Status of Selected Soil Properties under Croton macrostachyus Tree at Gemechis District, West Hararghe Zone, Oromia, Ethiopia

Desalegn Mamo[1] Zebene Asfaw (PhD)[2]
1.Arsi University, Assela, Ethiopia
2.Hawassa University, Wondo Genet College of Forestry and Natural resource, Wondo Genet, Ethiopia

Abstract
This study was designed to evaluate the status of some selected soil properties under Croton macrostachyus at Welargi and Hidha Dima kebeles in Gemechis district, West Hararghe Zone. Soil samples were collected from surface layers (0-20cm) at two distances (1 and 3m) under tree canopy and at adjacent open areas (16m) from crop fields. The result of soil analysis revealed that with the exception of soil texture and bulk density, all soil properties increased significantly under Croton macrostachyus canopy than in the open area in both kebeles showing a decreasing trend with increasing distance from the tree trunk, because of the input from Croton macrostachyus, like litter fall for organic carbon and accumulation of organic matter for moisture, nitrogen, available phosphorus, CEC and exchangeable potassium. In addition, the decrement of bulk density under canopy was due accumulation of organic matter. An increase of about 29.9% for organic carbon; 42.4% for total nitrogen; 12.6% for available phosphorus; 7% for CEC; 26.7% for exchangeable potassium; 14.8% for moisture content; 6.1% for soil pH, and a decline by 33.8% in bulk density values were detected under the canopy of Croton macrostachyus. This study demonstrated that Croton macrostachyus tree that was retained on crop fields improve soil properties under its canopy very considerably and this makes its integration into the farming system worthy and promising in the area.
Keywords: Tree-crop based farming, Gemechis, Croton macrostachyus, Hararghe, Soil fertility

1. Introduction

Agroforestry has been an age-old practice in the Ethiopian farming system, scattered trees grown 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 (Kindeya, 2004).There are numerous types of traditional agroforestry system in different parts of the country, in southern Ethiopia (Zebene, 2003; Tesfaye, 2005), southwestern Ethiopia (Tesfaye, 2003).

Scattered trees on crop lands are known to bring about changes in micro-climatic, floral, faunal and other components of the eco-system through biorecycling of mineral elements, environmental modifications (including thermal and moisture regime) and changes in floral and faunal composition (Shukla, 2009; Manjur *et al.,* 2014). Trees can improve the nutrient balance of soil by reducing unproductive nutrient losses from erosion and leaching and by increasing nutrient inputs through nitrogen fixation and increased biological activities by providing biomass and suitable microclimate (Clement and Olusegun, 2010).

One of the reasons for practicing agroforestry is for domestication of soil improving trees for enhancing soil productivity through a combination of selected trees and food crops on the same farm field (Kassa *et al*., 2010).Yield improvement and enhancement of soil fertility can be obtained under scattered tree canopies. Sorghum grain yields under *Cordia africana* tree canopy increased by 14% than those grown on farmlands without trees in Burkina Faso (Boffa, 2000). Under *Faidherbia albida* sorghum yields were also increased by 36% in Ethiopia (Poschen, 1986).

Growing tree species such as *Faidherbia albida, Cordia africana and Croton macrostachyus*, on farmlands is very well practiced in the eastern parts of Ethiopia (Poschen, 1986), including the study area, Gemechis district. Therefore, to promote agroforestry trees on crop fields at Gemehis district with different field crops on specific site conditions, empirical evidences are required to demonstrate the effect *Croton macrostachyus* on soil physicochemical properties in order to convince land users and policy makers to promote the integration of trees in farming systems. The information can help in designing sustainable land use that could enhance productivity of crops while maintaining and improving the resource base.

2. Materials and Methods

2.1. Descriptions of the study area

2.1.1. Location

The study was conducted in Gemechis district of the West Hararghe Zone of the Oromia National Regional State. Gemechis district is one of the fourteen districts in West Hararghe zone, which is located at 343 km east of Addis Ababa and about 17 km south of Chiro, capital town of the zone.The district is situated at the coordinate between $8^0$40'0" and $9^0$04'0" N and $40^0$50'0" and $41^0$12'0" E. It shares borders with Chiro district in the west and north, Oda Bultum district in the south and Mesala district in the east (DOA, 2014) (Fig. 1).

