos method using hydrometer [19]. Soil bulk density was determined using core-volume method by dividing the weight of oven dry soil in the core (g) to the inner volume of the core (cm^3).Soil moisture content was determined by gravimetric method oven drying at 105°C.

Soil pH was determined in water at a soil: water ratio of 1:2.5. Suspension [20]. Similarly, Electrical conductivity was measured from the same soil/water suspension prepared for pH determination using a conductivity meter at 25°C [20]. Total soil nitrogen and Soil organic carbon were determined by Kjeldhal, and Walkely and Black method, respectively [21]. Soil Carbon stock was calculated as recommended by Pearson et al. [22] from the volume and bulk density of the soil (SOC = (ρb (g cm^3) ∗ D (cm) ∗ %C: Where, SOC = Soil organic carbon (t/ha), % OC = Organic carbon concentration of the quadrate (%) expressed in decimal, ρb = Bulk density of the quadrate (g cm^{-3}), D = Depth of the soil sample (cm).). Available soil phosphorus was determined by Olsen method [23]. Available potassium was determined by neutral ammonium acetate extraction method [24]. Cation exchange capacity (CEC) was determined titrimetrically by distillation of ammonium displaced by sodium method. Exchangeable bases (Ca, Mg, Na and K): Atomic absorption spectrophotometer was used for Ca and Mg determination and Flame photometer was used for Na and K determination [24].

2.2.4 Statistical analysis

Statistical differences were tested using two way analysis of variance (ANOVA) following the general linear model (GLM) procedure of SAS Version 9 0 at 5% significant level. A two-way ANOVA was used to test variations in distances from tree base and canopy position and soil depth for the measured parameters at $p < 0.05$. Least significance difference (LSD) test was used for mean separation for the analysis of variance showed statistically significant differences ($p<0.05$).

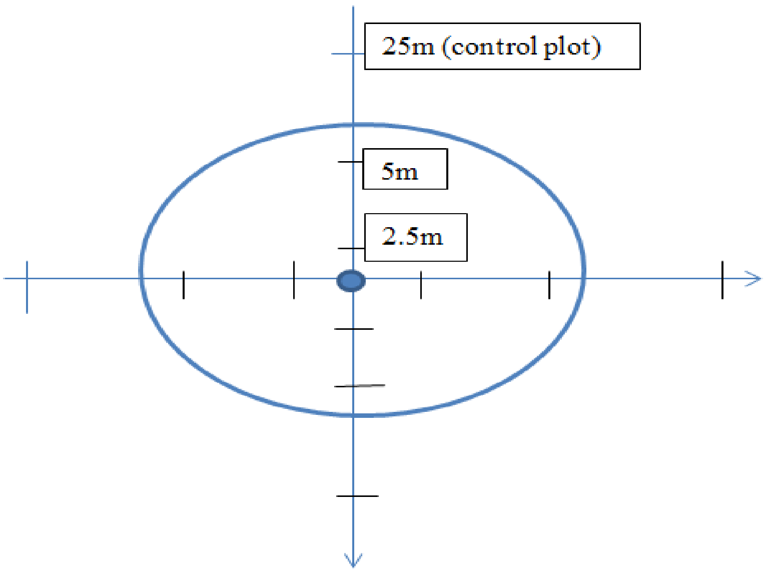

Fig. 1. The sampling in the field work, source: [17]

