

Impact of *Parkland* Trees (*Faidherbia albida* Delile and *Cordia Africana* Lam) on Selected Soil Properties and Sorghum Yield in Eastern Oromia, Ethiopia

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Abstract: The study was conducted to investigate the impact of Parkland trees in farmland on selected soil physicochemical properties and sorghum grain yields in Fedis District, Oromia, Ethiopia. For the experiment of soil physicochemical properties, three factors: distance from tree trunk with three levels (at 2.5m of crown, edge of crown radius and open field), soil depth with two levels (0-20cm and 20-40cm depth) and tree species with two levels with factorial arrangement in RCBD replicated six times were employed. For sorghum grain yield only two factors; distance from tree trunk with three levels (at 2.5m of crown, edge of crown radius and open field) and tree species (*F. albida* and *C. africana*) with two levels in RCBD replicated six times were used. The result revealed soil texture was not influenced significantly ($P>0.05$) by tree species. Soil bulk density was significantly ($p<0.05$) lower under canopy of trees than open field, and in surface than in subsurface soils. As well as soil moisture content was significantly ($p<0.05$) higher under canopy of trees than open fields. Soil chemical properties (EC, SOC, OM, Soil Carbon Stock, total N, available P, exchangeable Na, exchangeable K, exchangeable Ca, exchangeable Mg and CEC) 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. The grain yield of sorghum (sorghum bicolor) were significantly ($P<0.05$) higher under canopy of both trees species as compared to the open field. In general, the nutrients contents increased by 84.3% and 71.5% for OC, 84.2% and 70.8% for OM, 66% and 59% for SOC Stocks, 82% and 84% for TN, 96% and 79% for AP, 15.6% and 34.2% for CEC, 30% and 10% for EC, 82% and 27.2% for Na, 41% and 30.4% for K, 33.8% and 28.2% for Ca and 58% and 87% for Mg and 13.22% and 13.15% for MC and by 43% and 41% for Sorghum yield were detected under the canopies of *F. albida* and *C. africana* tree species respectively. It can be concluded that these tree species have the potential to improve soil fertility and moisture beneath its canopy. Thus, retaining these tree species and in particular *F. albida* on crop field in the study area is of paramount importance for soil fertility enhancement so as to improve food security of small farming households.

Keywords: Soil Properties, Tree Transect, Sorghum Grain Yield, Soil Carbon, Total N₂

1. Introduction

Growing parkland 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. The major reason for practicing agroforestry land use systems like parkland 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, [18]. Agroforestry parkland systems is 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, landscapes in which mature trees occur scattered in cultivated or recently fallowed areas, [3]. Parkland agroforestry which is a system practiced for many

local populations is very important for food security, microclimate amelioration, income generation and environmental protection, and is found at different corners of the world, primarily in the semi-arid and sub-humid zones of Africa. 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, [7]. *Acacia albida*, *Cordia africana* and *Croton macrostachyus*, on farmlands is very well practiced in the eastern parts of Ethiopia, including study area.

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, [27], *Cordia africana* has significantly more nutrients in the top soil underneath its canopy, improves soil fertility in southern Ethiopia, [32], *Faidherbia albida* improve barley productivity in Ethiopia, [12, 9] improves maize productivity, Gizachew *et al.*, [11, 26] 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, [4]. Decreased in maize (*Zea mays* L.) yield from 1.575 kg/4 m² at 15 m away from the scattered *Cordia africana* tree to 0.982 kg/4 m² under the tree at Bako even though the soil properties are improved under the tree than the open field [2]. Traditional scattered tree-crop based agroforestry system being practiced by the farmers in the eastern Ethiopia.

Growing tree species such as *Cordia africana*, *Croton*

macrostachyus, *Olea africana*, *Acacia* species, *Faidherbia albida* and *Psidium guajava* trees in the farmlands together with cereals, vegetables, and *chat* is common practice in eastern Ethiopian Hararghe highlands, [1], including the study area with socio-economic and ecological importance in Fedis district. Farmers have practiced maintaining a few tree species on small portions of their farmland and on farm boundaries. Although, parkland/scattered trees are common in the study area, there are different challenges to the parkland agroforestry practices and some of them include: land shortage as a result of population pressure, high demands of tree products, deforestation, and reduced parkland trees on farm fields, and low productivity. The influence of parkland trees on soils and crops in farmland is not well explored so far and the emphasis given from research on the soil properties and crop yield and the effort to assist farmers to improve productivity of their farm trees on scientific evidence is minimal.

The promotion of agroforestry trees on farmland, their compatibility with different field crops are important to furnish information on the impacts and appropriate management practices of these scattered tree species on field crops and soil physicochemical properties. Therefore, the study was initiated to investigate the effects of *F. albida* and *C. africana* trees on physical and chemical properties of the soil under and outside of the canopy; to assess the vertical and horizontal soil fertility gradients as influenced by the tree species and to evaluate the grain yield of sorghum under the canopies of trees species and compared to open field.