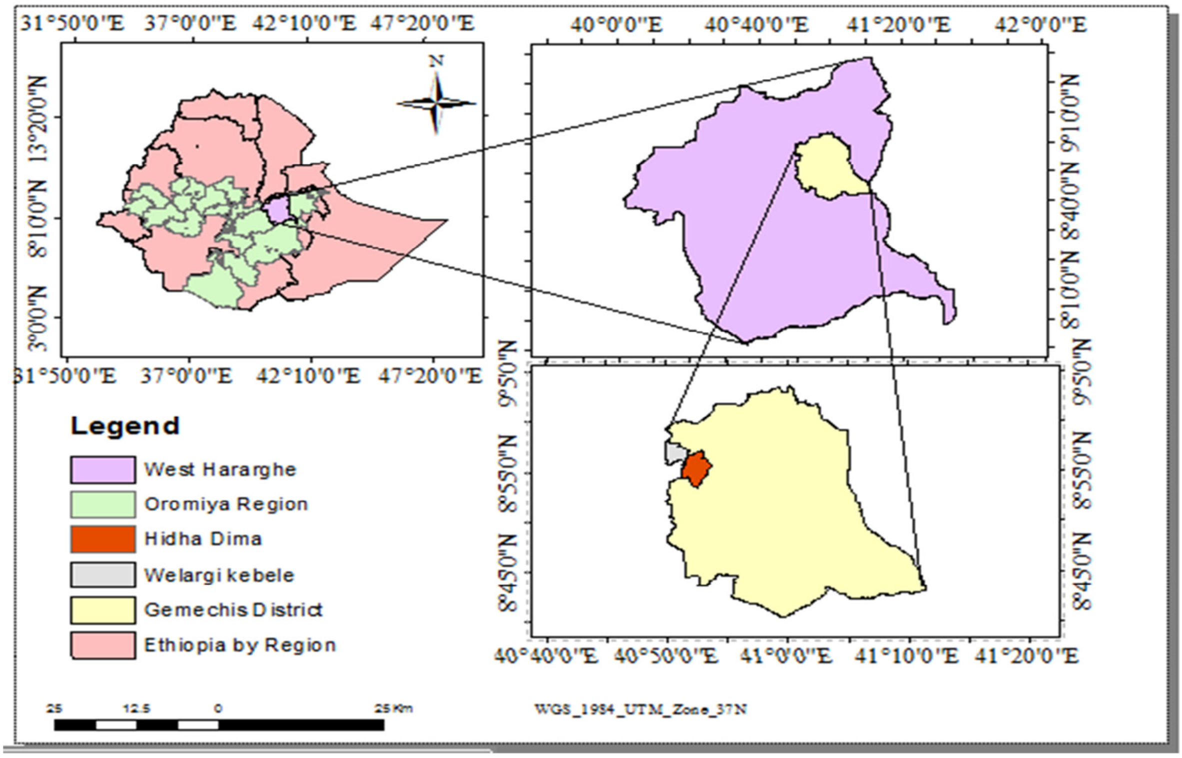

Figure 1. Map of Gemechis district (study area)

2.1.2. Soil and vegetation

The soil of the study area was dominantly loamy soils (moderately fine texture). The vegetation type of the district is characterized by forest, bushes and shrubs. The area of the district covered by forest, bushes and shrubs is 1385ha (DOA, 2014). The most dominant tree species found in the area include; *Croton macrostachyus*, *Cordia africana, Olea europaea, Vernonia amygdalina, Erythrina abyssinica* and many others.

2.1.3. Climate

Agro-ecologically, the district has three climatic zones classified as temperate climatic zone (highland) constituting (15%), warm mild climate (midland) (45%) and lowland climate (40%). The district is found within 1300 to 2400 meters above sea level (m.a.s.l). It receives an average annual rainfall of 850 mm. The district has bi-modal distribution in nature with small rains starting from March/April to May and the main rainy season extending from June to September/October (DOA, 2014). The average temperature is 20 ^{0}c.

2.1.4. Population

The total population of the district is 184,032 of which 93,659 are males and 90, 373 are females (CSA, 2007). It has thirty-five rural and one urban kebeles. The number of agricultural households in the district is estimated to 38,500 with 32,308 male headed and 6,192 female headed (DOA, 2014). The average family size is estimated to be 6 and 4 per household in rural and urban areas respectively. The district is the first most densely populated district in the zone.