3. RESULTS AND DISCUSSION

3.1 Effects of *F. albida* and *C. Africana* scattered Trees on Soil Physical Properties

3.1.1 Bulk density, Soil moisture content and soil texture

The mean values of soil bulk density showed significant difference *(P<0.05)* among distances from tree trunk to open field both in surface and subsurface soil depths for both tree species. Mean values of soil bulk density at distance of 2.5m significantly lower than value at 25m distance. The soil bulky density of *F. albida* and *C.africana trees increased* from 88. % to 9.1% within the distance of the trees from under the tree canopy (2.5m) to (25m) the open cultivated land and *decreased* from 96.8% to 96.1% with soil depth (0-20 cm) to (20-40 cm) but there was no significant difference (P>0.05) in bulk density between two tree species Table 1. However, the interaction effect of distance from tree trunk and soil depth was not significant different (P>0.05).This higher soil bulk density recorded in subsurface soil than surface soil and open field than under canopy might be due to declining of soil organic matter both with distance and depth. This decline in bulk density under tree canopy might be due to higher accumulation of organic matter than the open land. Abebe [14] reported the same result for *C. macrostachyus, F. albida* and *C. africana* trees in the Hararghe highlands of Ethiopia. Moreover, Jiregna et al. [17] also reported lower bulky density levels under *C.africana* and *C. macrostachyus* canopies as compared to open plot. But my findings repot include all soil fertility parameters and agro-ecology difference while Enideg [25] reported though not significantly higher bulk density outside the canopy of *F. thonningii* as compared to the canopy zone in Ethiopia. [26] reported the same result for ***C.*** *macrostachyu**s*** trees in the Gemechis district, West Hararghe Zone, Ethiopia. Alemayehu et al. [27] reported a similar result for under the Canopy of *Coffee* Shade trees effect (*C. africana* and *E. abyssinica*) in Arsi Golelcha District, Ethiopia.

The texture of the study area was sandy clay loam soils according to USDA textural classification with higher proportions of sand Table 2. The textural classification of the soil was dominantly sand, clay followed by silt. The clay (31.02%) and (31.3%) under the canopy of the *F. albida* and *C.africana trees* respectively. The soils of the areas were predominantly sandy (>53.6%). The clay content in the soil (31.8%) and silt content (14.7%) was small. The results of textural analysis indicated that soil particle fractions of sand, silt and clay did not significantly vary (p > 0.05) with distance from the tree trunk while silt soil texture varied with distance from the tree trunk under *F. albida tree**.*** This study also revealed that silt content was slightly higher under canopy than open area. The sand and clay content was higher in open area than under the canopy for both tree species. The ANOVA showed that there was no significant variation in soil texture horizontally as a function of distance from the tree base to nearby open area suggesting uniformity of the parent material across the agricultural landscape of the study area. It may be ascribed to decreased biological activities, which might have enhanced weathering process under the tree canopy, while, silt and clay fractions significantly varied in soil depths. Silt and clay fraction content variation in depth-wise found from parkland agroforestry ecosystem of *acacia nilotica* in India [28].

3.2. Effect of *F. albida* and *C. Africana scattered* Trees on Soil Chemical Properties

3.2.1 Soil pH and electric conductivity (EC)

The analysis of variance for soil pH revealed that under all the selected tree species soil pH was lower under the tree canopies than the open field, but it did not show any significant differences (P>0.05 ,Table 2. The soil pH of the study areas ranged from 8.38 to under the tree and 8.43 open cultivated lands for the tree species. However, in this study there was a significance variation (P<0.05) in soil pH between tree species by 0.15due to soils under the canopy of scattered *Cordia africana* trees were less alkaline than those of the adjoining open area, indicating that the trees have a buffering effect organic matter due to the leaf litter fall and the2decomposition of dead roots which reduces soil alkalinity in the agricultural landscape Tables 2. The result also showed that soil pH was not significantly (P<0.05) affected by all treatments interactions. Similar to this finding Jiregna et al. [17] reported that there was no significant difference in soil pH under the canopy of *Cordia africana* and *C. macrostachyus* compared to the open area. Contradicting to this finding Kahi et al. [29] reported significant difference (P<0.05) in pH between the soils within and outside the canopies of both trees,

Table 1. Mean values of soil bulk density, soil moisture content and soil textures at different radial distances and soil depths at study area