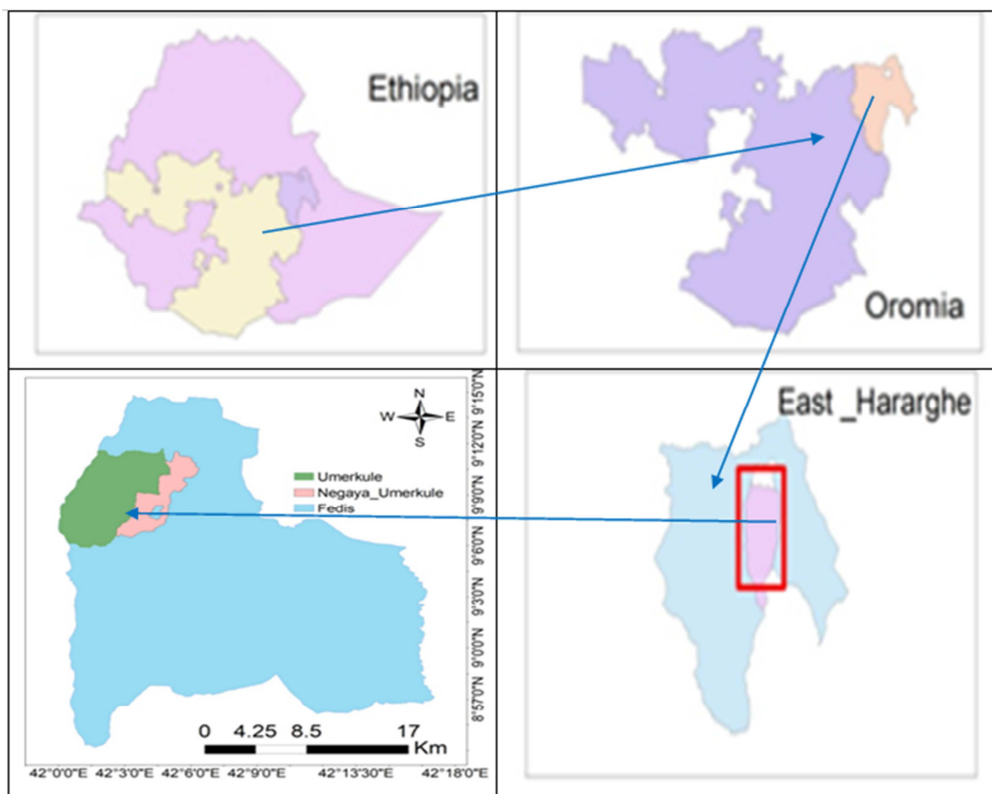


Figure 1. Location map of the study area.

2. Materials and Methods

2.1. Description of the Study Areas

The study was conducted in Fedis district of East Hararghe Zone, Oromia National Regional State; Ethiopia. It is located in the eastern part of the country at 550 km from Addis Ababa the capital city of Ethiopia and 24 km from Harar town in the southern direction (Figure 1). The geographical location of the district is 8° 22' 00" and 9° 14' 00" N and 42° 62' 00" and 42° 19' 00" E. The altitude of the area ranges from 500-2100 meter above sea level.

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. 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 was dominantly sand clay loam soils (moderately fine texture). 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*, *Faidherbia albida*, *Eucalyptus camaldulences*, and many others.

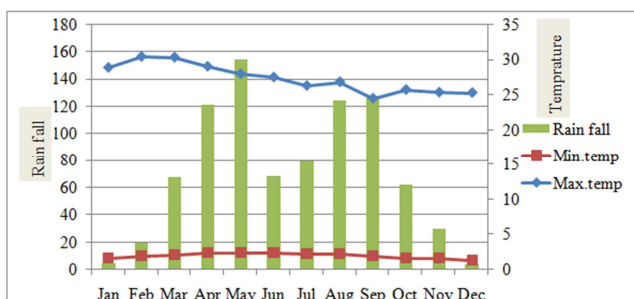


Figure 2. Rain fall and Temperature data of Fedis District, 2018 GC.

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. 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. Crop production is mainly rain-fed, practically all annual crops produced by this way for household consumption. Cereal crops including maize (*Zea mays* L.), sorghum (*Sorghum 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.

2.2. Sampling Design and Methods of Data Collection

2.2.1. Tree Sample Selection

F. albida and *C. africana* trees being the most abundant scattered tree species on crop fields were selected for this study. The selected farm fields with this tree species are characterized by a gentle slope where sorghum and maize are staple food crops of the area. Relatively homogenous site conditions in terms of aspect and topography and growth of the trees were also considered in the selection of the trees of each species. On the selected field, individual trees of *F. albida* and *C. africana* 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 individuals of *F. albida* and *C. africana* trees were systematically 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 27.5 cm, 10.67 m and 4.65 m for *F. albida*, respectively. Similarly, for *C. africana* the average DBH, height and crown radius were 31.83 cm, 12 m and 5.49 m respectively.

2.2.2. Treatments and Experimental Design

For soil experiment three factors; distance from tree trunk, soil depth and tree species were involved. The distance factor had three levels; at radius of 2.5m, edge crown radius and at three times total crown radius away from tree trunk which was used as control as following the procedure by, [15]. The depth factor had two levels: (0 - 20cm) depth representing surface soil and (20 -40cm) depth representing subsurface soil layer. Depths of 0 - 20cm and 20 - 40cm are selected because it is the depth where fine root of tree and crops dominate and consequently intense interaction is expected between the trees and crops grown on the same land management unit, [22]. The tree species factors involved two tree species; *F. albida* and *Cordia africana* trees that are traditionally grown commonly on croplands were selected independently. Design: 3*2*2 factorial arrangement of treatments in a randomized complete block design replicated six times, 3*2*2*6 =72 total treatment combinations were used in this study. For sorghum yield experiment had two factors which were distances from tree trunk with three levels; at radius of 2.5m, edge crown radius and at three times total crown radius away from tree trunk (open field) which was used as control, and tree species; *F. albida* and *Cordia africana* trees were involved. Design: 3*2 treatments arranged in a randomized complete block design replicated six times 3*2*6 =36 total treatment combinations were used.

2.2.3. Soil Sampling and Analysis

Three transect were made under each tree crown at 2.5m 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 (Figure 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 replications. 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 2mm 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 [10]. 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 [14]. Similarly, Electrical conductivity was measured from the same soil/water suspension prepared for pH determination using a conductivity meter at 25°C [14]. Total soil nitrogen and Soil organic carbon were determined by Kjeldhal, and Walkely and Black method, respectively [6] and [30]. While percentage organic matter was determined by ($\text{OM} = \% \text{C} \times 1.724$), and Soil Carbon stock was calculated as recommended by [25] from the volume and bulk density of the soil. Available soil phosphorus was determined by Olsen method [23]. Available potassium was determined by neutral ammonium acetate extraction method [21]. 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 [21].

