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Original Research Article

Eucalyptus camaldulensis Woodlot Influences Soil Properties and *Teff* Yield on the Adjacent Croplands in Guraghe Zone, Central Ethiopia

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Abstract: In Ethiopia five Eucalyptus species were adopt wide area and Eucalyptus camaldulensisi more dominant in low land and middle land area and economically very important. This leads to farmers converted portion of their farmland to Eucalyptus camaldulensis woodlots. The aim of this study was to assess the impact of E. camaldulensis woodlot on the soil properties and teff (Erogrsticteff) yields on an adjacent cropland. A plot of 2m x 1.5m area was laid down inside plantation (assumed zero m), at one, three, six, nine and20 m distances away from the E. camaldulensis woodlot in to the adjacent cropland. This was replicated on three farmlands. Teff was grown on the plots and the yield, height, and biomass of teff were measured and thirty six soil samples were collected from experimental field. The soil bulk density ($p<0.01$), soil moisture ($p<0.001$), SOC ($p < 0.05$), avail P ($p < 0.01$) and avail K ($p < 0.01$) were significantly varied with distance. The yield and height of teff were significantly ($p< 0.01$) affected by distance from the woodlot. Moreover, mean soil total N at three meter, avail P from one meter to six meter, avail K after nine meter, yield and biomass of teff up to six meter were reduced. The yield reduction of teff could be attributed to the soil moisture and soil nutrient competition between the Eucalyptus woodlot and teff. In this study we had concluded that E. Camaldulensis wood lot has effect on teff production up to six-meter distance from the woodlot and adjacent crop were recommended after Six meter.

Keywords: Agroforestry Biomass, distance from tree, E. camaldulensis, soil property, teff, yield.

1. INTRODUCTION

Eucalyptus is an exotic tree species that grows as form of plantation forests and woodlots particularly in Ethiopia. The tree was successfully introduced in many countries including Ethiopia, and it was cultivated as an important biomass sources under different environmental conditions (Davidson, 1993). *E. globulus* plantation stands were established initially around Addis Ababa at the beginning of the 20th century, and then *Eucalyptus* expanded all over the central plateau in the altitudinal range between 1400 to 3500 meters above sea level (Pohjonen and Pukkala, 1991). Then, *E. camaldulensis* is one from about five to ten species of *Eucalyptus* those were introduced to Ethiopia in the late nineties (Friis, 1995). *Eucalyptus* plantations can play useful environmental roles in natural and plantations forests. They can serve as a source of timber, fiber and essential oils; as ornamental and a shade tree in cities, and as a means to water tables in marshy areas (Leicach *et al.*, 2012). The farmers need the tree for fuelling and construction, and also they get economic benefit from selling the tree. This has motivated the farmers to grow trees more and more on their farms. As a result, the integration of *Eucalyptus* woodlots and crop production was high in the highlands (Lemenih, 2010).

Eucalyptus has long become an essential part of the agricultural landscape of Ethiopia. Early estimates indicate that about 200,000 ha of *Eucalyptus* have been planted on farm level plantation in Ethiopia (Davidson, 1993). Nowadays the small holder farmer *Eucalyptus* plantation has increased to 800, 000 ha (Lemenih and Kassa 2014). Despite the benefits of the tree, some studies claim that the expansion of *Eucalyptus* on farmlands has negative influence on soil fertility (El-khawas and Shehata, 2005; Forrester *et al.*, 2006). *Eucalyptus* is a fast-growing tree, and the tree has high nutrients up take capacity (Laclau *et al.*, 2005;

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Zhang *et al.*, 2015), which removes nutrients from the site with a harvest. The acidity of the soil increased in *Eucalyptus* plantations (Aweeto and Moleele, 2005 and Syad et al., 2006). The acidifying effect was demonstrated by comparing *Eucalyptus* plantations and natural forest (Alber, 2016). On the other hand, trees provide a convenient human habitation, improves soil nutrient, serves as wind break, and enhances the climatic condition of the area as well as providing shade for living organism (Verheij, 2004 cited in Kwaku and Wiafe 2014). Similarly, trees on agricultural fields play several important roles such as improving environmental health and for the wellbeing of mankind. Place *et al.*, (2012) stated that agroforestry creates some environmental benefits such as sustainability of biodiversity, watershed protection and carbon sequestration. Few studies investigated the impact of *Eucalyptus* woodlots on the productivity of crop on the adjacent agricultural land like maize and (Tilashwork, 2009; Alebachew *et al.*, 2015).

