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THE EFFECT OF *EUCALYPTUS GLOBULUS* WOODLOTS SPACING ON PHYSICO-CHEMICAL PROPERTIES OF SOIL IN SMALLHOLDER FARMERS, SIDAMA REGION, SOUTH CENTRAL ETHIOPIA.

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Abstract

The study was conducted in Gorche woreda, Sidama region, Ethiopia during November to December 2019. The study was carried out to evaluate the effect of different spacings on soil physical and chemical properties in 0-25cm top soil depths of smallholding farmers E. globulus woodlot plantations. 19 soil samples Results from soil laboratory analysis showed that soil pH were ranged between very acidic to slightly acidic nature and pH were decreasing with increasing density, but statistically insignificant with spacing. OC, OM, %MC, P, TN and CEC were decreasing with increasing density and ANOVA value revealed that these soil parameters are statistically significant among spacing regimes. Sand fraction of the soil was increasing with increasing density. However, bulk density, clay fraction and silt fraction were on the reverse trend/ decreased as spacing regime was decreasing. The reason behind the higher amount of sand fraction and lower clay in the soil with increasing density might be due to the absence/ lowering of vegetation cover on the ground of the woodlot in plantation. In conclusion, spacing regimes had seriously affected the soil physical and chemical properties. Finally, it could be better to see the effect of spacing on the soil properties that were not part of this study like in different soil depth and other soil physico-chemical properties.

Key words: Assortment, *E. globulus*, Ethiopia, Soil nutrient, Spacing regime, Woodlots

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“The effect of Spacing Eucalyptus globules woodlots on physico-chemical properties of soil in smallholder farmers, south central Ethiopia.”

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1. Introduction

1.1. Background:

The allegations raised by of the environmentalists, politicians and policy makers in Ethiopia discourage farmers from planting *Eucalyptus*. While rural and urban households supported the planting of *Eucalyptus*, district level politicians oppose its planting, and researchers had reservations about it.

According to the report by (1) in Ethiopia soils under *Eucalyptus globulus* plantations showed lower nutrient content compared to those in cedar and cypress forests. Other study in Ethiopia on *Eucalypt*us species also indicated for its high potential to absorb water from nearby stream than four other natural forest species (2). Furthermore, she added that *Eucalyptus* species have a potential to compete with agricultural crops and other natural forest species for soil nutrients, water and light.

The availability of more trees in a unit area in providing additional nutrient through litter fall and overall nutrient balancing were reported by (3). Further report from (4), also indicated that in *Eucalyptus* tree plantation there were increase in clay and silt content and decrease in sand content and an appreciable increase in the cation exchange capacity, organic carbon content, total and available nutrients.

Fast growing trees like *Eucalyptus* may lead to soil nutrient depletion and deterioration especially where they are poorly and improperly managed like spacing problem caused lack of ground vegetation cover was reported by (5). And as long in many studies trees spaced under high competition in addition to this soil nutrient depletion, mean yield from the tree was recorded lower. And also due to shortage of land smallholding farmers grow woodlots in a very high density that may intern affect the nutrient turnover and soil nutrient balance. And woodlots planted in the district are not objectively matched with the type of soil to reach appropriate size and those plantation are most likely planted in infertile and fragile lands that are inconvenient to produce annual crops (due to either sloppiness or fertility problems). Furthermore, limited information is available for farmers as well as limited biophysical research to fill this gap and improve site productivity. Therefore, additional documentation on the specific effects of *Eucalyptus* species plantations spacing or density in relation to prescribed age and soil physical (soil moisture, soil texture and soil bulk density) and chemical properties (pH; organic carbon, available phosphorus, total nitrogen and cation exchange capacity were required. So**, t**he purpose of this study was to test effect of 4 different initial spacings of 5 years age *Eucalyptus globulu*s woodlots on soil physical and chemical properties/nutrient status.

1.3. Objectives

1.3.1. General objective

-The general objectives of the study were to assess the effect of planting spacing on physical and chemical properties of soil in *E. globulus* woodlots plantation of smallholder farmers in Gorche district, south central Ethiopia

1.3.2. Specific objectives

The specific objectives of this study were

- To investigate the effect of spacing *Eucalyptus globulus* woodlot on soil physical properties

-To investigate the effect of spacing *Eucalyptus globulus* woodlot on chemical properties.