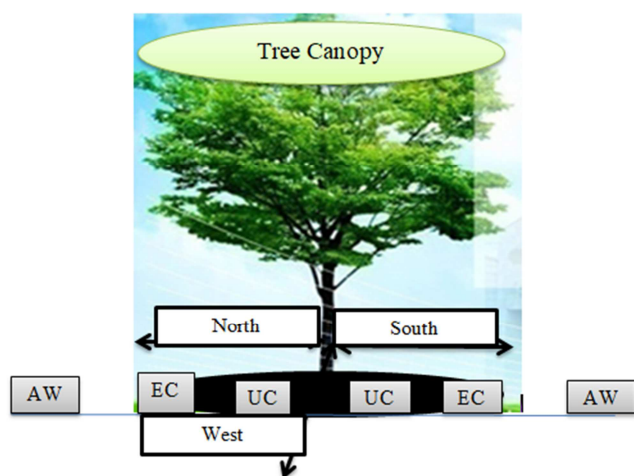


Figure 3. Experimental design of the sampling in the field work.

Where: UC = under canopy; EC = Edge of canopy; AW =Away of canopy (control)

2.2.4. Sorghum Yield Sampling

Under the selected tree species, one meter by one meter plot was laid at 2.5m, edge crown radius and open field in three compass directions (North, South, East and West). Sorghum was harvested from each plot. The harvested sorghum from the same radial distance was composited for each replication. Finally, the composited Sorghum grain was separated from their stock'. The separated Sorghum grain for each radial distance was weighed using sensitive balance.

2.2.5. 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. Least significance difference (LSD) test was used for mean separation for the analysis of variance showed statistically significant differences ($p < 0.05$).

3. Results and Discussion

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

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 1.17 gcm^{-3} to 1.32 gcm^{-3} and 1.18 gcm^{-3} to 1.31 gcm^{-3} , respectively within the distance of the tree from under the tree canopy (2.5m) to (25m) the open cultivated land and increased from 1.23 gcm^{-3} to 1.27 gcm^{-3} and 1.23 gcm^{-3} to 1.28 gcm^{-3} 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. [1], reported the same result for *C. macrostachyus*, *F. albida* and *C. africana* trees in the Hararghe highlands of Ethiopia. Moreover, [15], also reported lower bulky density levels under *C. africana* and *C. macrostachyus* canopies as compared to open plot. While [8], reported though not significantly higher bulk density outside the canopy of *F. thonningii* as compared to the canopy zone in Ethiopia. [20], reported the same result for *C. macrostachyus* trees in the Gemechis district, West Hararghe Zone, Ethiopia. [3], reported a similar result for under the Canopy of *Coffee* Shade trees effect (*C. africana* and *E. abyssinica*) in Arsi Golelcha District, Ethiopia.

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

Treatment		<i>F. albida</i>		<i>C. africana</i>	
Distances (m)	Depths (cm)	BD (gcm ⁻³)	MC (%)	BD (gcm ⁻³)	MC (%)
Mean (Std. Dev.)					
2.5	0-20	1.17±0.02	13.22±1.81	1.18±0.02	13.15±1.90
	20-40	1.22±0.01	11.02±1.35	1.23±0.01	10.59±2.23
5.0	0-20	1.25±0.01	10.18±2.22	1.25±0.01	9.70±0.36
	20-40	1.27±0.10	9.37±0.30	1.27±0.12	9.29±0.97
25	0-20	1.29±0.01	8.75±1.42	1.28±0.10	8.01±1.46
	20-40	1.32±0.01	8.10±0.49	1.31±0.12	7.55±1.95
LSD (0.05)		0.05	1.04	0.04	1.04
Overall	0-20	1.23 ^b	11.21 ^a	1.23 ^b	10.58 ^a
	20-40	1.27 ^a	9.01 ^b	1.28 ^a	8.85 ^b
LSD (0.05)		0.03	0.60	0.02	0.60
2.5	Overall	1.21 ^c	11.69 ^a	1.22 ^c	11.43 ^a
5.0		1.26 ^b	9.89 ^b	1.25 ^b	9.94 ^b
25		1.30 ^a	8.74 ^c	1.31 ^a	7.78 ^c
LSD (0.05)		0.03	0.74	0.03	0.74

* Means with the same letter are not significantly different at (P<0.05)

MC = Moisture content at the time of sampling, BD = Bulk density and Std. Dev=standard division

The analysis of variance for soil moisture content revealed that soil moisture content was significantly (P<0.05) affected by distance from the tree trunk and soil depth (Table 1). There was also significant interaction effect between distance from tree trunk and soil depth (P<0.05). The values soil moisture content was higher under the canopy of the *F. albida* and *C. africana* trees than outside the canopy of the adjacent open field and showed a decreasing trend with increasing distance from the base of the tree towards the open field (11.69% to 8.74%) and (11.43% to 7.78%) and decreased with depth (11.21% to 9.01%) and (10.58% to 8.85%) respectively. Moisture content at different distance and soil depth from the trunk of the tree indicated was not significant difference (P>0.05) for both *F. albida* and *C. africana* trees. The overall mean values of soil moisture content showed significant (p<0.05) differences among radial distances from tree trunk for both tree species. Similarly, mean values of surface and subsurface soil layer moisture content was significant difference (P<0.05). With regard to depth wise comparison, surface (0-20 cm) soil layer moisture content mean value was found to be significantly (p<0.05) higher than mean value of subsurface (20-40 cm) soil layer at 2.5 m, 5 m and 25 m. The highest mean values (13.22% and 13.15%) at 2.5 m under the canopy of surface soil layer and lowest mean values (8.10% and 7.55%) at 25 m were observed at subsurface soil layers under *F. albida* and *C. africana* were recorded, respectively.

Generally, the result showed a decreasing trend with increasing radial distances and soil depth. This may be ascribed to the reduction of soil water loss by evaporation because of the area is semi-arid with rain fall ranging 650 to

850 mm per year, there will be moisture shortage. Similar findings were reported by [24], under *Acacia nilotica* tree. According to [4] soil moisture content decreased significantly with increasing distance from karate (*Vitellaria paradoxa*) tree to open areas. Besides, [1], reported a significant variation in moisture content that varies with tree species and with geographical location of tree species from the Highland of Hararghe in 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 sand proportion was (53.4%) and (54.1%), silt (15.7%) and (14.6%), and 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. 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 [24].