Effects	**Soil Parameters**					
Distance from tree (m)	**Bulk Density (g/cm^{3})**	**Moisture Content (%)**	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Textural class**
2.5	1.21^{c}	11.56^{a}	53.63^{a}	15.54a	30.83^{a}	Sandy clay loam
5.0	1.25^{b}	9.92^{b}	53.25^{a}	15.42a	31.33^{a}	Sandy clay loam
25	1.29^{a}	8.26^{c}	54.38^{a}	14.38^{b}	31.32^{a}	Sandy clay loam
LSD (0.05)	0.04	0.14	1.35	0.23	1.37	
Soil depth (cm)						
0-20	1.23^{b}	10.89^{a}	54.31^{a}	15.64^{a}	30.11^{b}	Sandy clay loam
20-40	1.27^{a}	8.93^{b}	53.19^{b}	14.58^{b}	32.22^{a}	Sandy clay loam
LSD (0.05)	0.01	0.09	0.36	0.24	0.30	
Tree species						
F.albida	1.25^{a}	10.11^{a}	53.36^{a}	15.67^{a}	31.03^{a}	Sandy clay loam
Cordiaafricana	1.25^{a}	9.72^{b}	54.14^{a}	14.56^{b}	31.31^{a}	Sandy clay loam
LSD (0.05)	0.64	0.14	2.13	0.24	1.04	
Distance x Soil depth						
2.5m 0-20cm	1.18^{a}	13.18^{a}	55.00^{a}	16.67^{a}	28.75^{c}	Sandy clay loam
20-40cm	1.27^{a}	9.94^{c}	52.25^{a}	14.83^{a}	32.92^{a}	Sandy clay loam
5.0m 0-20cm	1.23^{a}	10.81^{b}	53.50^{a}	15.58^{a}	30.92^{b}	Sandy clay loam
20-40cm	1.28^{a}	9.02^{d}	53.00^{a}	15.25^{a}	31.75^{ab}	Sandy clay loam
25m 0-20cm	1.24^{a}	8.69^{d}	54.42^{a}	15.08^{a}	30.67^{b}	Sandy clay loam
20-40cm	1.31^{a}	7.82^{c}	54.33^{a}	13.67^{a}	32.0^{ab}	Sandy clay loam
LSD (0.05)	1.54	0.19	2.33	1.21	0.41	

Table 2. Mean of soil pH, electric conductivity, organic carbon, organic matter, soil carbon stock and TN along radial distance and soil depth by *F.albida* and *C. africana* trees Species in Fedis district

Effects		**Soil Parameters**					
Distance from the tree (m)		**pH(H_2O)**	**EC (dSm^{-1})**	**OC (%)**	**OM (%)**	**SCS (Mg ha^{-1})**	**TN (%)**
2.5		8.38	0.19^a	2.94^a	5.13^a	70.13^a	0.33^a
5.0		8.39	0.15^b	2.29^b	3.96^b	57.37^b	0.24^b
25		8.43	0.10^c	1.76^c	3.01^c	45.11^c	0.19^c
LSD (0.05)		NS	0.01	0.04	0.08	1.14	0.01
Soil depth (cm)							
0-20		8.39	0.17^a	2.64^a	4.56^a	64.27^a	0.29^a
20-40		8.41	0.13^b	2.01^b	3.51^b	50.79^b	0.21^b
LSD (0.05)		NS	0.01	0.04	0.08	1.16	0.01
Tree species							
F.albida		8.48^a	0.15	2.37	4.13	58.25	0.26^a
Cordiaafricana		8.33^b	0.16	2.29	3.94	56.82	0.24^b
LSD (0.05)		0.32	NS	NS	NS	NS	0.01
Distance x Soil depth							
2.5m	0-20cm	8.38	0.23	3.41^a	5.88^a	79.59^a	0.38^a
	20-40cm	8.38	0.18	2.46^b	4.39^b	60.66^b	0.28^b
5.0m	0-20cm	8.41	0.15	2.59^b	4.48^b	64.24^b	0.28^b
	20-40cm	8.39	0.13	1.98^c	3.44^c	50.49^c	0.21^c
25m	0-20cm	8.41	0.12	1.92^c	3.31^c	48.99^c	0.22^c
	20-40cm	8.46	0.09	1.58^d	2.71^d	41.23^d	0.16^d
LSD (0.05)		NS	NS	0.06	0.12	1.61	0.01

with a higher pH being found in the open cultivated land than under the canopy areas. Kamara and Haque [30] also reported a significant variation in soil pH horizontally under *F. albida* tree canopies.

