



Influence of Scattered *Cordiaafricana* and *Crotonmacrostachyus* Trees on Selected Soil Properties, Microclimate and Maize Yield in Eastern Oromia, Ethiopia

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Abstract: The study was conducted to investigate the impact of scattered trees in farmland on selected soil physicochemical properties, microclimates, and maize grain yield in Oda Bultum district, Eastern Oromia, Ethiopia. For the experiment of soil physicochemical properties, three factors: distance from tree trunk with four levels (at 0.5m of crown, mid of crown, edge of crown radius and open field), soil depth with two levels (0-15cm and 15-30cm depth) and tree species with two levels with factorial arrangement in RCBD replicated four times were employed. For microclimates and maize yield only two factors; distance from tree trunk with two levels (at mid crown & open field) for microclimates and distance with four levels (at 0.5m of crown, mid of crown, edge of crown radius and open field) for maize yield and tree species (*Cordiaafricana* and *Croton macrostachyus*) with two levels in RCBD replicated four 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. Soil chemical properties (SOC, total N, available P, exchangeable K and CEC) were significantly ($p<0.05$) higher in canopy than open field and in surface than subsurface. Soil pH and EC were not significantly ($p>0.05$) influenced by both tree species. Relative illumination, air temperature, soil temperature were significantly ($p<0.05$) higher at open field than canopy zone while soil moisture was significantly ($p<0.05$) higher under canopy of trees than open field. Though not significant, maize yield was slightly higher at open field than canopy zone. It can be concluded that these tree species have the potential to improve soil fertility and moisture beneath its canopy. Thus, integration of these trees on farmlands might require proper tree crown management to increase relative illumination under the canopy and increase grain yield of maize.

Keywords: Air Temperature, Trees on Farm, Relative Illumination, Soil Fertility, Soil Moisture, Under Trees Canopy

1. Introduction

Agroforestry is recognized as a land use option in which trees provide both products and environmental services. It is described as a deliberate integration of woody perennials with agricultural crops and/or animals on the same land management unit, with the aim of increasing income through integration of economical useful tree species. Agroforestry is an alternative land management system which has immense potential to solve global challenges like deforestation, unsustainable cropping practices, loss of biodiversity, increased risk of climate change, rising hunger, poverty and malnutrition. Agroforestry can also

play a significant role in alleviating the critical problem of the rural poor by providing a wider range of products and services from a given piece of land, as land is largely a major constraint for rural people [15, 24].

Agroforestry involves managing interactions between tree and non-tree components to produce diversified sustainable production system. The magnitude of positive and/or negative influence of trees on crop yield depends on management variables, canopy and root architecture, spatial and temporal arrangement, age and size of the tree and ecological type [19]. A scattered tree on crop land has a positive influence on maintaining soil fertility via addition of

nutrient to soil through biological nitrogen fixation and efficient nutrient cycling [15, 19, 24]. As compared to treeless area, the microclimatic variables such as air temperature, soil temperature and soil moisture beneath tree canopy could also be modified due to the influence of trees on radiation flux, air temperature and wind speed [14].

Planting or retaining scattered *Cordia africana*, *Croton macrostachyus*, *Olea africana*, *Acacia spp*, *Faidhrebria albida* and *Psidium guajava* trees in the farmlands and homestead is common practice in southeastern Ethiopian highlands. Thus, investigation of the contribution of existing native multipurpose tree species on soil fertility via comparing soil properties beneath individual tree with treeless areas of the same soil conditions is crucial to sustain the system in the area. Besides, the effect of trees on associated crop productivity is also based on cumulative effect both above and below ground component interaction especially in simultaneous type agroforestry system in which scattered *Cordia africana* and *Croton macrostachyus* trees on crop land is one in the case southeastern Ethiopian highlands. In this regard, scientific information on the effect of these tree species on soil physicochemical properties, microclimates and maize yield is not so far documented for the study area. Thus, this study was initiated to determine the impact of *Cordia africana* and *Croton macrostachyus* trees scattered in

farmland on selected soil properties, microclimatic variables and maize grain yield.

2. Materials and Methods

2.1. Description of the Study Area

Oda Bultum district is found in West Hararghe Zone, Oromia National Regional State, Ethiopia. It is located in the eastern part of the country at 362km from Addis Ababa the capital city of Ethiopia and 37km from Chiro town which is the capital town of West Hararghe Zone (Figure 1). The study area is longitudinal and latitudinal located at 8°30'0'' - 9°0'0''N, and 40°40'0'' - 41°20'0''E. Its Altitudinal range is from 1040 - 2500 meter above sea level. It has a mean maximum and mean minimum temperature of 28°C and 25°C; respectively. The mean annual maximum and minimum rainfall is 1200mm and 900 mm respectively. Livelihoods in the district mainly center on rain fed agriculture, with mixed farming system that constitute livestock rearing and crop production. Maize (*Zea mays*), sorghum (*Sorghum bicolor*), teff (*Eragrostis tef*), wheat (*Triticum aestivum*) and barley (*Hordeum vulgare* L.) are the major food crops while chat (*Khata edulis*), coffee (*Coffea arabica*) and pepper are the major cash crops that commonly grown in the study area.