1.4. Research Hypotheses

Ho; ‘No statistically significant differences exist between differently spaced *Eucalyptus globulus* woodlot plantations in their effects on soil physical properties’.

H1; ‘No statistically significant differences exist between *Eucalyptus globulus* woodlots plantations in their effect on soil physical properties’.

Ho; ‘No statistically significant differences exist between differently spaced *Eucalyptus globulus* woodlot plantations in their effects on soil chemical properties’.

> H1; ‘No statistically significant differences exist between *Eucalyptus globulus* woodlots plantations in their effect on soil chemical properties’.

3. Methodology

3.2. Description of the study area

3.2.1. Location of the study area

The study was carried out in Gorche 01 and Gorche 02 highland kebeles of Gorche district in Sidama region of south central Ethiopia having nearly similar geographic location. The district is 319km from Addis Ababa (capital city of Ethiopia) and situated between 6.41º–6.61’N latitude and 38.44º– 38.98’ E longitude (6).

The altitude of the area ranges between 1800 - 3200m.a.s.l. with 10.79% flat, 79% undulating, 10% mountain and 0.25% hilly landscape. The area is woyna dega (25%) and dega (75%) agro-ecological zone receiving bi- modal rainfall with mean annual rainfall of 1200mm (ranges between minimum 900 mm and maximum 1500 mm rainfall). The mean annual temperature of the district were 19.5 ^{0}c and ranges between minimum and maximum temperature of 12 – 27 ^{0}c respectively (Hawassa metrological station, 2019 G.C). The area is predominantly Nitosols, Andisols and Vertisol soil type mostly good to fairly good fertility with acidic and slightly acidic property.