Table 2. Soil texture at different radial distances and soil depths under *F. albida* and *C. africana* trees.

Treatments			Soil particle distribution			
Trees	Distances (m)	Depths (cm)	Sand (%)	Silt (%)	Clay (%)	Texture
F. albida		0-20	54.17	15.56	30.38	SCL
		20-40	52.41	15.78	31.66	SCL
C. africana		0-20	54.44	15.72	29.83	SCL

Treatments			Soil particle distribution			
Trees	Distances (m)	Depths (cm)	Sand (%)	Silt (%)	Clay (%)	Texture
		20-40	53.84	13.39	32.77	SCL
	LSD (0.05)		NS	0.51	1.28	
2.5			53.25	16.42	30.3	SCL
5.0	F. albida		53.25	15.92	30.83	SCL
25			53.58	14.67	31.92	SCL
2.5			54.0	14.67	31.33	SCL
5.0	C. africana		53.25	14.92	31.83	SCL
25			55.17	14.08	30.75	SCL
LSD (0.05)			NS	NS	NS	

SCL- Sandy clay loam, NS-Non significant

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

3.2.1. Soil pH and Electric Conductivity (EC)

The analysis of variance for soil pH revealed that under the selected tree species it was slightly lower under the tree canopies than the open field, and it was lower at 0-20 cm soil depth as compared to the 20-40cm soil depth but it did not show any significant differences (Table 3). The soil pH of the study area ranged from 8.45 to under the tree and 8.53 open cultivated lands for *F. albida* tree species while 8.30 to under

the tree and 8.38 open cultivated lands for *C. africana* tree. The measured soil pH increased with increasing distance away from the base of the tree i.e. it was lower beneath the trees and slightly higher in the open cultivated land. Soils under the canopy of *F. albida* and *C. africana* trees were less moderate 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 the decomposition of dead roots which reduces soil alkalinity in the agricultural landscape.

Table 3. Mean values of soil pH and electrical conductivity at different radial and soil depths.

Treatment		<i>F. albida</i>		<i>C. africana</i>	
Distances (m)	Depths (cm)	pH (H ₂ O)	EC (dsm ⁻¹)	pH (H ₂ O)	EC (dsm ⁻¹)
Mean (Std. Dev.)					
2.5	0-20	8.45±0.22	0.23±0.07	8.30±0.17	0.21±0.07
	20-40	8.45±0.22	0.18±0.09	8.31±0.17	0.18±0.07
5.0	0-20	8.51±0.26	0.15±0.07	8.31±0.17	0.17±0.07
	20-40	8.49±0.22	0.13±0.07	8.28±0.14	0.15±0.06
25	0-20	8.43±0.22	0.13±0.06	8.39±0.22	0.10±0.06
	20-40	8.53±0.26	0.09±0.05	8.38±0.22	0.09±0.05
LSD (0.05)		NS	0.03	NS	0.03
Overall	0-20	8.46	0.18 ^a	8.33	0.16 ^b
	20-40	8.49	0.12 ^c	8.33	0.14 ^c
LSD (0.05)		NS	0.01	NS	0.02
2.5	Overall	8.45	0.19 ^a	8.31	0.19 ^a
5.0		8.49	0.15 ^b	8.29	0.16 ^b
25		8.48	0.11 ^c	8.38	0.09 ^c
LSD (0.05)		NS	0.02	NS	0.03

* Means with the same letter are not significantly different at (P< 0.05), EC = Electrical Conductivity and Std. Dev=standard division

Similar to this finding [15], 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 [16], reported significant difference (P<0.05) in pH between the soil within and outside the canopies of both trees, with a higher pH being found in the open cultivated land than under the canopy area. [17] also reported a significant variation in soil pH horizontally under *F. albida* tree canopies.

The analysis of variance for soil electrical conductivity revealed that soil electric conductivity was significantly affected by distance (P<0.05) from the tree trunk and soil depth (P<0.05). Whereas, electric conductivity was not significantly (P>0.05) affected by the interaction of distance from the tree trunk and soil depth. 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 due to high biomass production of tree species and higher soil pH under tree canopies relative to open field. The electrical conductivity of the soil under *F. albida* and *C. africana* trees was decreased from 0.19 to 0.11 and 0.19 to 0.09, respectively varying the distance of the tree from under the canopy (2.5 m) to (25 m) the open cultivated land. As in pH, no defined trend of increase or decrease in electrical conductivity was observed at different depths. Soil electrical conductivity ranged from 0.09 to 0.23 dS/m and 0.09 to 0.21 dS/m respectively for *F. albida* and *C. africana* trees. Generally, higher soil electric conductivity under 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. [13] reported higher electric conductivity value under canopy than the open field of *B. aegyptiaca* at Limat site in northern Ethiopia.

3.2.2. Soil Organic Carbon

The soil organic carbon was a 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. Accordingly, a gradual and significant decrease in soil organic carbon was observed with increased distance away from the tree trunk regardless of tree species. The soil organic carbon was higher (3.52% and 3.31%) under the canopy of the *F. albida* and *C. africana* trees than outside the canopy of the adjacent open field and showed a decreasing trend with increasing distance from the base of the tree towards the open field and decreased with soil depth. 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 soil depth. The highest value of soil organic carbon was recorded under the canopy of the *F. albida* and *C. africana* at the surface (2.75% and 2.54%) soil layers and it decreased 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. The amount of soil organic carbon under *F. albida* tree species was also significantly higher by 84.3% to 27.2% compared to that of *C. africana* tree species (71.5% to 23.8%). There was no significant difference in soil organic carbon between tree

species. The main effects of 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 (Table 4). The mean values of soil organic carbon content among all radial distances at ($p < 0.05$) and between soil depths at ($p < 0.05$) for both tree species have showed significant difference were probably the contribution of high biomass production of tree species to nutrient input of the soil and minimal soil loss through erosion due to canopy cover in surface soil.