Most studies assessed the impact of *Eucalyptus* plantations by comparing the soil properties between croplands and Eucalyptus plantations (e.g. Lemma *et al.*, 2006; Duguma *et al.*, 2010). However, few studies attempted to show the effect of *Eucalyptus* on different crops like maize, wheat and sorghum grown adjacent to the tree stand with increasing distance from it to the cropland (Selamyihun *et. al.*, 2004, 2005; Tilashwork *et al.*, 2013). However, the effect of the tree on crops can be influenced by tree species, crop types, agro ecological zones and soil types. According to these, scientific studies on *E. camaldulensis* effect on soil and crop yield is limited in the country (Ethiopia) and almost nil in the study area particularly on teff (*Eragrostif teff*) and vertisols soil type. In addition, the studies done before are only laboratory based on field experiment like Selamyhun *et al.,* (2004) and in the area with nitosol soil type like Tilashwerk *et al.,* (2013). Therefore, this study is design to fill the gap on effect of *E. camaldulensis* on *teff* (*Eragrostif teff*) at adjacent crop land on field that have clay soil (Heavy vertisols). *E. camaldulensis* woodlots are established adjacent to croplands in the agro-ecosystems of southern Ethiopia. Particularly in the study area the extent of *E. camaldulensis* is rapidly increased. This setting provides a unique opportunity to test the influence of *Eucalyptus* woodlot on the adjacent croplands and the crops growing on it. Therefore, the present study assessed the effect of *Eucalyptus camaldulensis* woodlot on the soils of cropland and on *teff* (*Eragrostistef*) productivity in the agro-ecosystem of Gurage Zone, southwestern Ethiopia.

2. MATERIAL AND METHOD

Study site description

This study was conducted in Edja district, Garage Zone in the Southern Nation and Nationalities and Peoples' Regional State (SNNPRS), Ethiopia. It is located at about 197 km Southwest of Addis Ababa and 42km east of Worksite, the capital of the Garage zone (Fig 1). The study site (8^o3'18" N- 8˚14'42" N and 37^o49' 48"E - 38^o13'12" E) ranged between1895 to 3200 m.a.s.l. The mean annual rainfall of the study area was between 950 mm to 1100 mm, while the mean annual maximum and mean annual minimum temperature were 27.7 °C and *6.5°C*, respectively. The soil of the study area was classified as Heavy Vertisols (Eyes, 2016).

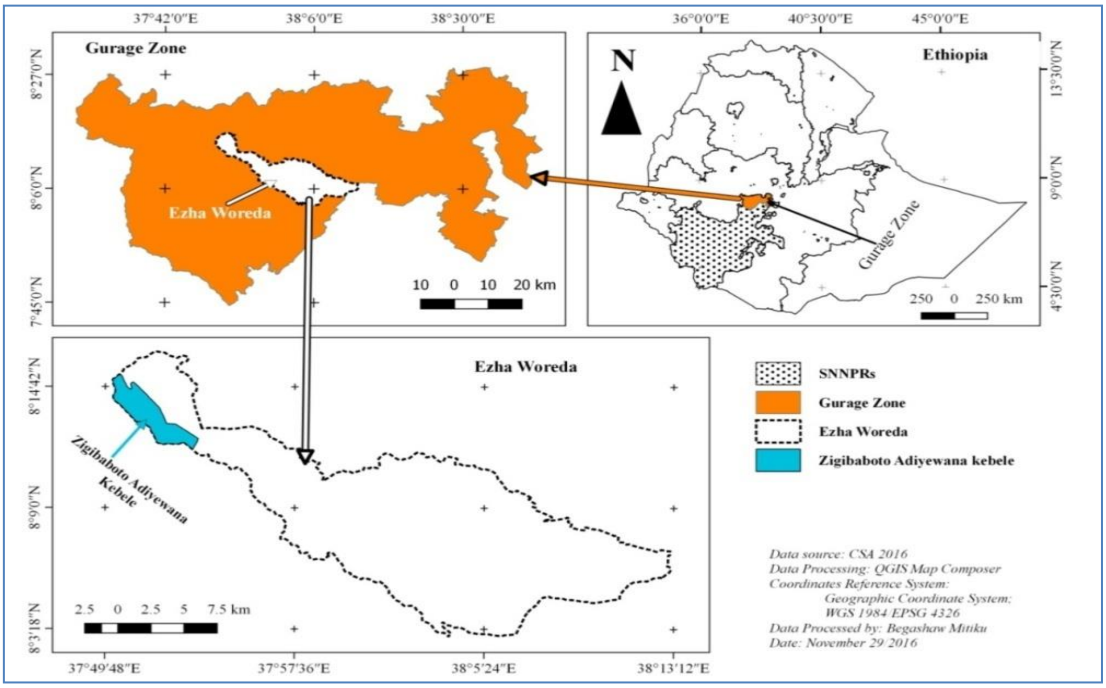

Fig-1: Map of study area

The major land uses in the study area includes cropland, natural vegetation, grazing land and *E.camaldulensis woodlots* (hereafter referred simply as *Eucalyptus* woodlot). The average land holding per household head is less than 0.5 ha, which is one of the main factors exerting a profound influence on land use changes and land use intensification. Enset and cereal based farming systems are the two-major farming system in the area. The common annual food crops in the area are *teff* (*Eragrostif teff*), maize (*Zea mays* L.), finger millet (*Panicum miliaceum*), and Nug (*Guizotia abyssinica*) (Ketema, 1997).