The analysis of variance for soil electric conductivity revealed that soil electric conductivity was significantly affected by distance (P<0.05) from the tree trunk and soil depth (P<0.05) Table 2. Whereas electric conductivity was not significantly (P>0.05) affected by the interaction of distance and soil depth from the tree trunk. The average value of electrical conductivity was lower at the open field of the two tree species as compared to under the tree canopy i.e. at a 2.5 m from the tree base. The electrical conductivity of the *soil was decreased* from 0.193, 0.153, and 0.100within the distance of the tree from under the canopy (2.5m) to (25m) the open cultivated land. Maximum (0.168) electrical conductivity was recorded in the surface soil (0-20cm) of soil depth, while minimum (0.129) electrical conductivity was found to be in the sub surface soil (20-40 cm) of soil depth. As in pH, no defined trend of increase or decrease in electrical conductivity was observed at different depths. The generally, higher soil electrical conductivity under the tree canopies as compared to soils outside canopy might be due to the relatively higher leaf biomass which upon decomposition release soluble nutrients to the soil. And also might be due to the increased accumulation of aboveground biomass and associated cation uptake by the *F.albida and C.africana* trees. Similar to this study, [1] found no significant difference in soil EC under the canopy of *B. aegyptiaca* as compared to the open field.

3.2.2 Soil organic carbon

Organic matter has an important influence on soil physical and chemical characteristics, soil fertility status, plant nutrition, and biological activity in the soil [31]. The analysis of variance for soil organic carbon was a significant (P<0.05) affected by the main effects (tree species, distance from the tree and soil depth) as compared to the open field and all forms of interaction effects. Accordingly, a gradual and significant decrease in soil organic carbon was observed with increased distance away from the tree trunk regardless of tree species. This variation of organic carbon with distance away from the tree canopies was quite logical as the higher contents of organic carbon under the tree canopies were due to the leaf litter fall and decomposition of dead roots from the tree. Soil organic carbon showed significant (P<0.05) variation with depth. The highest value of soil organic carbon was recorded at the surface soil layers and it decreased significantly with increase in soil depth. In general, the result of the study revealed that soil organic carbon showed a significant (P<0.05) difference both horizontally and vertically under both tree species. There was no a significant difference in soil organic carbon between tree species Tables 2. Organic carbon was higher under the tree canopies and all showed a decreasing trend with increasing distances from the base of the tree towards the open field. The mean values of soil organic carbon content among all radial distances at (p<.0001 and p = 0001) and between soil depths at (p =0001 and p = 0001) for both tree species have showed significant difference.

Generally, the result showed a decreasing trend with increasing a radial distances from tree trunk in both surface and subsurface soil depth and along soil depth for both tree species. Similar with to this finding, Abebe [14] reported that there was a gradual and significant decrease in soil organic carbon was observed with increasing distance away from the tree trunk in Harergie highlands Ethiopia. In line with this [32] reported that the content of organic carbon depicts a decreasing pattern with soil depths and with increasing radius from the closest to the middle and distant positions of the under *Hagenia abyssinica*. Jiregna [17], reported also the surface soil organic C under both *C. macrostachyus* and *C. africana* tree species was significantly higher (P<0.05) than that at the subsurface. Tadesse et al. [33], Abebe et al. [12] Zebene et al. [8] have also reported a significant decrease in organic carbon and organic matter away from the tree trunk to the open cultivated land.