2.1.5. Agricultural activities

The agricultural activities in the district are mainly characterized by the presence of subsistence mixed farming, of both agricultural crop production and livestock. Gemechis district is known for its crop production in West Hararghe zone. There are also households engaged in non/off-farm activities. On-farm trees are the main source of fuelwood demand for the whole communities. The major cereal crops produced in the district are Sorgum and Maize and vegetables (onion, potato, redroot, tomato and cabbage), fruits (banana, pineapple, mango, avocado, papaya), and chat (*Catha edulis).* Minor crops are teff, wheat and barley. The land used for cultivation in the district is 32,994.5ha (DOA, 2014). Based on climatic classification, the farming systems vary in such a way that in low lands one finds livestock dominated type of production system and as one goes up to mid and highlands, crop based mixed production system prevails in the district. Generally, the main sources of income for the local communities are selling of crops and livestock.

2.2. Methods

2.2.1. Tree sampling

Croton macrostachyus being the most abundant scattered tree species on crop fields was selected for this study. The selected farm fields with this tree species is characterized by a gentle slope where maize and sorghum are the dominant food crop. The farmers used both hand hoeing and oxen to cultivate the sampled farm fields. The sampled trees had also more or less similar management history. At each site, individual trees of *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 marked trees, eight individual *Croton macrostachyus* trees were randomly selected at each Kebele. For this study tree DBH, height and crown diameter were measured by using caliper, hypsometer and meter tape, respectively. The mean values of parameters (age, DBH, height and crown diameter) were presented in Table 1.

Table 1.Characteristics (mean±sd) of *Croton macrostachyus*(n=16) under which soil samples were taken at Welargi and Hidha Dima kebeles in Gemechis district, West Hararghe.

		Croton macrostachyus			
kebeles	Farmers' field	Age (yrs)	DBH (cm)	Height(m)	Crown diameter.(m)
	1	15	40	13	6
Welargi	2	20	47	14	6
	3	17	36	10	6
	4	19	40	11	5
	5	23	51	14	4
	6	22	48	14	5
	7	10	39	12	5
	8	14	41	15	4
	Mean±sd	**18±4.4**	**43±2.4**	**13±1.6**	**5±0.8**
	1	15	41	17	4
	2	10	40	10	6
Hidha Dima	3	23	49	17	6
	4	10	36	12	5
	5	13	38	14	4
	6	13	37	12	5
	7	20	47	13	4
	8	12	37	13	6
	Mean± sd	**15±4.6**	**41±2.6**	**14±2.3**	**5±0.8**

2.2.2. Soil sampling and analysis

Soil samples were collected from randomly selected eight farmers' farm fields in each kebele. Two sets of soil samples were collected for this study. The first set for bulk density using core sampler, whereas the second set for physicochemical analysis. Soil sampling was conducted to obtain representative soil samples for evaluating the influence of *Croton macrostachyus* tree species on crop fields on some selected soil physical and chemical properties.

Soil samples were taken under *Croton macrostachyus* canopy at two horizontal distances (1 and 3m) from the tree trunk and the canopy coverage of tree was divided into four radial transects as described by Hailu *et al.* (2001). Soil samples taken from the four radial directions under canopy across two horizontal distances were combined to make composite samples. The control sample was taken at a distance of 16m outside of the tree canopy in open area inside the farm field. This sampling was done under *Croton macrostachyus* tree in all fields. The upper 0-20cm soil depth was used for sampling. The composite samples were air-dried, ground and separated from non-soil materials by sieving with 2mm sieve. Finally, from each bulked samples, 0.5kg of sub sample was taken for laboratory analysis of selected physicochemical properties.

Soil analysis was done at Ziway soil laboratory. Soil moisture content at time of sampling was determined gravimetrically as described by Schroth and Sinclair (2003). Soil bulk density was determined by taking an undisturbed block of soil with core sampler as described by Miller and Donahue (1997). The particle size distribution was determined by the hydrometer method (Gee and Bauder, 1986). Organic carbon content was determined by the wet digestion method (Walkley and Black, 1934). Total nitrogen was determined using micro-kjeldahl procedure as described by Sahlemedhin and Taye, (2000). The available phosphorous content of the soil was analyzed using 0.5M sodium bicarbonate extraction solution (pH 8.5) method (Olsen and Sommer, 1982). Ammonium acetate extraction procedure is used to determine cation exchange capacity (CEC) of the soil. Exchangeable potassium was determined from the extract of 1M ammonium acetate at pH 7.0 with flame photometer. Soil pH was measured potentiometrically in the supernatant suspension of a 1:2.5 soil: water ratio using a pH meter (Thomas, 1996).