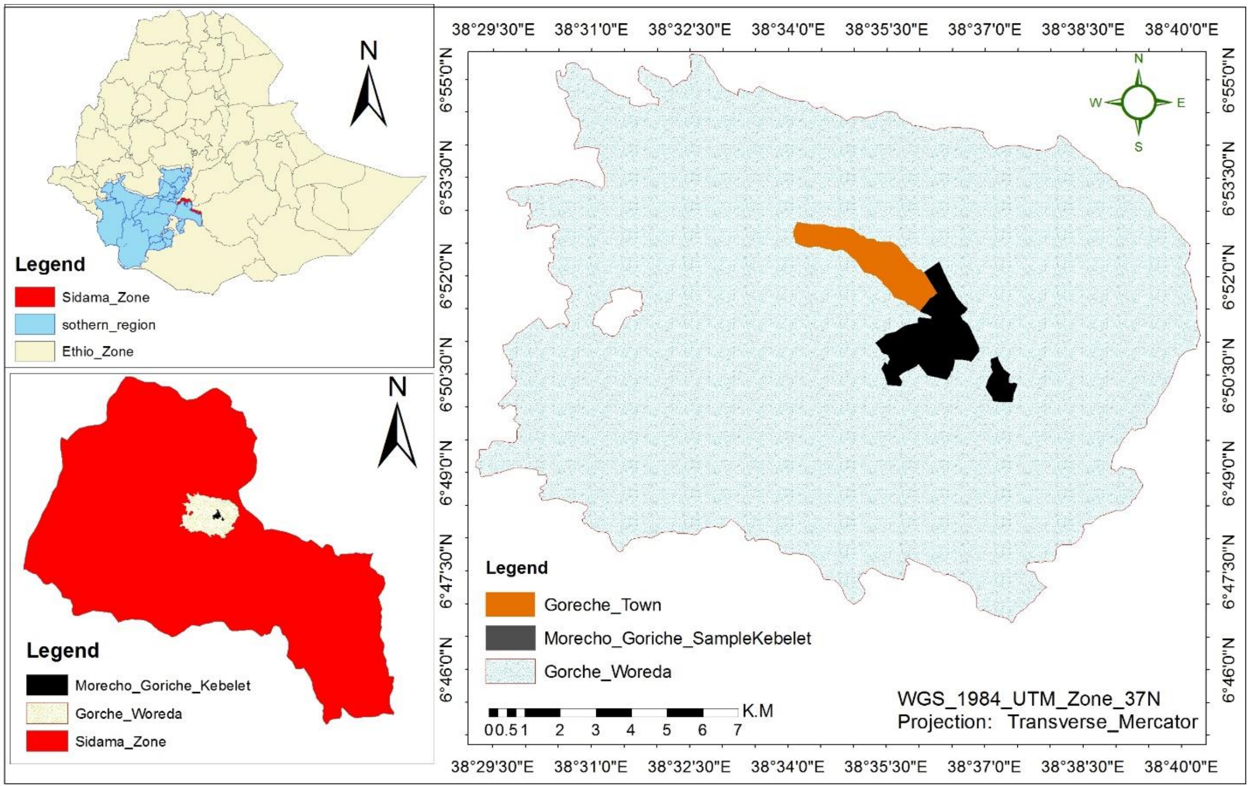


Figure 1. Map of the study area.

3.3.2. Experimental Design and Data Collection

3.3.2.1 Field experimental design for woodlots. For the purpose of the study four spacing regimes (1m x 0.75m (13334 trees/ha), 0.75m x 0.5m (26667 trees/ ha), 0.5m x 0.5m (40,000 trees/ha) and 0.5m x 0.25m (80,000 trees/ha)) E. globulus woodlot plantations established on farmer's field from June to August, 2014 (before five years) were selected. As the basic concern of the study were evaluating effect of spacing on soil properties, most spacing regimes with equal age were assessed to select representative woodlot samples with RCBD design systematically. Slope, Age, disturbance (full stocked), management system (similar woodlot management) were used as criterion for sample selection. 19 farmers' woodlot from each selected spacing regimes (as a replication) with a total of *76 sample woodlots were taken randomly whose age were between 59 to 61 months old.*

3.3.2.2. Soil sampling and data collection. Soil samplings were taken at each sample woodlots by digging the soil at depths of 0-25cm using a soil auger for most soil parameters and core sampler (by cutting the top soil at 1-2 cm depth to determine bulk density and moisture content). Three composite samples were taken from each of the farmer's woodlot with diagonal of woodlot plot (mixed to 1 sample), 19 soil samples from each spacing regimes and a total of 76 soil samples were taken for the study.

The collected soil sample was placed in plastic bags and transported to Hawassa Agricultural Research Center Soil Laboratory for analysis.

Soil samples were dried in accordance to the requirement of analysis procedure (air dried at room temperature for CEC, P, TN, SOC, PH, SOM and soil texture determination as well as oven dried for moisture content and bulk density). After all the gravel, leaf and dead organic residues have been removed, selected representative soil were grounded with wooden mortar and passed through 2mm nylon sieve and finally packed in the poly-thane bags and labeled for conducting physico-chemical analysis.

3.4. Data analysis

3.4.2. Soil preparation and Laboratory Analyses Procedure

Soil samples randomly collected from each plot were analyzed for target values at soil laboratory passing through the required analysis. All procedure was employed accordingly from labeling, drying and grinding to the final analysis by treating with different chemicals at soil laboratory. The soil properties (both physical and chemical properties) analyzed were; soil N, P, pH, CEC, organic carbon, organic matter, bulk density, moisture content and soil texture.

***3.4.2.1. Soil Moisture*.** Soil laboratory analysis for moisture content was used as the procedure determined by the gravimetric method of (7). A metal Can (core sampler) with a lid was weighed accurately with a Scout TM Pro 2000 g Balance (W1). About 100 g of soil was placed in the Can and weigh accurately along with the lid (W2). The Can covered with the lid and the soil was oven-dried for 72 hours at 105 ^{O}c. The Can was then removed from the oven covered tightly with the lid and placed in a desiccator to cool for about 30 minutes. After cooling, the Can was weighed accurately with the oven-dry soil in it and the weight recorded (W3). Percent moisture content on oven-dry basis was then calculated using the formula below:

% MC = Wt. of moist soil – Wt. of oven dried soil/ Wt. of oven dried soil * 100…. Equation 1

***3.4.2.2. Soil Dry Bulk Density*.** The core method which were prescribed for undisturbed soils were used to determine bulk density of soil collected from the woodlot plantation by cutting the top surface soil from 1 to 2 cm and letting a core sampler driven into the soil. The soil from around the core sampler was evacuated and the soil beneath was cut off. Both ends of the core sampler were trimmed and flushed with a straight edge knife. The core sample was oven dried to a constant weight using the WTC Binder Oven at 105 ^{O}C for 72 hours. The soil bulk density was calculated using the formula below:

BD (gcm^{-3}) = Wt. of soil core (oven dry basis) (g) /Volume of core soil (cm^{-3})...equation 2

3.4.2.3. Soil Texture (Particle Size Distribution). The Bouyoucos hydrometer method determined by (8) were used to analyze the soil texture under laboratory. Air-dried soil sample weighing 50 g was put in a plastic shaking bottle and 50 ml Calgon (dispersion agent) added. A blank sample (without soil sample) was also prepared (represented reading for blank sample, Rb). The mixture was placed on a mechanical shaker and shaken for 3 hours. The suspension was transferred into the sedimentation measuring cylinder, and top up to the 1000 ml mark. The mixture was stirred well using a metal plunger to bring the particles into suspension. By the use of a soil hydrometer, a reading was taken after 40 seconds (represented the first reading, R1, which sand fraction). After two hours, the hydrometer was used to take the second reading (R2). The second reading gave the clay content. The calculations were done as follow (equations 3, 4, and 5):

The first reading gives the sand fraction

% sand = 100-(d1+1-2) x 100/2........equation 3

(d1, 1& 2 = reading at 40 second, temperature (T^{o}) at 40 second, T^{o} at 2 hr., 2 = constant & 100/50 = conversion to Wt. to 100 basis)

The 2nd reading gives clay fraction

(d2 - 0.5 - 2) x 100/2..................equation 4

(d2 = hydrometer read at 2hr, 0.5 = T^{o} at 2 hr, & 2 = constant at every reading& 100/50 = conversion to Wt. to 100 basis)

Silt = 100 **-** (sand + clay)..........equation 5

After getting the percentage sand, silt and clay, the soil textural triangle were used to classify soil.

3.4.2.4. Soil pH. The 1:2.5 (w/v) soils: water ratio or water dispersion method was used read the soils pH using ST 10 OHAUS pH meter. By weighing 20 g of 2 mm air-dried soil into a 100 ml glass beaker and adding 50 ml distilled water. The soil was mixed with the distilled water and stirred intermittently using a stirrer for 30 minutes before pH was determined (9).

***3.4.2.5. Soil Total Organic Carbon (TOC) and total organic matter*.** Soil total organic carbon was determined by the colorimetric method described by (10). Air-dry soil sample weighing 1 g was scooped into a 50 ml Erlenmeyer flask.

The organic carbon in the soil sample was oxidized by 0.5 M K2Cr2O7•2H2O and 5MH2SO4. 10 ml of dichromate-sulphuric acid digestion solution was pipetted. A reagent blank without soil was also prepared in the same way. This was heated at 150 °C for 30 minutes to ensure complete oxidation. Barium chloride was added to cool the digest (indicator). After mixing thoroughly, the digests were allowed to stand overnight. 10 ml of the clear supernatant was transferred into a colorimeter tube. The soil organic carbon concentration was read on the Specord 200 plus Ultra Violet Spectrophotometer at 600 nm. And finally FeSO4 for titration. The 58 percent organic matter (OM) in the soil is estimated to be carbon and then estimated using the equation 6.

% OM = (% total OC x 1.724)**.......**Equation 6

Where OC = organic carbon concentration

OM = Organic matter

1.724 = (is conversion factor that 58% of OM)

3.4.2.6. Soil Total Nitrogen (TN). Total Nitrogen was obtained from the amount of soil total organic matter which is estimated to be 5% of the total organic matter (OM)

%TN = % OM/ 20 where TN = total Nitrogen

OM =organic matter

3.4.2.7. Soil Available Phosphorus. Soil available phosphorus was determined by (Bray II method; (11) mostly for acidic soil) air–dried soil sample weighing 2.0 g was put into a 50 ml shaking bottle and 20 ml of the extracting solution, bray II solution (100ml of HCl of 1 M with 30 ml of NH_4F 1M) added. The mixture was shaken for 1 minute and filtered through Whatman No. 40 filter paper. A 2 ml of the extract was transferred to a 25 ml flask and diluted to the mark. 8ml of Boric acid (0.5%) was added to each sample and waited for the blue color formation. After 30 minutes (within 12 hrs.), the concentration of P in the filtrate was determined at 882 nm wavelength using Specord 200 plus Ultra Violet.