Similar to this finding, [1] reported that a gradual and significant decrease in soil organic carbon was observed with increasing distance away from the tree trunk in Hararghe highlands of Ethiopia. In line with this [12] 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*. [15] reported also the surface soil organic carbon under both *C. macrostachyus* and *C. africana* tree species was significantly higher ($P < 0.05$) than that at the subsurface. [28] Observed higher organic carbon in the surface and subsurface soil under the canopy of *Milletia ferruginea* as compared to the open field. [2, 32] have also reported a significant decrease in organic carbon and organic matter away from the tree trunk to the open cultivated land. The findings of this study indicate that scattered trees have at least some capacity for modifying an agricultural landscape that is otherwise uniform. It's an important influence on soil physical and chemical characteristics, soil fertility status, plant nutrition, and biological activity in the soil [5].

Table 4. Mean values of soil organic carbon, organic matter and soil carbon stock at different radial distances and soil depths.

Treatments			Soil parameters		
Trees	Distances (m)	Depths (cm)	OC (%)	OM (%)	SCS (Mg ha ⁻¹)
Mean (Std. Dev.)					
F. albida	2.5	0-20	3.52±0.66	6.06±0.32	81.23±16.32
		20-40	2.81±0.48	4.47±0.61	70.08±13.34
	5.0	0-20	2.43±0.34	4.85±0.84	58.84±14.72
		20-40	1.96±0.18	3.44±0.32	49.70±4.32
	25	0-20	1.91±0.18	3.29±0.32	48.95±4.32
		20-40	1.59±0.18	2.66±0.20	40.70±4.71
C. africana	2.5	0-20	3.31±0.6	5.69±1.13	77.96±24.09
		20-40	2.50±0.36	4.31±0.7	62.49±13.16
	5.0	0-20	2.39±0.34	4.11±0.6	58.40±14.72
		20-40	2.00±0.02	3.45±0.36	51.29±3.62
	25	0-20	1.93±0.18	3.33±0.32	49.03±4.32
		20-40	1.60±0.18	2.76±0.2	41.75±4.71
LSD (0.05)			0.21	0.64	8.67
F. albida	Overall	0-20	2.75 ^a	4.73 ^a	66.75 ^a
		20-40	1.99 ^b	3.52 ^b	49.75 ^b
C. africana	Overall	0-20	2.54 ^a	4.38 ^a	61.79 ^a
		20-40	2.04 ^b	3.51 ^b	51.84 ^b
LSD (0.05)			0.25	0.37	5.01
2.5	F. albida	Overall	2.97 ^a	5.26 ^a	70.03 ^a
5.0			2.38 ^b	4.14 ^b	59.89 ^b
25			1.75 ^c	2.97 ^c	44.83 ^c
2.5	C. africana	Overall	2.90 ^a	5.00 ^a	70.22 ^a
5.0			2.19 ^b	3.78 ^b	54.85 ^b
25			1.77 ^c	3.05 ^c	45.39 ^c
LSD (0.05)			0.35	0.45	6.13

* Means with the same letter are not significantly different at ($P < 0.05$), OC-Organic carbon, OM-Organic matter and Soil Carbon Stock

3.2.3. Soil Organic Matter (SOM)

Organic matter (OM) is usually expressed in the form of organic carbon (OC). The organic matter has an important influence on soil physical and chemical characteristics, soil fertility status, plant nutrition, and biological activity in the soil. Both *F. albida* and *C. africana* trees had influence on the organic carbon and organic matter. The soil OM was a significant difference between the radial distance from the tree trunk and soil depth ($P<0.05$) and interaction effect between distance from the tree and soil depth was significant ($P<0.05$ and Table 4). The soil organic matter was higher 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 and decreased with depth in the study area. Soil Organic matter was significantly ($P<0.05$) higher under tree canopies of both trees than the outside the canopy. It was higher by 84.2% and 70.8% under the canopies of the *F. albida* and *C. africana* tree species, respectively, than an open field. The range of OM 2.66-6.06% in both tree species falling into moderate to high organic matter level. This implies that soils have an average to good structural condition and structural stability.

Generally, the result showed a decreasing trend with increasing radial distances from tree trunk in both surface and subsurface soil depth and along soil depth for both tree species.

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. This finding is in agreement with previous studies in different sites of Ethiopia, where higher organic carbon recorded under *Cordia africana* and *Milletia ferruginea* trees canopy than that of open area [33]. The variation in organic carbon with depth in the present study was similar to other scholars for example, [28] observed higher organic carbon in the surface and subsurface soil under the canopy of *Milletia ferruginea* as compared to the open field. In contrast to the finding of the present study [15] found that organic carbon was not enriched under both *Cordia africana* and *Croton macrostachyus* trees on farm lands compared with areas away from canopies in Badessa area, Ethiopia.

3.2.4. Soil Carbon Stock

The analysis of Soil carbon stock indicated that, the Soil carbon stock was significantly different between the distance from the tree trunk and soil depth for both trees species. In this study, Soil carbon stock was significantly ($P<0.05$) 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 were higher under the canopies of the *F. albida* and *C. africana* tree species and shown a decreasing trend with increasing distances from the base of the tree towards the open field (Table 4). 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. Overall mean value of SCS in surface soil depth were significantly higher than mean values of the subsurface soil depth for both tree species. Soil carbon stock was higher under the canopy of the trees compared to the open area ($P<0.05$). *F. albida* and *C. africana* on SOC stocks was significantly ($P<0.05$) higher under canopies of both trees than the outside canopy. It was higher by 66% and 59% under the canopies of *F. albida* and *C. africana* tree species, respectively, than an open field. The Soil carbon stock of the present study ranged from 41.75 to 81.25 Mg ha⁻¹ for both tree species

There was a decreased in soil carbon stock with depth, higher at 0-20 cm as compared to the 20-40 cm soil depth. The interaction effect between distances from the tree and soil depth was also significantly different ($p<0.05$). Generally, the 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 and supply of more organic fertilizer and litter fall from trees. This finding is in agreement with previous studies, where [8] had reported that total average soil C stock was higher beneath the canopy of trees than the open field. [25] also reports that soil C stock was observed up to 40 cm soil depth under legumes trees and the total mean carbon stocks in the surface soil (0–10 cm) higher than in the deeper soil layer (10–30 cm). [8] also reported a SCS that ranged from around 13000 to 26000 kg ha⁻¹, this variation in SCS might be the soil depth (15 cm of this against 10 cm of considered).