2.2.3. Data analysis

Analysis of variance (ANOVA) was done to determine differences among the means of the treatments (distances from tree trunk) with respect to soil physicochemical properties through SAS software program (SAS, 2002) following the General Linear Model (GLM) procedure. The means that showed significant differences by F-test would be separated by least significant difference (LSD) and significances was declared at 0.05 levels, which are the most widely used multiple comparison procedures (Zar, 1996).

3. Results and Discussion

3.1. Effect of *Croton macrostachyus* on soil physical properties

Soil texture

As the size of mineral particles in a soil is readily subjected to change by management practices, the soil textural class is important and permanent characteristics of a soil and gives a general picture of the soil physical property (Prasada and Power, 1997). The textural class of the soil in the study area was mainly sandy clay loam at both kebeles (Table 2).The result showed that the soil texture was not significantly (p> 0.05) influenced by horizontal distance from the tree trunk in both kebeles, suggesting that the horizontal influence of *Croton macrostachyus* on soil texture was minimal.

This finding indicates that slightly higher clay content under the tree canopy zone than in the open area in Hidha Dima kebele. However, in Welargi kebele, under the tree canopy zone clay content is similar with that of the open area (Table 2). Slightly higher clay content under the tree canopy than open area in Hidha Dima kebele may be ascribed to increased biological activities, which might have enhanced weathering process under the tree canopy. This present study is consistent with the results reported in other related study that indicated the clay fraction was slightly higher under the *Faidherbia albida* canopy and *Croton macrostachyus* than open area (Manjur *et al*., 2014).

Table 2.Soil textural class under *Croton macrostachyus* within different distance from its trunk (n=48) at Welargi and Hidha Dima kebeles in Gemechis district, West Hararghe.

Kebeles	Distance (m)	Soil texture		
		Sand%	Silt%	Clay%
		Mean ± Sd	Mean ± Sd	Mean ± Sd
Welargi	1	30.0a ± 3.2	25.0a ± 2.8	24.0a ± 2.1
	3	29.5a ± 3.8	24.0a±2.3	24.0a ± 1.9
	Open area	29.0a ± 4.3	23.0a ± 3.6	24.0a±1.9
Hidha Dima	1	47.0a ± 3.4	24.0a ± 2.5	26.0a±2.5
	3	46.0a±3.8	23.0a ± 2.6	25.0a ± 2.3
	Open area	46.0a ± 3.1	22.0a ± 2.6	25.0a±1.9

Within a column, means with the same letters are not significantly different at α = 0.05.

This study also revealed that silt content was slightly higher in under canopy than open area in both kebeles. The sand content was higher in Hidha Dima kebele than that of Welargi; contrary to this, it was slightly lower in open area than under canopy in both kebeles (Table 2).

A combined analysis of variance across kebeles showed a highly significant difference ($p \leq 0.001$) in sand content between the two kebeles. However, there was no significance (p>0.05) difference in sand content concerning distances and interaction effects; similarly, no significant difference (p>0.05) were detected among the kebeles, distances and interaction effects with regard to the silt and clay fraction.

Generally, the findings of this study was consistent with those of Kamara and Haque (1992), Tadesse *et al.* (2001) and Abebe *et al*. (2001) who reported no significant difference in soil texture under and outside the canopies of *Faidherbia albida, Milletia ferrugenia* and *Cordia africana* trees, respectively in Ethiopia.

Bulk Density

The soil bulk density under *Croton macrostachyus* at both Welargi and Hidha Dima kebeles increased from distance of under canopy to open area. There was no significant difference (P>0.05) in bulk density between the distance of under canopy, but there was significant difference (p<0.05) between the distance of under canopy to the open area in both kebeles (Table 3).