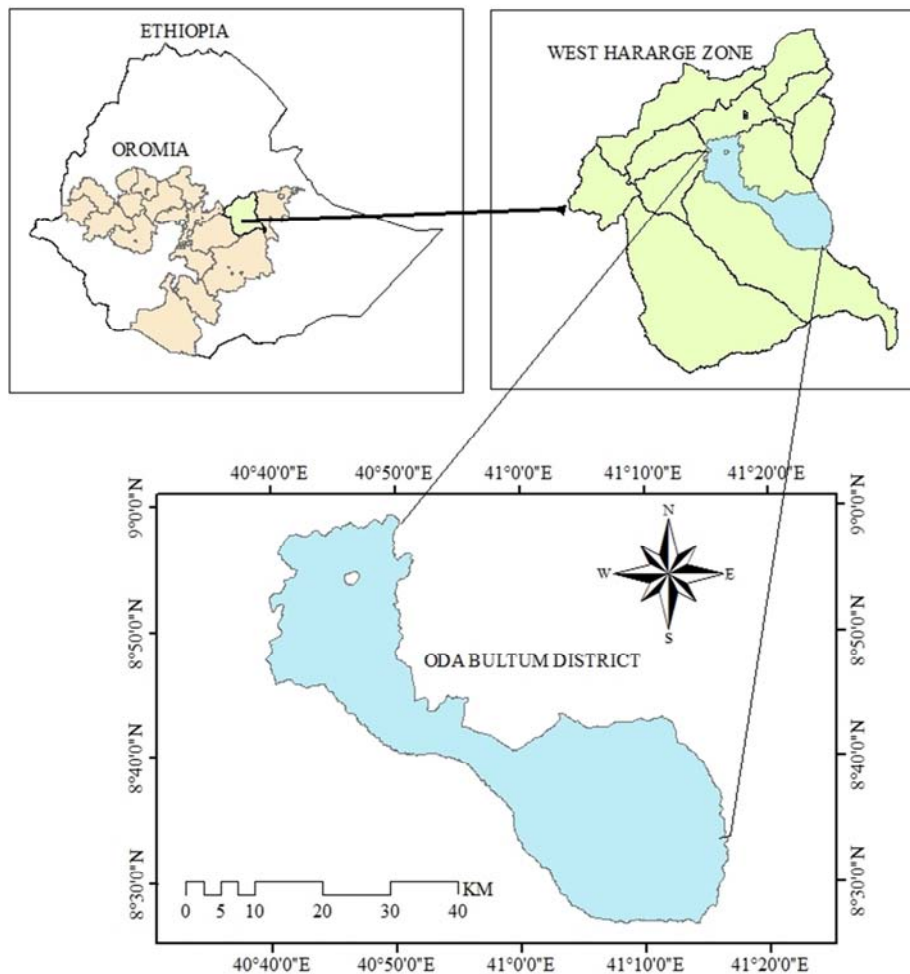


Figure 1. Location map of the study area.

2.2. Methods

Cordia africana and *Croton macrostachyus* trees being the most abundant scattered tree species on crop fields were selected for this study. The selected farmlands with these tree species is characterized as a gentle slope where maize and sorghum are staple food crops of the area. The farmers 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 *Cordia africana* and *Croton macrostachyus* 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, four individual *Cordia africana* and *Croton macrostachyus* trees were randomly selected for this study, their DBH, height and crown diameter were measured by using caliper, hypsometer and meter tape, respectively.

Table 1. The height, DBH and crown radius of individual trees considered in this study.

Tree species	Replications	DBH(cm)	Height(m)	Crown Radius(m)
<i>C. Africana</i>	1	34	13	5.54
	2	37	15	4.85
	3	32	11	4.56
	4	30	14	5.45
	Average	33.25	13.25	5.11
<i>C. macrostachyus</i>	1	23	10	4.12
	2	22	9	4.34
	3	24	11	4.52
	4	20	9.34	4.73
	Average	22.25	9.84	4.43

Each tree species was replicated four times. The dimension of each replication was almost uniform with the average DBH, height, and crown radius of 33.25cm, 13.25m & 5.11m for *Cordia africana*, respectively. Similarly, for *Croton macrostachyus* the average DBH, height and crown radius were 22.25cm, 9.84m & 4.43m respectively (Table 1).

2.2.1. Experimental Design

Soil Variables

For soil experiment three factors; distance from tree trunk, soil depth and tree species were involved. The distance factor had four levels; at radius of 0.5m, mid crown radius, edge crown radius and at three times total crown radius away from tree trunk which was used as control. The depth factor had two levels: (0 -15cm) depth representing surface soil and (15 -30cm) depth representing subsurface soil layer. Depths of 0-15cm & 15-30cm 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. The tree species factors involved two tree species; *Cordia africana* and *Croton macrostachyus* trees. Design: 4*2*2 factorial arrangement of treatments in a randomized complete block design replicated four times, 4*2*2 * 4=64 total treatment combinations were used in this study.

Maize yield

For maize yield experiment two factors which were distance from tree trunk with four levels; at radius of 0.5m, mid crown radius, edge crown radius and at three times total crown radius away from tree trunk which was used as control, and tree species; *Cordia africana* and *Croton macrostachyus* trees were involved. Design: 4*2 treatments arranged in a randomized complete block design replicated four times 4*2*4 =32 total treatment combinations were used.

Microclimates

To evaluate the influence of these two tree species on microclimatic variables, two factors namely distance from tree trunk with two levels (at mid crown radius and open field), and tree species: *Cordia africana* and *Croton macrostachyus* trees were involved. Design: 4*2 treatments arranged in a randomized complete block design replicated four times, 2*2*4 =16 total treatment combinations were employed.