The organic matter has an important influence on soil physical and chemical characteristics, soil fertility status, plant nutrition, and biological activity in the soil [31]. Differences in organic matter were observed for sample points inside and outside the tree canopy in the agricultural landscape of the study area. Both *Faidherbia albida* and *Cordia africana* trees had influence on the organic carbon and Soil organic matter of the study area ranged from 5.87% to2.71% under the trees falling into low organic matter level. There was a significant difference in soil organic matter between the radial distance from the tree canopy and soil depth (*P*<0.05).The interaction effect between distance from the tree and soil depth was significant *P*<0.05, Table 2. The soil Organic matter was significant under the canopy of the tree than outside the canopy of the adjacent open area and showed a decreasing trend with increasing distance from the base of the tree towards the open field (*P*<0.0001) and decreased with depth (*P*<0.0001). This variation in organic matter with distance away from the tree canopy could be due to decompositions of the plant residue: leaf litters fall, dead roots from the tree as compared to the adjacent open areas while the source of Organic matter outside the canopy was mostly grass residues. Yadessa et al. [13] had reported a significant decrease in OC and OM away from the tree trunk to the open cultivated land on *Cordia africana* tree [17] also reported the surface soil OC under both *C.macrostachyus* and *C. Africana* tree species was significantly higher (*P*<0.05) than that at the subsurface.

3.2.3 Soil carbon stock (Mg ha^{-1}) and total nitrogen

The analysis indicated that, the mean values of Soil carbon stock (Mg ha^{-1}) among all radial distances at (p<0.05) for both trees species have showed significant difference. In this study, Soil carbon stock (Mg ha^{-1}) was highly significantly (P<0.0001) affected by all of the main effects (tree species, distance from the tree and soil depth) as compared to the open field. Soil carbon stock (Mg ha^{-1}) were higher under the canopies of the scattered *F. albida* and C. *africana* tree species and all shown a decreasing trend with increasing distances from the base of the tree towards the open field Table 2. The overall mean values of soil carbon stock (SCS) among all radial distances at (p<.0.05) for both tree species have showed a significant difference. The level of statistical differences among radial distances from tree trunk were in the order of: 2.5m > 5m > 25m and an overall mean value of SCS in surface soil depth were significantly higher (13.5%) than mean values of the subsurface soil depth for both tree species . The mean values of SCS in the surface and the subsurface soil depth among a radial distances from tree trunk were significantly different (p<0.05). The interaction effect between distances from the tree and soil depth was significantly different (p<0.05).

Soil carbon stock (SCS) of the surface soil at the under canopy (2.5m) and canopy edge (5m) were 79.59 Mg ha^{-1} and 64.24 Mg ha^{-1} higher than the surface SCS beyond canopy (25m) while the subsurface SCS of the under the canopy (2.5m) and canopy edge (5m) were 60.66 Mg ha^{-1} and 50.49 Mg ha^{-1} higher than their respective subsurface SCS beyond canopy (25m). The SCS of the present study ranged from 7825 Mg ha^{-1} to 7458 Mg ha^{-1} for the soils under tree canopy and from 6,986 to 6,388 Mg ha^{-1} for the soils outside tree canopy for both tree species. Comparing the SCS of the present study (1997.4 to 3081.2 Mg ha^{-1}) with those reported by Enideg [25] for the same species, the SCS of the present study was higher. Enideg [25] reported a SCS that ranged from around 1300 to 2600 Mg ha^{-1}, this variation in SCS might be the soil depth (15 cm of this against 10 cm of Enideg) considered. Generally he result showed a decreasing trend with increasing radial distances from tree trunk in both surface and subsurface soil depth for both tree species. This may be associated with the accumulation of high litter from both above and below ground tree biomass. The analysis of variance indicted that, the total nitrogen contents of the soils was showed the same trend as soil organic carbon. Total nitrogen was significantly (P<0.05) affected by all of the main effects (tree species, distance from the tree, and soil depth) and all forms of interaction effects. Significant (P<0.05) horizontal and vertical variation of total nitrogen was observed under selected tree species. There were also significant differences in total nitrogen between tree species as well as the interaction effects between any two or three of the main effects considered in the study area Tables 2. The high value of nitrogen (i.e. 0.327) was observed at the distance of a 2.5m and it a gradually decreases to 0.185 at the distance of 25m away from the tree trunk. The total nitrogen was significantly affected (p<0.05) by the radial distances under the two tree species.