This decline in bulk density under tree canopy might be due to high accumulation of organic matter than the open area. It is well known that incorporation of organic matter in soil improves physical (aggregate stability, bulk density, water retention) and biological properties (nutrients availability, cation exchange capacity, reduction of toxic elements) of soils. Organic matter increases the porosity of the soil, resulting in lower bulk density, and similar was the case for soils under the tree canopy. Similar to the current study, lower bulk densities were observed under isolated *C.macrostachyus* (Ashagrie *et al*., 1999) trees in Ethiopia. Manjur *et al*. (2014) also reported lower bulk densities under scattered *Faidherbia albida* and *Croton macrostachyus* in the Umbulo Wacho watershed, southern Ethiopia.

Table 3. Bulk density (g/cm^3) and moisture content (%) under *Croton macrostachyus* within different distance from its trunk (n=48) at Welargi and Hidha Dima kebeles in Gemechis district, West Hararghe.

kebeles	Distance(m)	Bulk density (g/cm^3)	Moisture content (%)
		Mean ± Sd	Mean ± Sd
Welargi	1	0.9a± 0.12	22.8a± 1.2
	3	1a± 0.12	21.5a± 1.2
	Open area	2.2 b± 0.14	16.1b ± 1.2
Hidha Dima	1	0.86a ± 0.03	21.1a ± 0.9
	3	0.92a ± 0.03	20a ± 0.9
	Open area	1.58b ± 0.03	15.8b ± 0.9

Within a column, means with the same letters are not significantly different at α = 0.05.

Moisture content

The soil moisture content at the time of sampling was very highly significantly higher ($P \leq 0.001$) under canopy zone than open area, but there was no significance difference ($p>0.05$) between distance of under canopy at both kebeles (Table 3).

This variation in soil moisture content under the tree canopy versus outside the canopy might be attributed to the improved soil structure as a result of better porosity and more organic matter contents reflected in higher moisture retention of the soil under the tree canopy. This organic matter makes the soil to retain water by increasing its surface area and improving the structure of the soil to have better porosity. Tree canopy also resulted in reduced loss of soil moisture by evaporation, which contributed to higher soil moisture content under the tree canopy. Similar findings were reported by Pandey *et al*. (2000) under *Acacia nilotica* tree. According to Boffa *et al*. (2000) soil moisture content decreased significantly with increasing distance from karite (*Vitellaria paradoxa*) tree to open areas.

3.2. Effect of *Croton macrostachyus* on soil chemical properties

Soil pH

The results indicated that soils at study site are very slightly acidic at under canopy and open area at both kebeles (Table 4). According to Havlin *et al.* (1999), this value is within the range of optimum soil pH for crop production. Soil pH showed a significant ($P \leq 0.01$) decrease with horizontal distance from the tree trunk. Yet the difference was detected only between under canopy versus open area, not within the canopy zone (Table 4).

The results showed that the under canopy mean soil pH was 6.65, which was reduced to 6.1 at open area in Welargi kebele and similar trend was noticed in Hidha Dima kebele (Table 4). In line with this study, Kamara and Haque (1992) reported a significant variation in soil pH horizontally under *Faidherbia albida* tree canopies. Abebe *et al.* (2001) also reported similar results where soil pH decreased with the distance from the tree trunk significantly under *Cordia africana* tree in Bako area. In contrast to this study, Hailu *et al.* (2001) reported that even though soil pH decreased with the distance from the tree trunk, but no significant difference was observed horizontally and vertically under *Millettia ferruginea*. Jiregna *et al.* (2005) also reported that there was no significant difference in soil pH under the canopies of *Cordia africana* and *Croton macrostachyus* compared to the open area.

Table 4. Effect of *Croton macrostachyus* and distance from it on soil pH and cation exchange capacity (cmol (+)kg^{-1}) (n=48) at Welargi and Hidha Dima in Gemechis district, West Hararghe.

kebeles	Distance (m)	pH	CEC
		Mean±Sd	Mean±Sd
Welargi	1	6.7a ±0.2	46.2a ±0.6
	3	6.6a ±0.1	45a ± 0.6
	Open area	6.1b ±0.1	41b ± 0.5
Hidha Dima	1	6.6a ± 0.1	39.9a ±0.63
	3	6.5a ± 0.1	38.8a ± 0.63
	Open area	5.6b ±0.1	33b ± 0.63

Within a column, means with the same letters are not significantly different at α = 0.05.