2.2.2. Soil Sampling and Analysis

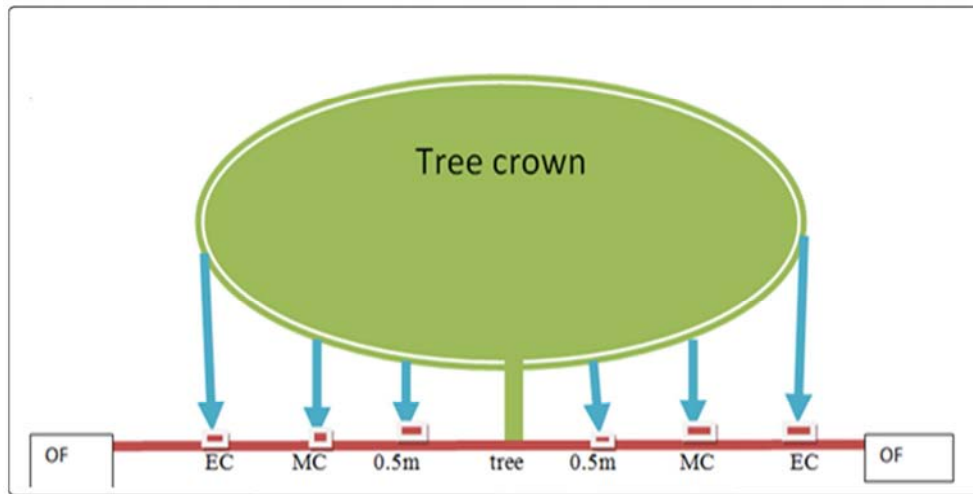
Three transect were made under each tree crown at 0.5m crown radius as transect one, mid crown radius as transect two and edge crown radius as transect three. Additionally, fourth sample was taken as a control from open field which was fourth transects (Figure 2). For representativeness of the soil samples, four sub-composite soil samples were taken from surface (0–15cm) and subsurface (15–30 cm) soil layers at each distance from four 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 2kg 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 [8]. 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 (cm³). 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 [27]. Available soil phosphorus was determined by Olsen method [20]. Available potassium was determined by neutral

ammonium acetate extraction method [17]. Cation exchange capacity (CEC) was determined titrimetrically by distillation of ammonium displaced by sodium method [4].



Where: EC = Radius at Edge Crown; MC = Radius at mid crown; OF = distance at open field

Figure 2. Tree transect design for data collection in four compass directions.

2.2.3. Crop Yield Sampling

Under the selected tree species, one meter by one meter plot was laid at 0.5m, mid crown radius, edge crown radius and open field in four compass directions (North, South, East and West). Maize was harvested from each plot. The harvested maize from the same radial distance was composited for each replication. Finally, the composited maize grain was separated from their cobs. Finally, the separated maize grain for each radial distance was weighed using sensitive balance.

2.2.4. Microclimate Sampling

Soil moisture (%) was determined gravimetrically. Initially, fresh soil was weighed and oven-dried at 105°C for 24 hours. Then, the percentage of water held in the soil was calculated as the weight difference between field and oven dried soils, divided by the weight of the oven dried soil, and multiplied by hundred. The soil temperature (°C) was taken only from depth of (0-15cm) by using soil thermometer, air temperature (°C) by using a mercury thermometer and relative illumination (%) by using Lux meter. For all microclimate parameters readings were taken from four compass directions at mid crown and open field, and repeated three times after 20 minutes; finally, means were calculated for each radial distance separately.

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. Tukey's honest significance difference (HSD) test was used for mean separation for the analysis of variance showed statistically significant differences ($p < 0.05$).

3. Results and Discussion

3.1. Soil Physical Properties

3.1.1. Soil Texture

The mean values of soil particle fractions of sand, silt and clay in the surface (0-15 cm) and subsurface (15-30 cm) soil layers were statistically comparable among radial distances from tree trunk at ($p = 0.0768$, $p = 0.164$ and $p = 0.935$) and between soil depths at ($p = 0.07$, $p = 0.223$ and $p = 0.158$) for both *Cordia africana* and *Croton macrostachyus* trees, respectively. Moreover, the mean values of sand fraction were slightly higher (25.78% & 26.62%) at radial distance of open field in subsurface (15-30cm) than other radial distances and slightly lowest (21.87% & 21.87%) at the radial distance of 0.5m in surface (0-15cm) soil depth. On the other hand, mean values of silt and clay fractions were slightly higher at radial distance of 0.5m from tree trunk in surface (0-15cm) and slightly lower at open field in subsurface (15-30cm) soil depth for both tree species. The mean value of sand exhibited slightly increasing tendency whereas silt and clay shown slightly decreasing with increasing radial distance from tree trunk and along soil depth. Generally, sand, silt and clay fractions were not significantly affected by presence of *C. africana* and *C. macrostachyus* trees. This may be due to similarity in soil parent materials for all radial distances and depths considered, and this result in line with study conducted on *Acacia senegal* var. *senegal* and *A. senegal* var. *leiorhachis* and *A. senegal* var. *Kerensis* from dry land areas of Kenya [12]. Similar results were also reported by different scholars from different areas by [1, 13, 7].