Sampling design and soil analysis

Three farmers' holdings with *Eucalyptus* woodlot and adjacent cropland uses were purposively selected to get woodlots and forms under similar age, management and land use history. Croplands were similar in land management and land use history. *Eucalyptus* woodlot had nearly similar age of six to seven years; the woodlots were in their fourth rotation, which coppiced after third harvest, and similar management. The DBH and height of Eucalypts woodlot are given below (Table 1).

Table-1: Mean (±SD) DBH and height of *Eucalyptus* in the three smallholder woodlots

Sample plots	Average DBH (cm)			Average Height (m)		
	W1	W2	W3	W1	W2	W3
	10.6 ±0.9	10.6 ±1.1	10.4± 1.0	22.9± 1.8	22.5 ±1.3	22.7± 1.5

*Note: W1= woodlot1; W2= woodlot2; W3= woodlot3

The design of the present study is Randomized Complete Block Design. Plots of size 2m x 1.5m were laid down at one, three, six, nine and 20 m distances away from the *Eucalyptus* woodlot along the adjacent cropland for both soils sampling and sowing of crop (teff). The first distances was fixed starting from the edge of the woodlot and then continue the next distance along the crop land. At the inside of plantation (assumed zero meters) one composite soil sample was taken using diagonal soil sampling methods, which is parallel to the experimental plots. This was replicated on three farmers' holdings.

Accordingly, a total of 18 plots (6 on each farm x 3 replications) were established. Composite soil samples were also collected using core sampler from each plot, the plot fixed parallel to the teff sown plot and free from fertilizer contamination that applied for the crop, at two soil depths (0-10 and 11-30 cm).A total of 36 composite soil samples (6plots x 2 soil depths x 3 replications) were collected for the soil analyses. For bulk density and moisture content determination, separate undisturbed soil samples were collected with a manual core sampler (diameter =5 cm; height =5 cm) from all plots and soil depths.

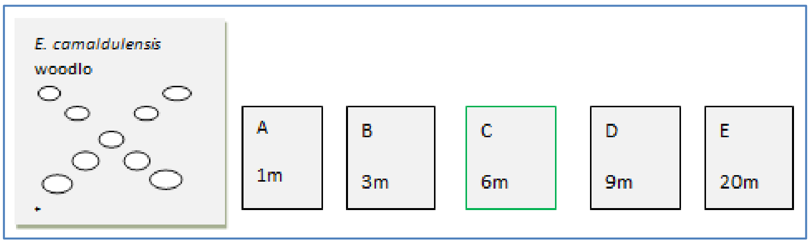

Fig-2: Schematic sketch of plot design in single woodlot; Note: A, B, C, D and E are plots for teff sowing adjacent and circle inside of plantation are pits for soil sampling inside woodlots.

***Teff* data collection**

An improved variety of teff (cross 37-Tsedey) was used for this study. This *teff* variety is early maturing and has good grain fillings ability. *Teff* was sowed at different plots established at each distance (section 2.2.1) and a blanket recommended amount of fertilizer (100 kg/ha DAP and 50 Kg/ha Urea) was applied each plot equally in plot based amount. In each plot, the height of *teff* was measured after seed setting, and the above ground biomass and yield of *teff* were measured after harvest. The effect of *Eucalyptus* woodlot on height, biomass and yield of *teff* was determined by comparing among the plots established at different distances. *Teff* height was measured by using average height of five random *teff* plants per plot. *Teff* biomass was determined after harvesting above ground biomass of *teff* from each plot and drying in sun for two days (48hr).The yield of *teff* grains was measured by a balance after separating the grains from straw and the moisture of the grain is corrected using 10% moisture reduction. The yield was expressed as quintal per hectare (qha-1) while the biomass was given t/ha-1.