3.4.2.8. Soil Cation Exchange Capacity (CEC). The soil CEC was determined by ammonium acetate method at pH 7.0. Ammonium acetate solution of 1M dissolved in 1L volumetric flask. 15 ml of 0.2 N H_2SO_4 to 250ml flask and distillation with sulfuric acid solution. 75 ml of NaCl percolate over 15ml of 0.2 N H_2SO_4 solutions in 250ml flask. Finally 0.1M of NaOH was also used for titration of purple to yellow color formation.

3.4.4. Soil data Analyses and Processing

Data obtained from the laboratory analyses were subjected to statistical analysis to determine the mean values, standard deviation and the standard error of the means using STATA version 16.0 and SPSS 20.0 Statistical Software and Microsoft Excel 2010. One-way ANOVA tests were used to compare the differences between spacing regimes of all the tested parameters of soil in *E. globulus* plantation. In this statistical analysis, the confidence level was set at 95 % such that if the P value is < 0.05, the test is significant and if P value is > 0.05, then there is no significant different between the variables compared (null hypothesis accepted). Correlation analyses were also used to compare strengths of relationships among some of the measured variables using SPSS 20.0 Statistical Software or STATA. When significant differences were observed, comparisons of means were performed using scheffe at 5% probability level. Pearson's correlation coefficient was computed to examine the relationship between different soil properties.

3.5. Data presentation

Finally, the soil analyzed values and observations were analyzed and organized by using descriptive statistical method in summaries.

The quantitative data obtained from measurement was analyzed and presented using tables, and figures. Tables and bar charts were used to display and explain the volume related (spacing, DBH, height and volume of stand) and soil physico-chemical properties of *Eucalyptus globulus* woodlot plantation compared in each spacing regimes.

4. Result and Discussion

After a through process of field collected data in the soil laboratory of Hawassa Agricultural Research Center in Southern Agricultural Research Institute, results of the different soil parameters tested were presented as indicated in the table 1.

4.3. E. globulus woodlot spacing and soil properties

The soil physical and chemical properties under the woodlot plantation was analyzed for bivariate correlations *(table 2.)* and found most of them positively and directly correlated for each other except with those bulk density and sand fraction of the soil texture, which were remained inversely correlated with all others. The individual correlation these nutrients had already discussed under each sub-title below.

4.3.1. Effect E. globulus plantations spacing on soil physical properties.

4.3.1.1. Effect on soil texture and bulk density. The soil texture analysis results (table 1.) showed that spacing regimes in Eucalyptus plantations had significantly effect on soils, which increased the sandy and lowered the clay contents. Narrow spacing in E. globulus woodlot plantation showed increased in sand content of the soil along with the decreasing spacing regimes. The one way ANOVA result showed that there was a significant different between spacing regime of 0.25m x 0.5m and 1m x 0.75m in sand and clay content the soil. However, there were no significant difference in sand and clay fraction of the soil between 0.5m x 0.5m and 0.5m x 0.25m spacing regimes. The silt fraction of the soil in the plantation was left lower interms of volume and statistically insignificant. Interms of the percentage (%) of soil fraction, the sand and clay content has shown a controversy result: within decreased spacing regimes, decreasing in clay fraction and increasing in sand content). The textural particle size indicated that spacing regimes had affected biological growth of the woodlot via nutrient intake. The larger values of clay soil particles with wider spacing were important to nourish the plant by holding water and nutrients that favored the diameter and volume of the E. globulus; narrower spacing/ resulted in lower growth of the plant due to insufficient nutrient supply. The sand fraction was inversely correlated with most of other soil nutrient except bulk density of the soil. The result were similar to the report of (12), who reported for the reason behind that the higher sand and lower clay fractions may be due to the absence of vegetation cover and lack of organic matter. Or otherwise wash up of important soil nutrients by soil erosion due to unavailability of co-occurring undergrowth by allelopathic effect of Eucalyptus (12). Similar finding were reported in cropland soils by (13) with higher sand and lower clay content due to continuous cultivation and removal of clay particles.