3.1.2. Soil Bulk Density

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 species. Similarly, mean value of soil bulk density for surface and subsurface soil depth have increased with increasing distances, and also increased with increasing depth at all radial distance (Figure 3 & 4). 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. In agreement to this result, significantly lower soil bulk density under canopy as compared to open field were also reported for *Acacia nilotica*, *Ficus thonningii* and *Acacia seyal*, *Acacia tortilis* and *Balanitosaegyptica* [21, 7, 5]. The current result was also in line with the other study reported lower soil bulk density under tree canopy than outside canopy zone [23].

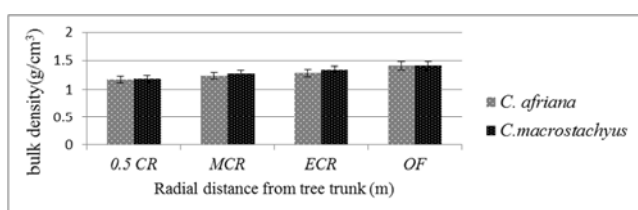


Figure 3. Mean values of soil bulk density (g/cm^3) at radial distances.

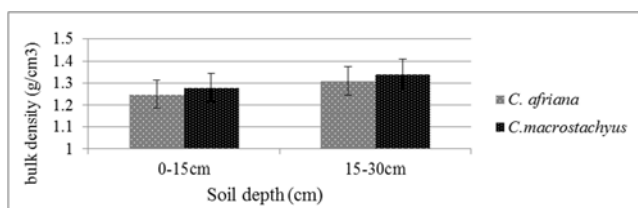


Figure 4. Mean values of soil bulk density (g/cm^3) at surface and subsurface soil layer.

3.2. Soil Chemical Properties

3.2.1. Soil Electrical Conductivity

In this study, overall mean values of soil electrical conductivity among all radial distances at ($p = 0.346$ and $p = 0.453$) and between soil depths at ($p = 0.421$ & $p = 0.634$) were not significantly influenced by *C. africana* and *C. macrostachyus* trees (Figure 5). The surface and subsurface soil electrical conductivity at all radial distances also did not exhibit significant variation ($p = 0.334$ & $p = 0.451$) (Figure 6). However, the result showed slightly decreasing trend with radial distance from tree trunk for both tree species.

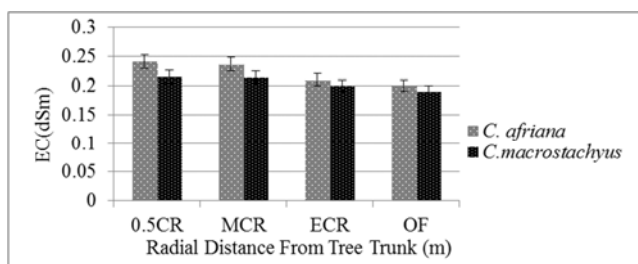


Figure 5. Mean values of soil electrical conductivity for overall radial distances.

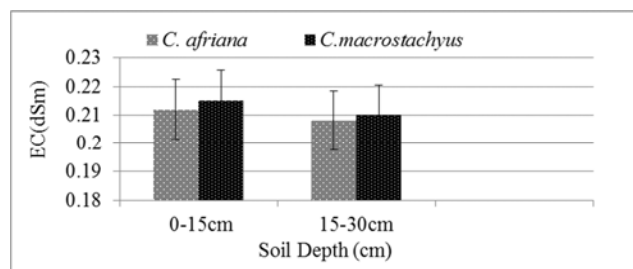


Figure 6. Mean values of soil electrical conductivity for both soil depth.

3.2.2. Soil pH (H_2O)

The surface, subsurface and overall mean values of soil pH at all radial distances from both *C. africana* and *C. macrostachyus* tree trunks were not significantly ($p = 0.874$ & $p = 0.732$) influenced (Figure 7 & 8). Likewise, the mean value of surface soil at all radial distances were also statistically comparable ($p = 0.965$ & $p = 0.854$) with their respective subsurface soil depth. However, mean values of soil pH exhibited slightly decreasing trend as it goes from tree trunk to open field for both surface and subsurface soil layer for both tree species.

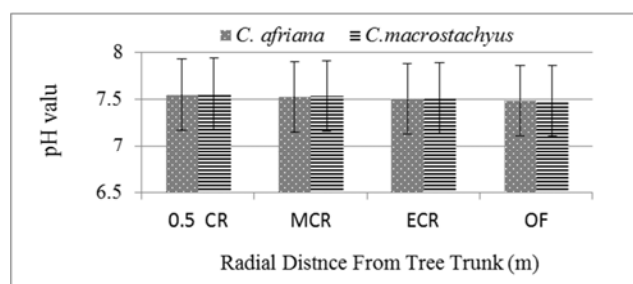


Figure 7. Mean values of soil pH for overall radial distances.