Thus, the surface soils in the 0-20 cm soil depth contain much higher content of nitrogen than those in the sub surface (20-40 cm) soil depth. Soil under all the tree canopies studied showed higher nitrogen than soils in the open cultivated land. These horizontal variations in total nitrogen might be mainly due to the high accumulation of organic matter under the tree canopy. Similarly, Enideg [25] reported that total average soil nitrogen was higher beneath the canopy of trees than the open area. Soils under *F .albida* canopy had higher total nitrogen as the soils in the adjacent open areas and more than soils under *C.africana* .This finding is in agreement with previous studies in different sites of Ethiopia, Abebe [14] for *C. africana, F.albida* and *C. macrostachyus*; Zebene and Agren [8] *Millettia* f*erruginea* and *Cordiaafrican*; Tadesse et al. [33] for *Millettia*f*erruginea* and Abebe et al. [12] and [34] for *C.macrostachyus* and *C. africana* reported significantly higher total Nitrogen under tree trunk compared to the open cultivated land.

3.2.4 Available phosphorus and Cation exchange capacity (CEC)

In the study area, available phosphorus was significantly (P<0.05) affected by the all main effects (tree species, distance from the tree and soil depth) and all forms of interaction effects was significant (P<0.05, Table 3. It was higher by 96% and 79% under the canopies of the *F. albida* and *C. africana* tree species, respectively, than an open field. As compared to the open field available phosphorus was significantly different (p<0.05) under the canopy of *the tree* species than the open cultivated land. It also showed a decreasing trend with increasing distance from the tree base towards the open cultivated land. Similarly, its values were significantly decreased with increased soil depth for both tree species. The available phosphorus in the upper surface (0-20cm) and subsurface soil depths (20-40cm) were significantly different (p<0.05). The study also revealed that available phosphorus in the soils varied significantly (P<0.05) between tree species. This variation could be attributed to high organic matter accumulation under the tree canopies than the control one. This organic matter accumulation has the potential to overcome phosphorus deficiency. The mean value of available phosphorus (i.e.8.41 ppm) was observed at the distance of 2.5m and it gradually decreases to 4.52 at the distance of 25 m away from the tree trunk. The mean value of available phosphorus (i.e. 7.26 ppm) in the upper surface (0-20cm) and (5.72 ppm) in the subsurface soil depths (20-40cm) were significant different (p<0.05). The study also revealed that available phosphorus in the soils varied significantly (P<0.05) between tree species. Available phosphorus under *F.albida* tree was significantly different (p<0.05) than under *C. africana* tree.

This might be due to the high accumulation of organic matter under the canopies of *F.albida* tree Table 3. In line with this study, Abebe [14] found higher level of available soil phosphorus in the canopy of the *C. africana*, *F. albida* and *C. macrostachyus* trees than the outside of the canopy of the tree in the Harergie Highlands. Similarly, Tadesse et al. [33] reported that available soil phosphorus increases under the canopy of *M. Ferruginea* tree than the open land. Contrary to these findings, Abebe et al. [12] and [34] reported significant decrease in available soil phosphorus under *C.macrostachyus* and *C.africana as* compared to the open cultivated land. Contrary to this finding Kahi et al. [29] reported that Available phosphorus was significantly (p<0.05) higher in the open areas than under the canopies of both *A. tortilis* and *P. juliflora* trees.