Soil analysis

The soil samples were air-dried at room temperature (25^{o}C), crushed, homogenized, sieved (mesh size <2mm), and analyzed at the Southern Agriculture and Natural Resource Soil Testing Laboratory, Hawassa, Ethiopia. It was further crushed and sieved (mesh size <0.5mm) for soil organic C (SOC) and soil total N (TN) analyses. The SOC was determined by Walkley and Black method (Walkley and Black 1934).Total N concentration was determined by the Kjeldahl method (Jackson, 1958). The avail P concentration of the soil was analyzed by Olsen method (Olsen et al., 1954). Available K concentration of soil extract was determined by using flame photometer (Jackson, 1958). The soil pH was measured using pH meter in 1:2.5 ratios (soils: water solution). Soil moisture content was determined by gravimetric method after oven drying to a constant weight at 105ºC for 24 hrs (Anderson and Ingram, 1993). Bulk density was determined after oven drying the undisturbed soil sample at temperature of 105°C for 24 hours and then by dividing the oven-dried weight of the sample by its volume.

STATISTICAL ANALYSIS

Bulk density, moisture content, pH, SOC, TN, avail P, and avail K of soil data and the yield, biomass and height of *teff* data were analyzed using two-and one-way analysis of variance (ANOVA), respectively, with SPSS statistical software (version 16). Significant results were followed by mean separation using Turkey's test ($p<0.05$).

RESULTS AND DISCUSSION

Results

The effect of *Eucalyptus* woodlot on bulk density, soil moisture and pH

Bulk density showed a significant difference with distance ($p < 0.01$) from the *Eucalyptus* woodlot and with soil depth. Bulk density inside and near the *Eucalyptus* woodlot was significantly lower and increased with increasing distance (Table 2). The soil moisture content showed significant difference with distance from the *Eucalyptus* woodlot ($p<0.001$) and with soil depth ($p < 0.01$). The moisture contents near the woodlot were significantly lower than the moisture contents away from the woodlot (Table 2). The pH did not significantly vary ($p > 0.05$) with distances from woodlot and soil depth (Table 2) indicating the similarity of soil reaction with the cropland.

Table-2: Means (±SD) values of bulk density, moisture content, pH and soil organic carbon (SOC) at 0-10 and 11-30 cm soil depths with distance from *Eucalyptus* woodlot

distance from *E. camaldulensis* woodlot	Depth (cm)	bulk density (gcm-3)	Soil moisture (%)	pH (H2O)	SOC (g/kg)
Inside woodlot	0-10	1.04±0.08c	12.5±2.1b	5.4±0.1a	14.6±2.6b
	11-30	0.99±0.08C	13.7±1.2B	5.6±0.1A	13±2.6A
One meter distance	0-10	1.08±0.05c	12.1±0.6b	5.5±0.1a	21.0±7.0a
	11-30	1.06±0.10B	14.4±1.1B	5.6±0.0A	11.5±3.6A
three meter distance	0-10	1.15±0.02bc	12.5±1.1b	5.6±0.2a	15.0±3.5b
	11-30	1.08±0.08B	14.5±0.5B	5.6±0.1A	9.9±1.9B
Six meter distance	0-10	1.18±0.02ba	12.7±1.8b	5.4±0.8a	17.1±3.0ab
	11-30	1.14±0.11B	13.6±0.9B	5.5±0.1A	8.6±0.2B
Nine meter distance	0-10	1.22±0.03a	15.3±1.2a	5.5±0.1a	16.8±2.3b
	11-30	1.28±0.0A	15.4±1.1A	5.6±0.1A	10.3±2.1AB
Twenty meter distance	0-10	1.29±0.03a	16.2±0.4a	5.6±0.1a	17.3±3.8ab
	11-30	1.24±0.12A	15.0±0.9A	5.6±0.1A	10.7±2.4AB

Note: Mean values with distances from the woodlot for the same soil depth followed by the same small letter are not significantly different.

The effect of *Eucalyptus* woodlot on SOC

Soil OC was significantly high ($p <0.05$) at one meter distance as compared with the rest of the distances zero, three, six, nine and twenty meters from the woodlot (Table 2). However, with exception of SOC at one meter distance, mean SOC showed slightly increasing trend towards the cropland with increasing distance.

The effect of *Eucalyptus* woodlot on soil nutrients (TN, avail P and avail K)

Soil TN did not show significant difference with distance from *Eucalyptus* woodlot, but soil TN is relatively higher at one meter and relatively lower at zero meter distances. Soil TN was higher at the surface soil layer (0-10 cm) than sub surface soil layer (10-30 cm; Figure 2). The concentration of avail Pin the soil significantly differed($P < 0.01$) with distance from *Eucalyptus* woodlot, but not with soil depth (Figure 3).The lowest mean concentration of avail P was recorded at six-meter distance. Avail P showed a declining trend with distance up to six-meter, and then increasing to nine-meter and remained similar up to twenty meter(Fig. 3).The avail K concentration in the soil was significantly different ($P < 0.01$)with distance from the *Eucalyptus* woodlot and with soil depth. The lowest avail K concentration was found at nine-meter distance from the woodlot. Available mean K concentration in the soil showed a declining trend with distance up to nine-meters and increased thereafter from the woodlot (Fig 4).