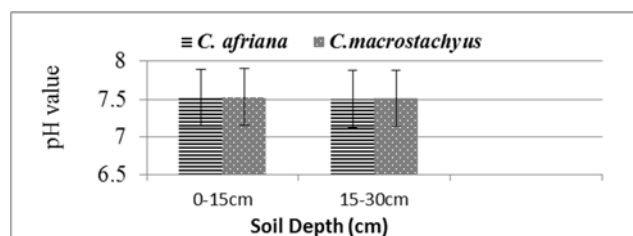


Figure 8. Mean values of soil pH for both soil depths

3.2.3. Soil Organic Carbon

The overall mean values of SOC content among all radial distances at ($p < 0.0001$ & $p = 0.0001$) and between soil depths at ($p < 0.0001$ & $p = 0.0001$) for both species have showed significant difference. The level of statistical differences among radial distances from tree trunk were in the order of: $0.5\text{m} > 2.6\text{m} > 5.19\text{m} > 15.6\text{m}$ and overall mean value of SOC in surface soil depth were significantly higher than mean values of subsurface soil depth for both tree species (Table 2). Moreover, the mean values of SOC in surface and subsurface soil depth among radial distances from tree trunk were significantly different ($p < 0.0001$ & $p = 0.0001$). Besides, the mean values of surface soil depth at all radial distance from tree trunk were significantly higher ($p < 0.0001$ & $p = 0.0001$) than their respective subsurface soil depth. 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 may be

associated with the accumulation of high litter from both above and below ground tree biomass.

Table 2. Mean \pm SE values of SOC and total soil nitrogen at different radial distances from tree trunk and soil depths.

Species	Parameters	Soil depth (cm)	Mean values at different radial distances from tree trunk (m)				Overall depth
			Mean values at 0.5m	Mean values at 2.5m	Mean values at 5m	Mean values at 15m	
<i>C. africana</i>	SOC%	0 – 15	2.83aA \pm 0.0001	2.32aB \pm 0.0001	1.95aC \pm 0.0001	1.47aD \pm 0.0001	2.14a \pm 0.0001
		15 -30	2.13bA \pm 0.001	1.86bB \pm 0.001	1.46bC \pm 0.001	1.12bD \pm 0.001	1.64b \pm 0.0001
		Overall	2.48 A \pm 0.001	2.09 B \pm 0.0001	1.71 C \pm 0.0001	1.30 D \pm 0.0001	
<i>C. macrostachyus</i>	SOC%	0 – 15	2.7aA \pm 0.0001	2.3aB \pm 0.002	1.91aC \pm 0.002	1.43aD \pm 0.001	2.085a \pm 0.04
		15 -30	2.1bA \pm 0.07	1.81bB \pm 0.002	1.42bC \pm 0.001	1.11bD \pm 0.001	1.61b \pm 0.05
		Overall	2.4A \pm 0.05	2.06 B \pm 0.06	1.67 C \pm 0.06	1.27 D \pm 0.06	
<i>C. africana</i>	TN%	0 – 15	0.29aA \pm 0.0001	0.23aA \pm 0.0001	0.20aB \pm 0.0001	0.18aB \pm 0.0001	0.22a \pm .01
		15 -30	0.22bA \pm 0.001	0.21bA \pm 0.001	0.18bB \pm 0.01	0.17bC \pm 0.01	0.19b \pm 0.1
		Overall	0.25A \pm 0.0001	0.22A \pm 0.0001	0.19 \pm 0.001B	0.18C \pm 0.0001	
<i>C. macrostachyus</i>	TN%	0 – 15	0.26aA \pm 0.01	0.22aA \pm 0.003	0.18aB \pm 0.001	0.17aB \pm 0.001	0.205a \pm .01
		15 -30	0.2bA \pm 0.01	0.19bA \pm 0.001	0.16bB \pm 0.001	0.14bC \pm 0.001	0.173b \pm 0.1
		Overall	0.23A \pm 0.01	0.205A \pm 0.01	0.17 \pm 0.01B	0.15C \pm 0.01	

Mean values, followed by different small letter (s) across the same column and different capital letter(s) across the same row are significantly different at ($p < 0.05$).

In line with this finding, the study conducted in different area by different scholar also indicated that higher soil organic carbon levels by 47% and 55% under the canopies of *C. apiculatum* and *P. africanum* than open field respectively, in semi-arid traditional grazing land from south eastern Botswana [3]. Likewise, significantly higher soil organic carbon was reported under *C. africana* than open field [30] and [1]. Furthermore, results from different tree species such as *F. thonningii* and, *M. ferruginea*, *Acacia seyal*, *A. tortilis* and *B. Aegyptica* showed significantly higher SOC under canopy zone than outside canopy zone [7, 24, 25].

3.2.4. Total Nitrogen

The overall mean values of total soil nitrogen among radial distances ($p < .0001$ & $p = .0001$) and between soil depths ($p < .0001$ & $p = .0001$) have exhibited significant differences for both tree species (Table 2). The results were highest (0.29% & 0.26%) at the first radial distance from tree trunk (0.5m) and lowest (0.17% & 0.17%) at open field (15m) for both *C. africana* and *C. macrostachyus* trees respectively. Likewise, the overall mean values in the surface soil were significantly different from subsurface soil depth. With regard to surface soil depth versus radial distance, the mean values of total soil nitrogen at the radial distances of 0.5m and mid crown were statistically similar but significantly higher ($p < .0001$) than the mean values at 5m and open field for both species. Furthermore, the subsurface total soil nitrogen of the latter two distances was significantly ($p < .0001$) different from each other and from the first two radial distances for both species. With respect to soil depth, total soil nitrogen of surface soil at all radial distances were statistically significantly higher ($p < .0001$) than their respective subsurface soil both for *C. africana* and *C. macrostachyus* trees. Overall, the result shows a decreasing trend of total nitrogen mean values with increasing distances

from tree trunk to open field both in surface and subsurface soil depth. This may be associated with the accumulation of high litter from both above and below ground biomass.