The result of cation exchange capacity showed a highly significantly (p<0.05) affected by all of the main effects (tree species, distance from the tree and soil depth) but not significantly different in all forms of interaction effects Tables 3. Accordingly, the cation exchange capacity of the soils showed significant horizontal variation (P<0.05) in both soil depths and under two selected tree species. A gradual and significant decrease in the values of cation exchange capacity was also observed as the distance from the tree trunks increased Tables 3. This could be mainly due to high organic matter accumulation under the tree canopies than the open fields. The higher amounts of soil organic matter under the tree canopies may imply that more cations would be released to the soil through mineralization as result, the amount of negative charges in the soil would be higher. In this study, the values of cation exchange capacity for surface soils were 18.93 and sub-surface soils16.81 (Meq/100 g soil) soil at the distance of under the canopy of *F. albida* and *C. africana* tree species. These values were observed to decrease to 19.72and 16.09 (Meq/100 g soil) soil at the distance of 2.5m to 25m (open cultivated land) away from the tree trunk under *F.albida* and *C. africana* tree species.

The cation exchange capacity measurements indicate potential fertility of a soil and possible responses to fertilizer application. Soils with a cation exchange capacity of <16 meq/100 g are considered to be not fertile (such soils are often highly weathered), while fertile soils have a cation exchange capacity of >24 meq/100 g [35] In the current study, soil cation exchange capacity in the canopy zone of *F. albida* and *C. africana* trees ranges from19.718 to16.091 meq/100g) that falls in the range of

Table 3. Mean of Available P, CEC and cation exchange base along radial distance and soil depth by *F.albida* and *C. africana* trees species in fedis district

Effects		**Soil Parameters**					
Distance from the tree (m)		**AVP (ppm)**	**CEC(meq)/100g**	**Na (cmol (+)/Kg soil**	**K (cmol (+)/Kg soil**	**Ca (cmol (+)/Kg soil**	**Mg(mol (+)/Kg soil**
2.5		8.41[a]	19.72[a]	0.25[a]	1.79[a]	10.65[a]	3.12[a]
5.0		6.54[b]	17.79[b]	0.18[b]	1.22[b]	9.38[b]	2.67[b]
25		4.52[c]	16.09[c]	0.09[c]	0.75[c]	8.33[c]	1.84[c]
LSD (0.05)		0.52	0.01	0.01	0.26	0.63	0.41
Soil depth (cm)							
0-20		7.26[a]	18.93[a]	0.19[a]	1.37[a]	9.95[a]	2.61
20-40		5.72[b]	16.81[b]	0.16[b]	1.13[b]	8.96[b]	2.48
LSD (0.05)		0.53	0.01	0.02	0.27	0.66	NS
Tree species							
F.albida		6.77[a]	18.73[a]	0.19[a]	1.39[a]	9.47	2.63
Cordiaafricana		6.21[b]	17.01[b]	0.16[b]	1.10[b]	9.43	2.46
LSD (0.05)		0.53	0.01	0.01	0.26	NS	NS
Distance x Soil depth							
2.5m	0-20cm	9.43[a]	21.08	0.28	2.00	11.42	3.23
	20-40cm	7.38[b]	18.36	0.19	1.58	9.87	3.02
5.0m	0-20cm	7.30[b]	18.72	0.19	1.26	9.69	2.78
	20-40cm	5.77[c]	16.88	0.16	1.17	9.07	2.55
25m	0-20cm	5.03[d]	16.98	0.11	0.85	8.72	1.81
	20-40cm	4.01[e]	15.19	0.09	0.64	7.93	1.86
LSD (0.05)		0.73	NS	NS	NS	NS	NS

moderately fertile soil .The same trendwas reported by Abebe [14] for surface soil at Harergie Hirna site in Ethiopia. The cation exchange capacity of soil is a measure of soils negative charge and thus of the soils capacity to retain and release cations for uptake by plant roots. The cation exchange capacity of a soil is strongly related with the organic matter content of as soil [31]. With increase in organic matter under canopy of the studied trees, the total negative charges of the soil increased which in turn increased the cation exchange capacity of the soil. Horizontal variations; significant cation exchange capacity increments under the tree canopy than the open one has been also reported by Abebe et al. [12], [18] and [34] under *C. africana, M. ferruginea*, and *C.macrostachyus* respectively. In line widths finding, [32] also reported that the lowest cation exchange capacity values we rerecorded under *B. polystachya* at the 0- 15and 15-30 cm soil depths of all the three horizontal positions.