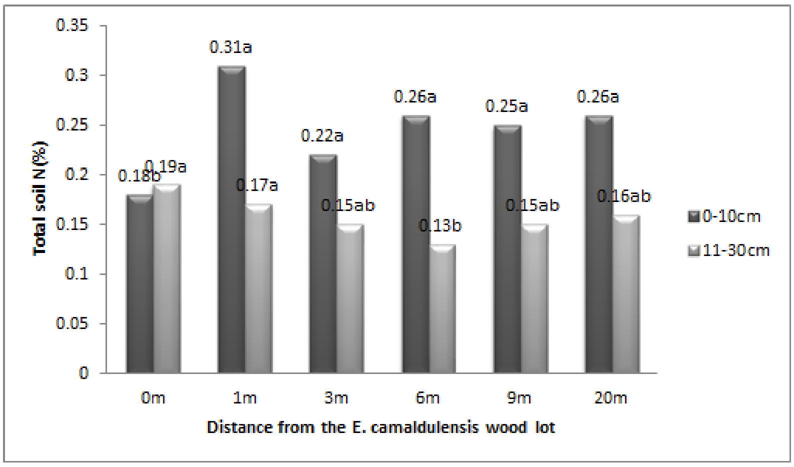

Fig-3: Total nitrogen in percent (%) at different distance from the *E. camaldulensis* stand and open area at p valu=0.05.

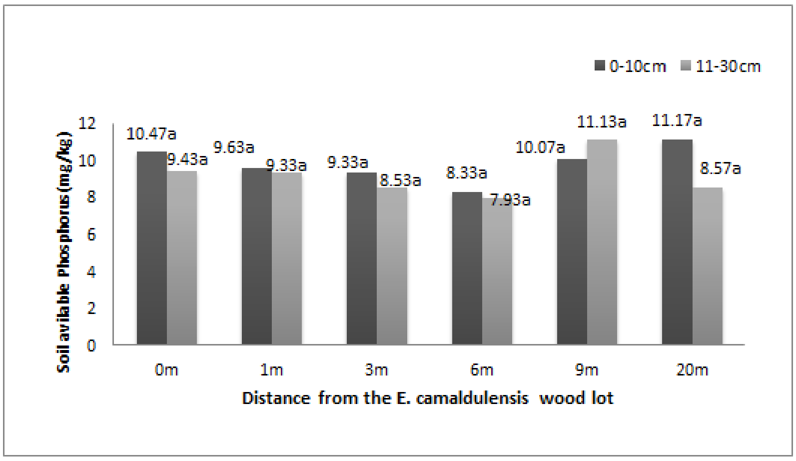

Fig-4: The effect of *Eucalyptus Camaldulensis* stand on available P at different distance from the stand (at p valu=0.05).

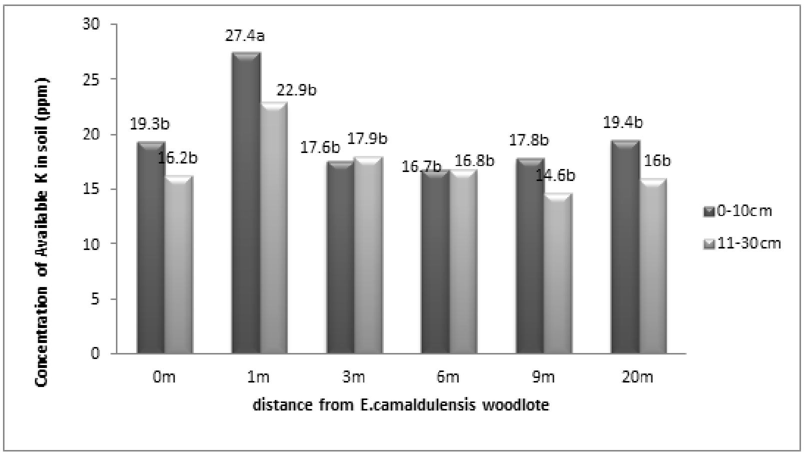

Fig-5: The effect of *Eucalyptus Camaldulensis* stand on avail K at different distance from the trunk at *p valu=0.05*.

The relationship between physico-chemical properties of soil and distance from the stand

The present study shows that some of soil properties under this study were significantly affected by the distance from the *E. camaldulensis* stand to far apart. Their regression graph also shows that physical properties of soil like soil moisture and bulk density are have highly relation with distance from the *E. camaldulensis* stand. The bulk density of soil decrease with increase of distance but, soil moisture is increase with increase of distance from the *Eucalyptus* stand. On the other hand from the chemical properties of soil shows that weak relation with distance from the *Eucalyptus* tree stand.