In line with this, the study conducted by indicated in different area by different scholar also revealed that higher soil total nitrogen level under the canopies of *C. apiculatum* and *P. africanum* than open field in semi-arid traditional grazing land from south eastern Botswana [3]. Similarly, significantly higher soil total nitrogen was reported from under *C. africana* and, *F. thonningii* and, *M. ferruginea* and, *Acacia seyal*, *A. tortilis* and *B. Aegyptica* than outside canopy [30, 1, 10, 7, 24, 25].

3.2.5. Available Potassium and Phosphorous

The overall, surface and subsurface mean values of soil available Potassium & Phosphorous content at all radial distances were significantly different for both studied species ($p < 0.0001$). Similarly the mean values of surface soil depth at all radial distance from tree trunk were significantly higher ($p < 0.0001$) than its immediate subsurface soil depth for both studied tree species (table 3). According to the present finding, soil available K and P under the canopy of scattered *C. africana* and *C. macrostachyus* trees were significantly enriched as compared to open field. The result implies that, soil available K and P decreased with increasing distances from tree trunks of *C. africana* and *C. macrostachyus*. These higher concentration of available soil K and P in the canopy zone as compared to open field may also be due to higher litter accumulation from above and belowground tree biomass. With regard to soil depth, significantly higher soil available K and P were recorded in the surface soil than subsurface soil. This higher soil available K and P in the surface soil than subsurface soil may be ascribed to relatively higher litter input to the surface soil than organic matter removals from the surface soil layer by different forms.

Table 3. Mean \pm SE values of soil potassium (ppm), phosphorous (ppm) and CEC (meq/100g) at different radial distances and soil depths.

Species	Parameters	Soil depth (cm)	Mean values at different radial distances from tree trunk (m)				Overall depth
			Mean values at 0.5m	Mean values at 2.5m	Mean values at 5m	Mean values at 15m	
<i>C. africana</i>	Av.P (ppm)	0 – 15	13.81aA \pm 0.041	12.32aB \pm 0.041	9.97aC \pm 0.001	7.23aD \pm 0.031	10.83a \pm 0.411
		15 -30	12.02bA \pm 0.032	11.32bB \pm 0.033	7.53bC \pm 0.001	6.72bD \pm 0.001	9.40b \pm 0.41
		Overall	12.92A \pm 0.001	11.82B \pm 0.001	8.75C \pm 0.001	6.98D \pm 0.001	
<i>C. macrostachyus</i>	Av.P (ppm)	0 – 15	11.81aA \pm 0.021	11.31aB \pm 0.031	10.97aC \pm 0.031	7.35aD \pm 0.021	10.36a \pm 0.411
		15 -30	11.02bA \pm 0.011	10.20bB \pm 0.021	7.53bC \pm 0.0021	6.72bD \pm 0.021	8.87b \pm 0.41
		Overall	11.42A \pm 0.00	10.76B \pm 0.00	9.25C \pm 0.001	7.03D \pm 0.001	
<i>C. africana</i>	Av.K(ppm)	0 – 15	88.81aA \pm 0.0021	75.79aB \pm 2.23	68.02aC \pm 0.02	58.45aD \pm 0.20	72.77a \pm 2.8
		15 -30	56.91bA \pm 0.041	52.84bA \pm 0.00	49.1bA \pm 0.051	30.94bB \pm 0.00	48.20b \pm 2.23
		Overall	72.86A \pm 5.4	64.32B \pm 4.2	58.56C \pm 2.9	44.70D \pm 4.9	
<i>C. macrostachyus</i>	Av.K(ppm)	0 – 15	86.81aA \pm 0.0021	70.79aB \pm 3.23	63.02aC \pm 0.02	57.45aD \pm 0.20	69.52a \pm 2.8
		15 -30	53.91bA \pm 0.0001	49.84bA \pm 0.001	45.1bA \pm 0.04	27.94bB \pm 0.08	44.2b \pm 2.23
		Overall	70.36A \pm 5.4	60.32B \pm 4.2	54.06C \pm 2.9	42.7D \pm 4.9	

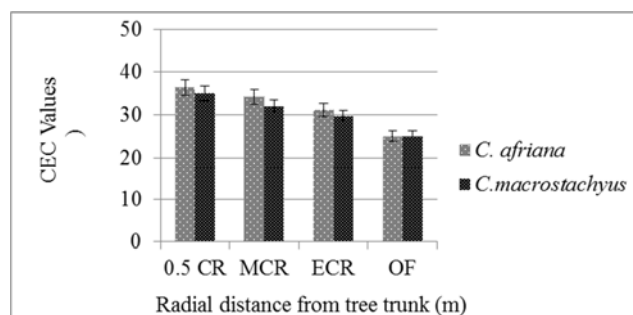
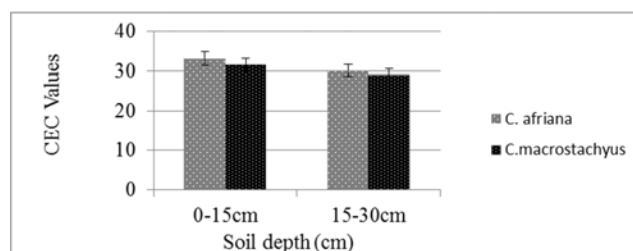
Mean values, followed by different small letter (s) across the same column and different capital letter(s) across the same row are significantly different at ($p < 0.05$).