3.2.5. Total Nitrogen (TN)

Total soil nitrogen was influenced by the presence of *F. albida* and *C. africana* trees on farm field. The total nitrogen contents of the soils showed the same trend as soil organic carbon. This suggests that the main source of N is organic matter. It significant ($P<0.05$) horizontal and vertical variation was observed under the selected tree species. Soil nitrogen decreased with increasing distance from the tree trunk and soil depths. TN was significantly different between the distance from the tree trunk and soil depth and was higher under the canopy of the tree compared to the open area ($P<0.05$) as well as decreased with soil depth, higher at 0-20cm as compared to the 20-40cm depth ($P<0.05$). There were also significant differences in total nitrogen between tree species as well as the interaction effects between two or three of the main effects considered in the study area (Tables 5). Soil total nitrogen was significantly ($P<0.05$) higher under tree canopies of both trees than the outside the canopy. It was higher by 82% and 84% under the canopies of the *F. albida* and *C. africana* tree species, respectively, than an open field. The range of TN 0.15–0.4% in both tree species falling into moderate to high TN level (Hazelton P. B and Murphy, 2007). Thus, the surface soils in the 0-20 cm soil depth contain a much higher content of nitrogen (i.e. 0.30% and

0.28%) than those in the sub surface (20-40 cm) soil depth (0.22% and 0.20%) respectively, under the canopy of the *F. albida* and *C. africana* trees.

These horizontal variations in total nitrogen might be mainly due to the high accumulation of organic matter under the tree canopy. This finding is in agreement with previous studies in different sites of Ethiopia, where [8], 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, [1] for *C. africana*, *F. albida* and *C. macrostachyus*; [32] *Milletia ferruginea* and *C. african*; [28] for *Milletia ferruginea* and [2] for *C. macrostachyus* and *C. africana* reported significantly higher total nitrogen under tree trunk compared to the open cultivated land.

Table 5. Mean values of total nitrogen, available phosphorus and cation exchange capacity at different radial distances and soil depths.

Treatments			Soil parameters		
T. species	Distances (m)	Depths (cm)	TN (%)	AP (ppm)	CEC (meq/ 100 g soil)
Mean (Std. Dev.)					
<i>F. albida</i>	2.5	0-20	0.40±0.08	9.92±3.35	21.25±1.76
		20-40	0.29±0.06	8.09±1.35	19.75±2.48
	5.0	0-20	0.28±0.07	7.58±3.80	19.21±1.91
		20-40	0.23±0.02	6.21±3.25	18.38±2.35
	25	0-20	0.22±0.04	5.06±2.25	18.38±1.72
		20-40	0.16±0.01	3.74±2.16	15.99±2.41
<i>C. africana</i>	2.5	0-20	0.35±0.07	8.95±1.13	20.92±1.74
		20-40	0.27±0.03	7.18±3.35	17.69±2.49
	5.0	0-20	0.26±0.07	6.50±1.74	17.50±1.95
		20-40	0.21±0.02	5.34±2.18	15.98±2.49
	25	0-20	0.19±0.06	5.00±2.18	15.59±1.25
		20-40	0.15±0.06	4.27±3.16	14.40±2.40
LSD (0.05)			0.02	0.65	1.02
<i>F. albida</i>	Overall	0-20	0.30 ^a	7.69 ^a	19.79 ^a
		20-40	0.22 ^c	5.84 ^c	17.66 ^b
<i>C. africana</i>	Overall	0-20	0.28 ^b	6.82 ^b	18.06 ^b
		20-40	0.20 ^d	5.59 ^c	15.96 ^c
LSD (0.05)			0.01	0.38	0.59
2.5	<i>F. albida</i>	Overall	0.35 ^a	8.75 ^a	20.23 ^a
5.0			0.25 ^c	7.15 ^c	18.76 ^b
25			0.19 ^e	4.40 ^e	17.19 ^c
2.5	<i>C. africana</i>	Overall	0.31 ^b	8.06 ^b	19.21 ^b
5.0			0.23 ^d	5.92 ^d	16.84 ^c
25			0.18 ^e	4.64 ^e	14.99 ^d
LSD (0.05)			0.02	0.46	0.72

* Means with the same letter are not significantly different at ($P < 0.05$)

TN-Total nitrogen, AP- Available potassium and CEC- Cation exchange capacity

3.2.6. Available Phosphorus (AP)

In the study area, available soil phosphorus was influenced by the presence of *F. albida* and *C. africana* trees on farmlands. It was significantly ($P < 0.05$) affected by all main effects (tree species, distance from the tree and soil depth) and all forms of interaction effects was significant ($P < 0.05$, Table 5). Available phosphorus was significantly higher under the tree canopies than in the open field in respective soil depths. 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 field. The available phosphorus was significantly ($P < 0.05$) higher under tree canopy than outside the canopy area. It was higher by 96% and 79% under the canopies of the *F. albida* and *C. africana* tree species, respectively, than an open field. The range of AvP of the study area is 3.74–9.92 mg /kg in both tree species. The mean value of available phosphorus (i.e. 7.69 and 6.82mg /kg) in the upper surface (0-20cm) and (5.84 and 5.59mg /kg) in the subsurface soil depths (20-40cm) were significant different ($p < 0.05$).

This might be due to the higher accumulation of organic matter under the canopies of *F. albida* tree and fast litter decomposition than *C. africana* tree (Table 5). This finding is in agreement with previous studies in different sites of Ethiopia, [1] 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 Hararghe Highlands. Similarly, [28] had reported that available soil phosphorus increases under the canopy of *M. ferruginea* tree than the open land. Contrary to these findings, [2] reported a significant decrease in available soil phosphorus under *C. macrostachyus* and *C. africana* compared to the open cultivated land. Contrary to this finding [16] 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.