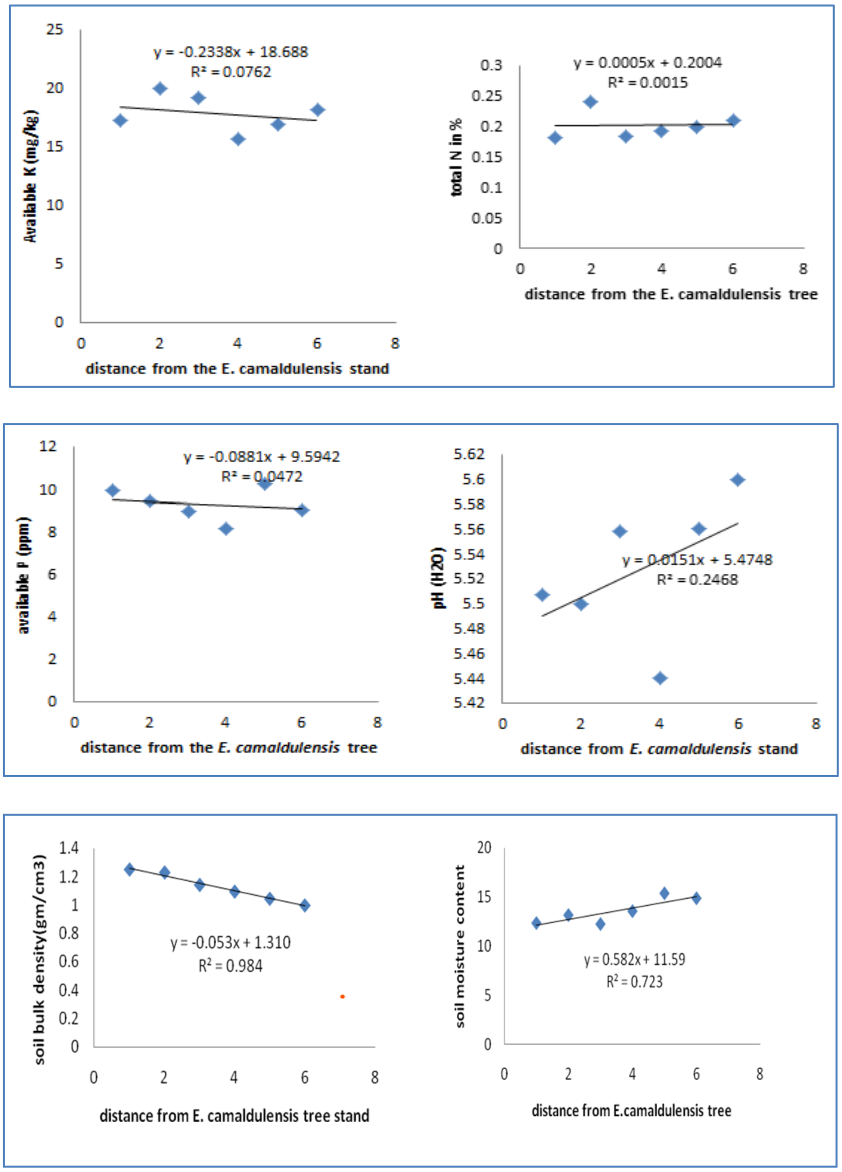

Fig-6: The relationship b/n soil physical and chemical parameters with distance from the woodlot distances (m)

The effect of *E. camaldulensis* woodlot on *teff* yield planted on the adjacent cropland

Grain yield of *teff* (*Eragrostif teff*) was significantly varied (P<0.01) with distance from *Eucalyptus* stand (Table2). The highest grain yield was 12.8qha^{-1}and the lowest 9.2qha^{-1}at 20m and 1m distance from Eucalyptus woodlot, respectively. The yield of *teff* at one, three and six meter distances from *Eucalyptus* stand showed significant difference (P<0.01) from twenty meter distance. Biomass of *teff* was not significantly different at different distances from the woodlot (Table 5). Mean biomass showed an increasing trend with distance from the woodlots.

Table-3: Mean (±SE) values of yield and biomass of *teff* with distance from *E.camaldulensis*

Distance from *E. camaldulensis* woodlot	Yield (q/ha)	Biomass (t/ha)
One meter distance	9.2±1.7b	7.4±0.8a
Three meter distance	9.8±1.4b	9.1±2.1a
Six meter distance	10.8±2.1ab	9.5±2.0a
Nine meter distance	12.7±0.4a	11.1±5.4a
Twenty meter distance	12.8±0.5a	12.16.0±6.0a

*Mean values with the same letter are not significantly different.

The growth parameters of *teff* varied significantly (P<0.01) at different distances from the *Eucalyptus* woodlot. The highest plant height (97.33±3.62) was recorded at twenty meter distance from the woodlot and the lowest was recorded at one meter distance (72.53±0.82) from woodlot. Similarly for tiller number and spike length high at twenty meter distance and lower results were recorded at one meter distance.