In agreement to the current finding, higher soil available K and P under canopy zone than outside canopy and in surface soil than subsurface soil were reported for *M. ferruginea* tree for *F. albida* for *F. thonningii* and for *A. seyal*, *A. tortilis* and *B. aegyptica* [24, 1, 25, 10]. In addition, the present study is also in line with the study conducted by different scholars that reported significantly higher soil phosphorous and soil potassium under canopy zone than outside canopy [23, 7]. On the other hand, the current result disagrees with the result reported for *C. africana* and *C. macrostachyus* which revealed slightly higher but not significant in soil K and P under canopy and in surface soil than open field and subsurface soil layer, which may be due to species, age variation and site variation [1].

3.2.6. Cation Exchange Capacity

According to present finding, soil CEC under canopy of scattered *C. africana* and *C. macrostachyus* trees were higher as compared to outside canopy zone both for surface and subsurface soil depth. The mean values of soil CEC for surface and subsurface soil depth as well as their overall mean values at all radial distances from tree trunk were significantly different ($p < 0.0001$). Similarly, mean values of surface soil at all radial distance from tree trunk were significantly higher ($p < 0.0001$) than their respective subsurface soil depth for both species (Table 3). This may be attributed to higher organic matter beneath canopy than open field and in surface soil than subsurface soil depth. On the other hand, soil organic carbon and other fertility parameters considered in this study were decreased with distance and depth. Similarly, soil CEC also decreased with increasing distance from tree trunk and soil depth, and soil CEC is highly associated with SOM and clay contents of the soil. Besides, though it was not significant, clay content was slightly decreased with depth and distances which shows a similar trend with soil CEC. Soils with CEC of <16 meq/100g are considered not to be fertile and such soils are highly weathered while fertile soils have a CEC of >24 meq/100g [11]. In the current study, soil CEC in the canopy zone of *C. africana* and *C. macrostachyus* trees ranges from

(30.86-36.89 & 30.96-36.71 meq/100g), respectively (Table 3), that falls in the range of fertile soil. In harmony with this study, significantly higher soil CEC under canopy than outside canopy were reported for *C. apiculatum* and *P. africanum*, for *A. Senegal* for *F. albida* and for *A. seyal*, *A. tortilis* and *B. Aegyptica* [25, 3, 12, 23].

**Figure 9.** Mean values of soil CEC for overall radial distances.**Figure 10.** Mean values of soil CEC value for overall soil depth.

3.3. Microclimatic Factors

3.3.1. Relative Illumination, Soil Temperature and Air Temperature

The mean values of relative illumination at all radial distances showed significant ($p < 0.0001$) difference (Figure 11), with maximum (100%) and minimum (40 & 44%) mean value at 15m and 2.5m from tree trunk of *C. africana* and *C. macrostachyus* trees, respectively. Accordingly, the maximum amounts of light intercepted by leaf and branch biomass at canopy zone were 60 and 56% (100-40 & 100-44%) for *C. africana* and *C. macrostachyus* trees

respectively. Similar to the current finding, 45 to 65% reduced incoming solar radiation was reported for *A. tortilis* and *Adansonia digitata* and 45% reduced for under *V. paradoxa* trees 20% reduced for under *P. biglobosa* trees were also reported [16, 4]. In addition, reduced photo synthetically active radiation (PAR) also reported by 40% under *V. paradoxa* trees and by 75% under *P. biglobosa* trees [5, 15].

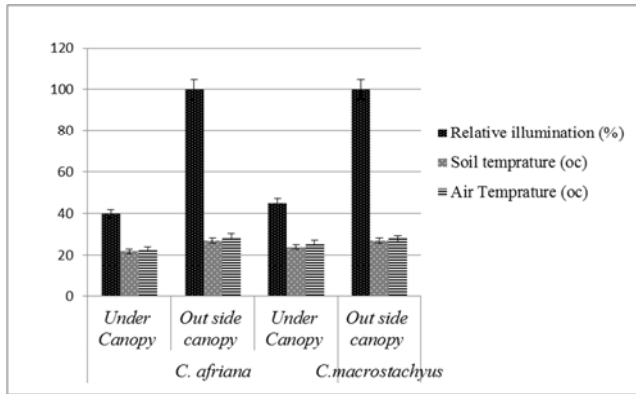


Figure 11. Mean values of relative illumination, soil temperature and air temperature under canopy and open field.

The result of this study indicated that mean values of air temperature at 2.5m crown radius and open field (15m) were statistically par for both tree species ($p = 0.091$) (Figure 11). However, the maximum (29°C) was observed for both species at 15m away from their trunks, and minimum mean values (22 & 23°C) were observed at 2.5m from tree trunk of *C. africana* and *C. macrostachyus* trees, respectively. Similar to air temperature, the result of this study indicated that mean values of soil temperature at 2.5m crown radius and open field (15m) were statistically par for both species ($p = 0.091$). However, the maximum (28°C), and minimum mean values (21 & 23°C) were recorded at 15m and 2.5m from tree trunk of *C. africana* and *C. macrostachyus* trees respectively. Similar to this finding, it was reported that reduced soil temperature by 6°C for under *A. tortilis* tree and by 5°C to 10 °C for under *F. Albida* tree [4, 26, 2].