3.2.7. Cation Exchange Capacity (CEC)

The result of cation exchange capacity showed a highly significantly ($P<0.05$) affected by all of the main effects (trees species, distance from the tree and soil depth) but not significantly different in all forms of interaction effects (Tables 5). 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 5). This could be mainly due to high organic matter accumulation under the tree canopies than the open fields. The higher number of soil organic matter under the tree canopies may imply that more cation 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 19.79 and 18.06 and sub-surface soils 17.66 and 15.96 (meq/100 g soil) soil at the distance of under the canopy of *F. albida* and *C. africana* tree species respectively. These values were observed to decrease from 20.23 to 17.19 and 19.21 to 14.99 (meq/100 g soil) soils at the distance of 2.5 m to 25 m (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 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 (Hazelton and Murphy, 2007). In the current study, soil cation exchange capacity in the canopy zone of *F. albida* and *C. africana* trees ranges from 20.23 to 14.99 meq/100 g that falls in the range of moderately fertile soil. The same trend was reported by [1] for surface soil at Hararghe, Hirna site in Ethiopia. The cation exchange the capacity of the soil is a measure of soils negative charge and thus of the soils capacity to retain and release cation for uptake by plant roots. The cation exchange capacity of the soil is strongly related with the organic matter content of a soil [5]. 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 the canopy than the open one has been also reported by [2, 28], under *C. africana*, *M. ferruginea*, and *C. macrostachyus* respectively. In line with this finding, [12], also reported that the lowest cation exchange capacity values were recorded under *B. polystachya* at 0- 15 and 15-30 cm soil depths of all the three horizontal positions

3.2.8. Exchangeable Bases

The values of exchangeable cations at different distances and soil depths under tree canopies are presented in (Tables 6). The mean values of exchangeable base cations (Na, K Ca, and Mg) showed significant variation ($p< 0.05$) with distance from tree trunk and also significantly varied ($p<0.05$) with in soil depth from the surface (0-20cm) to the subsurface (20-40cm) soil depth. The values of the exchangeable cations (Na, K Ca, and Mg) under the canopy of *F. albida* and *C. africana* trees were significantly different ($P<0.05$). The basic cations (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. The mean values (meq./100 g soil) of exchangeable (Ca 11.54, Mg 3.22) were higher in soils at 2.5 m distance from the bases of the trees under *F. albida* tree followed by *C. africana* (Ca 11.31, Mg 3.27) and decreased with increasing distance from tree bases. The mean values (meq./100 g soil) of soil exchangeable Na and K at 2.5 m from tree bases under *F. albida* tree were recorded (Na 0.31, K 2.19) to the soils under *C. africana* (Na 0.25, K 1.82) in soils. Whereas the highest values (meq./100 g soil) of exchangeable cations for the surface soil (0-20 cm) (Ca 9.94, Mg 2.61), and (Na 0.21, K 1.54) were recorded and the values were found to decrease to (Ca 8.99, Mg 2.31), and (Na 0.17, K 1.00) (meq/100 g soil) the subsurface (20-40cm) soils under the *F. albida* and *C. africana* trees, respectively.

On the other hand, the exchangeable magnesium was not significantly varied across soil depth or according to the distance from the tree and canopy. This 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 followed by mineralization and release of simple products to the soil. As a result, the amount of exchangeable cations would be higher under tree canopies than the open field. [12] was also reported that 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 of the soil under *H. abyssinica*, *Senecio gigas* and *Chamaecytisus palmensis* trees. similarly, [28], carried a research on the impact of *Milletia ferruginea* on soil fertility in southern Ethiopia. The authors found that significantly higher level of surface soil exchangeable base forming cations and cation exchange capacity under the tree.

Table 6. Mean values of Exchangeable bases at different radial distances and soil depths.

Treatments			Exchangeable bases			
Trees	Distances	Depths	Ex. Na	Ex. K	Ex. Ca	Ex. Mg
			Mean (Std. Dev.) (meq/100g soil)			
F. albida	2.5m	0-20cm	0.31±0.07	2.19±0.78	11.54±1.95	3.22±0.51
		20-40cm	0.24±0.20	1.78±0.55	9.98±1.15	3.18±0.63
	5.0m	0-20cm	0.21±0.20	1.52±0.42	9.67±0.94	2.77±1.2
		20-40cm	0.17±0.04	1.39±0.53	9.13±1.13	2.66±1.06
	25m	0-20cm	0.11±0.05	0.91±0.21	8.62±0.80	2.04±1.27
		20-40cm	0.11±0.01	0.60±0.40	7.89±0.98	1.87±0.90
C. africana	2.5m	0-20cm	0.25±0.18	1.82±0.56	11.31±1.38	3.27±0.55
		20-40cm	0.21±0.16	1.37±0.47	9.77±0.94	2.81±0.66
	5.0m	0-20cm	0.19±0.14	1.00±0.39	9.72±1.06	2.79±1.23
		20-40cm	0.15±0.06	0.96±0.21	9.01±1.3	2.44±0.87
	25m	0-20cm	0.11±0.04	0.79±0.32	8.82±1.10	1.75±0.45
		20-40cm	0.08±0.03	0.68±0.3	7.97±0.79	1.68±0.38
LSD (0.05)			0.04	0.32	0.80	0.53
F. albida	Overall	0-20cm	0.21 ^a	1.54 ^a	9.94 ^a	2.61
		20-40cm	0.17 ^{bc}	1.26 ^b	8.99 ^b	2.64
C. africana		0-20cm	0.18 ^b	1.21 ^b	9.95 ^a	2.60
		20-40cm	0.15 ^c	1.00 ^c	8.92 ^b	2.31
LSD (0.05)			0.02	0.19	0.46	0.30
2.5m	F. albida	Overall	0.27 ^a	1.98 ^a	10.76 ^a	3.20 ^a
5.0m			0.19 ^c	1.46 ^b	9.39 ^b	2.72 ^b
25m			0.10 ^d	0.76 ^c	8.26 ^c	1.96 ^c
2.5m			0.23 ^b	1.59 ^b	10.54 ^a	3.04 ^a
5.0m	C. africana	Overall	0.17 ^c	0.98 ^c	9.37 ^b	2.62 ^b
25m			0.09 ^d	0.74 ^d	8.39 ^c	1.71 ^c
LSD (0.05)			0.023	0.23	0.57	0.37