Table-4: Report table for the growth parameter of teff at different distance from the stand

Distance from *E. camaldulensis* woodlot	Growth parameter of teff (Mean ± SE)		
	plant height(cm)	spike length(cm)	tiller no.
One meter distance	72.53±0.82^{b}	24.27±0.44^{b}	3.4±0.23^{b}
Three meter distance	79.85±2.83^{b}	25.80±1.06^{b}	4.2±0.20^{b}
Six meter distance	84.87±2.72^{ab}	29.53±2.13^{ab}	3.8±0.07^{b}
Nine meter distance	84.60±3.47^{ab}	28.40±1.75^{ab}	3.8±0.20^{b}
Twenty meter distance	97.33±3.62^{a}	34.27±1.52^{a}	5.3±0.13^{a}

*Mean values with the same letter are not significantly different

DISCUSSION

The effect of *Eucalyptus* woodlot on bulk density, soil moisture and pH

According to this study with increase the distance from the *E. camaldulnsis* woodlot to farmland soil bulk density is increase while soil moisture is decrease. This result is in line with Hailu *et al.* (2003), who reported that soil bulk density near *Eucalyptus* stand, was lower than that of the adjacent grazing land, attributed to the difference in SOC. In addition the soil bulk density under *Eucalyptus* was low and increased with distance from tree stand. The soil bulk density was negatively correlated with SOC, because it improves soil aggregation and soil porosity. Therefore, the difference in bulk density at the distances in this study could be attributed to the difference in SOC with distance from *Eucalyptus* woodlot. In addition, soil compaction in the cropland, which caused by continuous tillage by trampling and also oxidation of SOC indirectly (Yoshinori *et al*., 2009).

In the present study, the soil moisture content had increased with distance from wood-lot, which could be attributed to the high consumption of water by *E. Camaldulensis* tree in and closer to the wood-lot, whose influence decreases with distance from wood-lot and high accumulation of fiber roots of *E. camaldulensis* (Tilashwork, 2009). Eucalyptus has high water uptake potential and its roots grow up to six to nine meters, extracting water from a greater depth (Mekonnen, 2016). The high water need and its deep root systems enable *Eucalyptus* to compete successfully over other plants (Jagger and Pender, 2003). *Eucalyptus* consume high amount of water, which much affects the moisture content of the surrounding soil (Tegenu *et al.*, 2008). Similarly, the moisture content of soil under *E. saligna* was significantly lower compared to soil under the farm land (Fikadu *et. al.*, 2012). In contrast, Ambachew *et. al.*, (2012) reported that the moisture content *Eucalyptus* species was not different from the other land uses like crop land. As shown the section 3.2 below the organic carbon is higher near to the woodlot than far distance in contrast to soil moisture which lowers near to the woodlot, it may be as result of higher fiber root concentration at 5 distances (Tilashwork, 2009).

The pH did not significantly vary ($p > 0.05$) with distances from woodlot and soil depth that indicates soil reaction with the cropland is similar. This was in contrast to the claims that *Eucalyptus* has high acidifying effect on soil. Consistent to our findings, Juice (2016) showed that agricultural land and *E. camaldulensis* stand shad similar soil pH in the northern Ethiopia. In addition, the soil pH in *Eucalyptus* stands was similar to the soils in the adjacent agricultural land (Tegenu *et al*., 2008; Hailu, 2009). In contrast to the present study, the pH was lower in *Eucalyptus* stand and the closer distances than in the cropland (Telashwork, 2009).

3.2. The effect of *Eucalyptus* woodlot on SOC

The mean SOC decreased with increase in distance from Eucalyptus stand and it contributed by low litter fall with distance from wood-lot is increased (Yuri *et al.*, 2002). In contrast, Duguma *et al.*, (2010) reported that SOC was lowest for cereal farms and with relatively higher values in woodlot. Similar works found that SOC in *Eucalyptus* plantation stand was higher than agricultural land (Syad, 2006; Juice *et al.* 2016; Schulte, 1995). The low SOC in agricultural land than in *Eucalyptus* wood_lote is higher oxidation of SOC due to intensive cultivation (Dessie and Erkossa, 2011). Fernando *et al*. (2010) found that better SOC as result of high organic matter addition and low decomposition rate because of low nutrient concentrations those important for soil microbes. Hailu *et al.* (2003) showed that SOC concentrations did not differ among *Eucalyptus* plantation and agricultural land at two sites. However, the result of the present study showed a significantly high SOC value at one meter distance might be related to weeds and other herbaceous plants, which grow in the space between the edge of woodlot and the cropland, and their litter inputs. The SOC decreased with soil depth, and SOC was higher in the surface soil layer (0-10 cm), which is due to addition of litter on the surface.