Cation exchange capacity (CEC)

The CEC was very highly significantly ($P \leq 0.001$) affected by distances under canopy to open area from tree trunk both at Welargi and Hidha Dima kebeles, but not significantly ($P>0.05$) different within distances under canopy at both kebeles (Table 4). The under canopy mean value of CEC was observed to be higher as compared to open area with significant decrease with distance from the tree trunk increased (Table 4).This could be mainly due to high organic matter accumulation under the tree canopy than the open fields implying the release of more cations to the soil through mineralization resulting in increased negative charges in the soil.

The cation exchange capacity of a soil is strongly related with its organic matter content (Brady and

Weil, 2002). As the amount of organic matter in the soil increases the total negative charge in the soil increases which in turn increase the CEC of the soil. Horizontal variations in CEC under tree canopies have also been reported by Abebe *et al.* (2001), Tadesse *et al.* (2001) and Yeshanew *et al.* (1998) under *Cordia africana, Millettia ferruginea,* and *Croton macrostachyus,* respectively. They reported that CEC showed significant increments under the tree canopy compared to outside the canopy area.

Organic Carbon

Organic matter (OM) has an important influence on soil physical and chemical characteristics, soil fertility status, plant nutrition and biological activity in the soil (Brady and Weil, 2002). Soil organic carbon (SOC) was determined to estimate the amount of organic matter in the soil. In this study, organic carbon content was significantly higher ($P \leq 0.05$) under canopy of *Croton macrostachyus* zone than open area at both kebeles (Table 5). This variation of organic carbon was quite logical as accumulation of the litter falls and dead roots from the tree may result in higher contents of organic carbon under the tree canopy. The animal excretion including birds might also contribute to enhance organic carbon concentration.

In line with these finding, Nyberg and Högberg (1995), Tadesse *et al.* (2001), Abebe *et al.* (2001), Zebene and Goran Agren (2007) have reported an increase in soil organic carbon under trees compared to away from trees. Abebe (2006) also reported that there was significant decrease in SOC with increasing distance away from the tree trunk in Harerge highlands, Ethiopia.

Table 5. Effect of *Croton macrostachyus* and distance from it on organic carbon (OC %) and total nitrogen (TN %) (n=48) at Welargi and Hidha Dima kebeles in Gemechis district, West Hararghe.

kebeles	Distance (m)	OC (%)	TN (%)
		Mean ± Sd	Mean ± Sd
Welargi	1	5.2a ± 0.6	0.13a ±0.02
	3	4.9a ±0.6	0.11a ± 0.02
	Open area	2.3b ± 0.6	0.04b ±0.02
Hidha Dima	1	6.3a ± 0.4	0.17a ±0.01
	3	5.8a± 0.4	0.16a ± 0.02
	Open area	3.9b ± 0.4	0.08b ±0.02

Within a column, means with the same letters are not significantly different at α = 0.05.

Total Nitrogen

The total nitrogen content for both canopy zone and open area rated medium according to Landon, (1991). Nitrogen content was significantly higher ($P \leq 0.05$) under distances of canopy than the open area at both kebeles, but in contrary to this at distance under canopy it was not significantly ($P \geq 0.05$) different at both kebeles (Table 5). This implies that total nitrogen content decreased as we gofrom tree canopy to open area at both kebeles. These horizontal variations in total nitrogen might be mainly due to high accumulation of organic matter under the tree canopy.

Significant variation in total nitrogen between soils under the tree canopies and the open field was also reported by different authors. Yeshanew *et al.* (1998) and Abebe *et al.* (2001) reported that total nitrogen contents were significantly higher under the canopy relative to the control under *Croton macrostachyus* and *Cordia africana,* respectively. Similarly, Tadesse *et al*. (2001) noted total nitrogen decrease with distance from *Millettia ferruginea* tree.

Available Phosphorus (AP)

The result of this study revealed that available phosphorus of under canopy was significantly($P \leq 0.05$) higher than open areaat both kebeles (Table 6).The available phosphorus in the soil under tree canopy is rated low where as in open area rated very low according to Halvin *et al.* (1991).

This horizontal variation could be attributed to high organic matter accumulation under the tree canopy than the control. Decomposition of organic matter results in release of phosphorus containing materials, which increase the availability of phosphorus (Brady and Weil, 2002).