3.3.2. Soil Moisture Content

The overall mean values of soil moisture content showed significant ($p < 0.0001$) differences among radial distances from tree trunk and between soil depths for both species ($p = 0.0032$) (Figures 12 & 13). Similarly, mean values of surface and subsurface soil layer moisture content revealed significant ($p < 0.0001$) difference among radial distances from tree trunk. With regard to depth wise comparison, surface soil layer moisture content mean value was found to be significantly ($p = 0.0032$) higher than mean value of subsurface soil layer at 0.5m, 2.5m and 5m. The highest mean values (17% and 16%) at 0.5m crown radius of surface soil layer and lowest mean values (9% and 9%) at 15m were observed at subsurface soil layers under *C. africana* and *C. macrostachyus* 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 shade provided by trees and enhancing of soil water holding capacity via organic matter enhancement. This finding was consistent with study revealed higher soil moisture content in surface 19.6% and subsurface soil 10% under canopy zone than surface soils 15.9% and subsurface soils 8.9% at outside canopy of *M. ferruginea* tree [24].

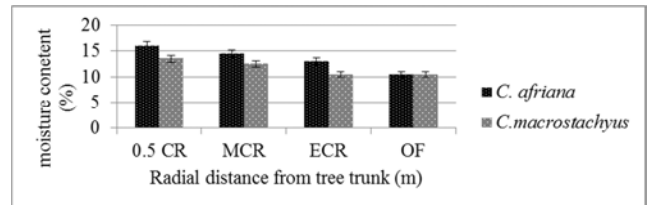


Figure 12. Mean values of soil moisture content for overall radial distances.

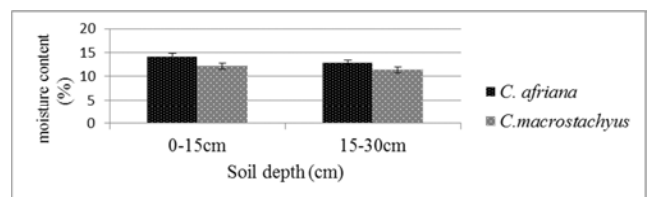


Figure 13. Mean values of soil Moisture content for soil depth.

3.4. Maize Yield

The mean values of maize yield (t/ha) at all radial distances from tree trunk were not significant ($p = 0.0934$) (Table 4). The highest (1.51 ton /ha) was recorded at 15m from tree trunk, and lowest (1.05 & 1.12 ton /ha) mean values were recorded at 0.5m from tree trunk of *C. africana* and *C. macrostachyus* trees, respectively. The pooled mean values of maize yield at canopy zone were lower by 8.53 & 7.75% than mean value at open field for *C. africana* and *C. macrostachyus* tree, respectively. Generally, the result showed slightly increasing with increasing distances from tree trunk. Accordingly, the overall mean values at canopy zone were lower than at open field. This may be attributed to the shading effect by trees on the crops; reduced growth due to intercepted photosynthetically active radiation (IPAR). In line with this current result, decreased in sorghum yield under canopy of *V. paradoxa* and *P. biglobosa* trees and lowered wheat yields under *A. nilotica* than outside canopy also reported by different scholars which may be due to above and/or below ground competition [16, 28]. Contrary to the current study finding, higher yield of groundnut, sesame and roselle under canopy of *A. senegal* trees as compared to sole cropping from Sudan reported by [9]. Moreover, the current result is also disagreed with highest yield reported under tree canopy than outside canopy by 101% (sorghum) 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* [22].

Table 4. Mean \pm SE values of maize yield in (t/ha) at different radial distances from tree trunk.

Species	RadialDistance from Tree Trunk			
	Mean valuesat0.5m	Mean valuesat 2.5m	Mean values at 5m	Mean values at 15m
<i>C. africana</i>	1.11A \pm 0.004	1.12AB \pm 0.002	1.13AC \pm 0.002	1.142 A \pm 0.001
<i>C. macrostachyus</i>	1.2A \pm 0.004	1.24A \pm 0.002	1.3A \pm 0.002	1.43A \pm 0.001

4. Conclusion & Recommendation

Soil textural fractions (sand, silt and clay) were not considerably influenced by presence of *C. africana* and *C. macrostachyus* trees. Whereas, soil bulk density was notably lower under canopy of *C. africana* and *C. macrostachyus* trees than outside canopy, and increased with increasing radial distances. Likewise, bulk density of surface soil was also significantly lower than subsurface soil layer. With the regard to soil chemical properties, soil OC, TN, Av. P, Av. K, and soil CEC for surface and subsurface soil layers of under *C. africana* and *C. macrostachyus* trees were considerably improved than outside their canopies. Similarly, as compared to outside canopy, relative illumination, soil temperature and air temperature were markedly lowered by *C. africana* and *C. macrostachyus* trees. Soil moisture content under *C. africana* and *C. macrostachyus* 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. On the other hand, maize yield was slightly lower under canopy of *C. africana* and *C. macrostachyus* trees zone than open field.

Further research should be required on *C. africana* and *C. macrostachyus* 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 *C. africana* and *C. macrostachyus* trees litters' decomposability and their chemical compositions. Moreover, tree phenology is different in different season thus its effect on beneath canopy microclimates might be different for different season. So, further study will be important to know the effect of these trees on microclimatic parameters under their canopies in different seasons. Finally, Because of its role in ameliorating microclimate and improving soil fertility under their canopies, retaining of *C. africana* and *C. macrostachyus* trees on crop land is important for the farmers with appropriate component management practices like lopping and crown opening.

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