3.3. The effect of *Eucalyptus* woodlot on soil nutrients (TN, avail P and avail K)

Different land use studies have compared the soil nutrients between woodlot and croplands. Janice (2010) found no difference in soil TN between

Eucalyptus stand and cropland in northern highlands of Ethiopia. Similarly, TN was not different between the soils of *Eucalyptus* plantations and adjacent agricultural lands in Ethiopia (Hailu *et al.*, 2003). In contrast, the total N concentration was lower in the *E. camaldulensis* stand as compared to an open area in South Africa (Tererai *et al.* 2014) while TN in the soil was higher in *Eucalyptus grandis* stand than in the croplands in southwestern Ethiopia (Lemma *et al.*, 2006). Differences in the results could be due to differences in soil type, climate and management of *Eucalyptus* as well as croplands.

The results of avail Pin the present study agrees with other studies (Tilashwork, 2009; Yoshinori *et al.* 2009; Muche *et al.*, 2015). Yoshinori *et al.* 2009 showed that the available P concentration in the *E. Camaldulensis* stand was lower than other land uses like agricultural land. Available P was also low in plantation dominated by *Eucalyptus* than crop lands in (Muche *et al*., 2015). Tilashwork (2009) indicated that fine roots are responsible for nutrient absorption and *Eucalyptus* stand can influences ten-meters away from the stand. The declining trend in the present study was up to six-meters and it is the influence of much accumulated *E.camaldulensis* fine roots.

Low concentration of avail K was found in *Eucalyptus* stand when compared to croplands (Syad, 2006). In contrast, Hailu, *et al.* (2003) has found high avail K concentration in the soils of *Eucalyptus* as compared to adjacent cropland. Similarly, *Eucalyptus* plantation forest had higher avail K concentration than cropland (Muche *et al*., 2015). On surface soil layer, avail K concentration was higher than sub-surface layer and similar results were found in other studies (Syad, 2006).

The effect of *E. camaldulensis* woodlot ongrowth and yield of *teff* planted on the adjacent cropland

Comparable to the present study, Tilashwork (2009) found that the yield, biomass and height of maize increased with distance from the *Eucalyptus* woodlot. She agreed that the loss of crop yield is the competition of soil nutrients and light by *E. camaldulensis* to crops (Tilashwork *et al.*, 2013). Similarly, Alebachew *et al.* (2015) showed that the height, biomass and grain yield of maize decreased with decrease distance from the adjacent *Eucalyptus* stands. Mugunga *et al.* (2017) recognized that the reduction in maize yield planted adjacent to *E. saligna* woodlot to the soil moisture as the soil moisture near the woodlots was lower compared to the values in open areas. In his study, the amount of the solar radiation near the woodlots was reduced by 68% compared to the open areas. The trend in soil nutrients with distance from the *Eucalyptus* woodlot could be related to the reduction in *teff* growth parameters (e.g. Figure 3 & 4). Some studies have describes the loss of crop yield at closer distances from *Eucalyptus* stands to the competition of *Eucalyptus* for soil nutrients with crops (Tilashwork *et al.*, 2013, Mugunga *et al.*, 2017). Moreover, Florentine and Fox (2003) showed that certain phenolic acids and volatile oils in *Eucalyptus victrix* seedlings functioned as allelopathic agents on a grass species in Australia. Lisanework (1993) studied the allelophatic effect of *Eucalyptus* leaves and he showed that aqueous extract of the leaves of *E. camaldulensis* and *E. glubulus* influence *teff* growth than other tree species. Thus, *Eucalyptus* could influence crops growing either under or adjacent to it due to the production of allelopathic chemicals. These factors could influence the yield and other parameters of teff in the present study.

CONCLUSIONS AND RECOMMENDATION

According to this study, soil properties and *teff* growth parameters on the cropland varied with distance from the adjacent *E. Camaldulensis* woodlot. Soil bulk density, moisture content, SOC, avail P and avail K showed a decreasing trend up to six and nine meter distance from the woodlot and increasing trend thereafter. The yield and height of *teff* was significantly reduced with distance from *Eucalyptus* woodlot. The yield and height of *teff* was strongly affected up to six meter distance from the woodlot. The decline in yield of the *teff* crop in this study was attributed by the decline in the soil moisture and soil nutrient. In the studied agro ecosystem and other similar agro ecosystems, where *Eucalyptus* woodlots are an integral part of the agricultural landscape, we recommend crop cultivation at distances six meter or greater away from the woodlot to minimize effects of *E. camaldulensis* associated with crop.

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Conflict interst

The authors declare that they have no conflict of interest.

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