3.2.5 Exchangeable bases (Ca, Mg, Na and K)

The values of exchangeable bases at different distances and soil depths under tree canopies were presented in Tables 4. The analysis of variance of the abdications (Ca, Mg, Na, and K) varied significantly (P<0.05) both horizontally and vertically. The amounts of cations in the soils decreased gradually and significantly (P<0.05) as the distance from the tree trunk increased for both tree species. The values of exchangeable cations at different distances under tree canopies in the soil depth are presented in Table 4.The ANOVA of the basic cation content (Ca, Mg, Na, and K) varied significant(P < 0.05) by the distance from the tree bases. The mean values of exchangeable calcium (10.65), Mg (3.12), K (1.79 meq./100 g soil), and Na (0.25 meq./100 g soil)were higher in soils at 2.5 m distance from the bases of the trees under *F. albida* and C*ordia Africana* tree and Calcium (8.33), Mg (1.84),K (0.75),and Na (0.09)were decreased in soils at 25 m distance decreased with increasing distance from tree bases. There were also significant differences in exchangeable Ca, Na, and K levels (P < 0.05) vertically Table 3. Exchangeable magnesium, on the other hand, was not significantly varied across soil depth under and outside the tree canopy. Values of exchangeable Ca and Mg were markedly higher under tree canopy compared to the soils of the open land for both two tree species whereas; exchangeable Na and K were significantly (P<0.05) varied with soil depth and selected tree species. This observation could be due to the high accumulation of litter under the tree canopies. As the cations would be released when the accumulated litters from the canopies of the trees undergo microbial decomposition that leads to subsequent mineralization and release of plant available nutrients to the soil. As a result, the amount of exchangeable cations would be higher under tree canopies than in the open field. [32] also reported that the content of K, Ca, and Mg decreased at greater distance from Hagenia abyssinica trees.

4. CONCLUSIONS AND RECOMMENDA-TIONS

The scattered *F.albida* and *C. africana* trees are important for the restoration of soil fertility, particularly in the study area where the low soil fertility was the main barrier to crop production. Based on the results of the study, the fertility status of the soils gradually decreased as the distance away from the tree trunk is increased. Soil textural fractions (sand, silt and clay) were not considerably influenced by presence of *F.albida* and *C. africana* trees. Whereas, soil bulk density was notably lower under canopy of *F.albida* and *C. africana* trees than outside canopy, and increased with increasing radial distances. Likewise, bulk density of surface soil was also significantly lower than subsurface soil layer. Soil moisture content under *F.albida* and *C. africana* trees at all radial distances were significantly higher under canopy than outside canopy, and decreased with increasing radial distances from tree trunk. Likewise, surface soil moisture was significantly higher than subsurface soil moisture. With the regard to soil chemical properties, electric conductivity, organic carbon, organic matter, soil carbon stock, total nitrogen, available phosphorus and exchangeable cation (Mg, Ca, Na and K) for surface and subsurface soil layers of under *F.albida* and *C. africana* trees were considerably improved than outside their canopies. Further research should be required on *F.albida* and *C. africana* trees fine root temporal and spatial distribution since fine root affects either directly or indirectly soil fertility and yield of associated crops. Litter quality is one among various factors which affects soil fertility based on its type and chemical contents. Therefore, further investigations will also needed on *F.albida* and *C. africana* trees litters' decomposability and their chemical compositions. Similar future research should be coupled with more measurements on soil physical and chemical properties related to soil texture and soil pH. Finally, Because of its role in ameliorating microclimate and improving soil fertility under their canopies, retaining of *F.albida* and *C. africana* trees on crop land is important for the farmers with appropriate component management practices like lopping and crown opening

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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