Horizontal and vertical variations in available phosphorus under the tree canopies were also reported by different researchers in Ethiopia and elsewhere. For example,Yeshanew *et al.* (1998),Abebe *et al.* (2001) and Tadesse *et al.* (2001) reported that there were significant horizontal and vertical variations in available phosphorus under *Cordia africana, Millettia ferruginea,* and *Croton macrostachyus*, respectively. Hailu *et al.* (2002) also reported higher Available Phosphorus under the canopy of *Milletia ferruginea* tree than the open land. Moreover, Abebe Nigusie (2006) found higher level of Available Phosphorus under the canopy of the *Cordia africana*, *Faidherbia albida* and *Croton macrostachyus* than the outside of the canopy in the Harergie Highlands. Similarly, Manjur *et al.* (2014) also reported that Available Phosphorus was higher under the canopy of *Faidherbia albida* and *Croton macrostachyus* tree species than the open cultivated land in the Umbulo Wacho watershed, Southern Ethiopia.

Table 6. Effect of *Croton macrostachyus* and distance from it on available phosphorus (AP) (mg kg^{-1}) and exchangeable potassium (EK) (cmol (+)/ kg soil) (n=48) at Welargi and Hidha Dima kebeles in Gemechis district, West Hararghe.

kebeles	Distance (m)	AP	EK
		Mean±Sd	Mean±Sd
Welargi	1	9.9a±0.4	2.5a±0.2
	3	9.5a±0.4	2.1a±0.2
	Open area	8.2b±0.4	1.3b±0.2
Hidha Dima	1	8.9a±0.6	1.9a±0.1
	3	7.7a± 0.6	1.8a±0.1
	Open area	5.9b±0.6	1.1b±0.1

Within a column, means with the same letters are not significantly different at α = 0.05.

Exchangeable Potassium (EK)

There was very highly significant ($p \leq 0.001$) difference between distances of under canopy to open area at Welargi kebele. Similarly, significant variation in exchangeable potassium as affected by distance under canopy to open area ($P \leq 0.01$) was observed at Hidha Dima kebele (Table 6). There was very highly significant difference between the distances across kebeles ($P \leq 0.001$) with regard to exchangeable potassium, but the combined analysis of variance showed no significant difference ($P \geq 0.05$) between the kebeles.

This result indicated that the concentrations of exchangeable potassium exhibited a decreasing trend with increasing distance from tree trunk. This may be due to more organic matter deposition (leaf litter, root) under the trees and increased biological activities that enhance organic matter decomposition and subsequent mineralization. The fertility effect of trees is based on the mineralization of nutrients from leaf and root litter and build-up of soil organic matter, as reported by different authors (Isichei & Muoghalu, 1992; Belsky *et al.*, 1993; Parthiban *et al.*, 1994). This is because organic matter serves both as a source of nutrients through mineralization and as a sink by increasing the nutrient retention capacity of the soil. Apart from this, deposition of nutrients by stem flow and through fall to the under canopy soil may also be a considerable input.

4. Conclusion and Recommendations

The result of soil analysis revealed that with the exception of soil texture and bulk density, all soil properties increased significantly under the *Croton macrostachyus tree* canopy than in the open area at both kebeles showing decreasing trend with increasing distance from the tree trunk. This is expressed in terms of increased concentrations of organic carbon, total nitrogen, available phosphorus, cation exchange capacity, exchangeable potassium, moisture content, and soil pH under the tree canopy as compared to the nearby open area.

This study demonstrates that *Croton macrostachyus* tree that was retained on crop fields of study area improved soil properties under its canopy very considerably. The study revealed that the fertility of the soils gradually decreased with the distance away from the tree trunk due to the inputs from *Croton macrostachyus* tree species. Provided that the litter cover is maintained, the organic matter produced will continue to accumulate under the canopy. As a result, many of the essential elements could be derived from this organic matter. 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, the solubilization effect on difficultly available plant nutrients, 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.

The improved soil physical conditions under the tree canopy were primarily due to increased SOM compared with open areas. The tree which are retained as on crop fields of the farmers have contributed positively to the increment of SOM; TN and other soil nutrients, which play a role in sustaining the crop production system in the area.

Based on these findings the following points are recommended:

- Study on litter quality (litter decomposition) and nutrient dynamics in the canopy tissues of this tree species should be conducted in order to determine when branches have to be pruned and pollarded for off-site uses or *in situ* soil conservation activities.
- Studies regarding the microfloral population associated with scattered tree of *Croton macrostachyus,* such as Rhizobia species and mycorrhizal fungal associations.
- Last but not the least, the root architecture of the tree needs better investigation.

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