* Means with the same letter are not significantly different at ($P < 0.05$), Ex. Na- Exchangeable Sodium, Ex. K- Exchangeable Potassium, Ex. Ca- Exchangeable Calcium and Ex. Mg- Exchangeable Magnesium

3.3. The Effect of *F. albida* and *C. africana* Trees on Sorghum Yield in the Study Area of Fedis District

The analysis of variance of the study showed that the grain yields of sorghum (*Sorghum bicolor*) were significantly different ($P < 0.05$) due to the effects of tree species and distance from the tree trunk (Table 7). But the interaction between tree species and distance from the trees was not significantly different ($P > 0.05$). The mean values of grain yield of sorghum (*Sorghum bicolor*) decreased significantly and gradually as the distance away from the trees trunk increased. Increased yield under the canopy of *F. albida* and *C. africana*, trees by 43% and 41% respectively than outside canopy and these values were decreased by 24% and 22% under *F. albida* and *C. africana*, respectively at the distance of 25 m open filed (control). The increase in grain yield under the trees could be due to improvement of soil properties under the tree canopies than the open fields.

Table 7. The effect of *F. albida* and *C. africana*, trees on sorghum yield in (kg/ha) at different distances from tree trunk.

Distance from the trunk (m)	<i>F. albida</i>	<i>C. africana</i>
	Means of Sorghum grain yield in (kg/ha)	
2.5	2089.51 ^a	1789.53 ^b
5.0	1805.02 ^b	1559.22 ^c
25	1459.40 ^c	1266.01 ^d
LSD (0.05)	109.31	109.31
CV	9.56	9.56

* Means with the same letter are not significantly different at ($P < 0.05$)

Generally, the result showed slightly decreased with increasing distances from tree trunk. Accordingly, the overall mean values at canopy zone were higher (2089.51 kg/ha and 1789.53 kg/ha) for *F. albida* and *C. africana*, both species than at open field. Soils under tree canopies were more fertile than the outside due to higher accumulation of soil organic matter, nutrient cycling and nitrogen fixation by tree species. The mean value under the two tree species was significantly different ($P < 0.05$) from each other, the mean value under *F. albida* was greater than that grown under *C. africana*, as compared to sorghum grown under both tree species, which could be as result of phonological characteristics of the tree species. *F. albida* shades its leaves during crop growing season, which allows more lights for photosynthesis reaction. Moreover, to reduce the effect of shading of trees on the crop growing beneath canopies, farmers in the study area pollard the branches and leaves of trees species. Farmers at the study area practice pollarding tree crown even after planting the sorghum.

In line with this current result, increased yield reported under tree canopy than outside canopy by 101% (*sorghum bicolor*) at Welinchiti, 67%, (*maize*) at Buta-Jira, and 40% (*wheat*) and 12% (*teff*) at Mojo, and increased maize yield by 76% and sorghum yield by 36% from Hararghe under canopy of *F. albida* [26]. Contrary to the current study finding, decreased in sorghum yield under canopy of *Vitellaria paradoxa* and *P. biglobosa* trees and lowered wheat yields under *A. nilotica* than outside canopy were also reported by

different scholars which may be due to above and/or below ground competition [31], Yadav, *et al.*, 1993). As a result, crops that were growing under the tree had additional benefits over the control one. [1] Reported increased grain yield of sorghum and haricot bean under the canopy of *F. albida*, *Cordia africana* and *C. macrostachyus* trees as compared to the open cultivated land on Hararghe high lands. Likewise, [26], reported yield increments in sorghum, *maize*, *wheat*, *teff* and *pearl millet* production when grown under *F. albida* canopy compared to the open fields. The parkland systems and summarized the influence of parkland trees on crops and soils and noted that crop-yield increases have been widespread under open and well managed canopies of fully grown trees.

4. Conclusions and Recommendations

The parkland *Faidherbia albida* and *Cordia africana* trees are important for the restoration of soil fertility, particularly in Fedis district where the low soil fertility was the main barrier to crop production. The tree species improve soil fertility in different ways and they can be integrated into crop production and soil restoration. 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. The MC, EC, soil OC, OM, soil CS, TN, available P, soil CEC, Na, K, Ca and Mg were significantly higher under the canopy of the tree as compared to the open field. The reason for this variation is attributed to inputs from *Faidherbia albida* and *Cordia africana* tree species. *F. albida* and *C. africana* trees have influenced on grain yield of sorghum and there were increased under the tree canopy to open field. Moreover, the soil fertility advantage of the selected tree species could be brought through the input of litter and various plant parts from living trees; biological nitrogen fixation, and reduction in the leaching losses of nutrients due to more plant cover on the soils and the subsequent increase in plant cycling fraction of nutrients in the soil-plant system.

Hence, the growing of *Faidherbia albida* and *Cordia africana* trees on small holder farms improve soil fertility. In general, *F. albida* and *C. africana* in the study area had improves both physical and chemical soil properties. As compared to *Faidherbia albida* and *Cordia africana* had a significantly higher contribution to soil property enhancement and increased sorghum yield. Retaining these tree species and in particular *Faidherbia albida* on farms in the study area is of paramount importance for soil fertility enhancement so as to improve food security of small farming households. Thus, the existence of tree on farm is useful contribution to improve soil fertility rather than being cutting as nowadays by the farmers in the study area.

Based on the findings the following recommendations are forwarded. 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. further study also needs on appropriate component management practices and

the number of trees retaining per hectare associated crop productivity. In addition to their role in maintaining soil fertility, these two species provide various products and services to the farmers. Thus, the continued use of these species in the agricultural setting of Fedis district and other areas in the eastern Hararghe area to maintaining soil fertility and provide services to the farmers. The result of sorghum yield reported in this study was from under farmer's management practice. So, further study is needed under controlled experiment in association with these trees. Similar future research should be coupled with more measurements on soil physical and chemical properties related to soil texture and soil pH

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