The soil bulk density was significantly affected by spacing regime (table 6). The one way ANOVA result showed that bulk density significantly differ between spacing regime of 1m x 0.75m and 0.5m x 0.5m as well as between, 0.75m x 0.5m and 0.5m x 0.25m spacing. However, there were no statistically significant difference between subsequent spacing regimes (between 1m x 0.75m and 0.75m x 0.5mas well as between, 0.5m x 0.5m and 0.5m x 0.25m). The mean values showed increased bulk density along with decreasing spacing regime (table 6.).On the other hand the soil bulk density were correlated inversely with pH, OC, OM, TN, P, MC and clay; but direct with sand fraction. This increased bulk density as in closer spacing might be associated with increased nutrient competition, reduced infiltration and soil compaction. Soil bulk density is used as a measure of soil compaction and health (14). The finding is similar to the report of (15) who reported; higher soil bulk density means less amount of water held in the soil at field capacity and at lower soil bulk densities; soils are less compacted and are able to retain water.

The gravimetric soil moisture content recorded was 27.17±5.4, 24.4±5.5, 22.9±4.4 and 20.54±6.26 (in %) in 1m x 0.75m, 0.75m x 0.5m, 0.5m x 0.5m and 0.5m x 0.25m spacings regimes respectively (Table 4). The soil moisture content in the *E. globulus* woodlots plantation of smallholder farmers was significantly affected by the spacing regimes. And also different between 1m x 0.75m (27.17%) and 0.5m x 0.25m (20.54%) spacing regimes, but there were no statistically significant different between 0.75m x 0.5m and 0.5m x 0.5m spacing regimes. The moisture content in wider spacing resulted for better yield of *E. globulus* woodlot through continuous supply of moisture via root system and the lower percentage of moisture in narrower spacing produced smaller diameter and yield that might be due to shortage of moisture though intense competition between densely populated woodlot plantations, but lower moisture in general is in agreement with (16),who reported the higher rate of evapotranspiration in light canopy of the *Eucalyptus* trees can lead to the reduction in soil moisture content and poor infiltration. This observation also agrees with Cao et al., (2010) who found low soil moisture contents, ranging from 20.2 to 30.5% in the top soil (0–10 cm) under *Eucalyptus* species plantations aged from 3 to 13 years in China.

4.3.2. Effect of spacing in *E. globulus* woodlot on soil chemical properties.

4.3.2.1. The Soil pH

The pH of soils was recorded between 3.48 and 5.65 that showed statistically insignificant difference among spacing regimes. The soil pH in all spacing regime showed numerically different ranged (from moderate acidic in some sample woodlot farms to a very acidic in almost all sampled soils of woodlot plantation). The Pearson correlation analysis of pH showed a direct relationship (r = 0.81, 0.66, 0.53, 0.57, 0.73, 40 and 0.47) with OC, OM, CEC, P, N, MC and clay respectively; This means that soil pH were increased with increase in the amount of these mineral nutrients in the soil, and vice versa. But inversely correlated with bulk density and sand fraction. The analyzed numerical value indicated that acidity were increased as spacing regime was decreased/ more acidic soil were recorded as spacing became closer that led growth limited by pertaining soil mineral nutrients to stay unabsorbed or leached. This might be due to the effect of the species to immobilize soil exchangeable bases leading to increased acidity as in agreement with the report (16). And also unavailability of most soil nutrients in acidic soil might lower pH of the woodlot plantation especially as came the closer spacing. Similar to the finding of (17) those most nutrient elements occur in available forms at a soil pH range of 5.5 to 6.5. This finding also agrees with those of (16), who found that soil pH, was significantly lower in soil under *E. camaldulensis* in both the 0–10 and 10–20 cm soil depths in Botswana, compared to native *Acacia* forest. Furthermore, soil with pH of below 5.5, soil toxicity increment as a result of micronutrients availability increases so that soluble nutrients tend to form insoluble compounds with Al and Fe in acidic soils were also reported (18).

4.3.2.2. Cation Exchange Capacity of the soil (CEC) (Cmolekg-^{1}). The Cation exchange capacity (CEC) recorded (mean and standard deviation) were 21.5±3.3, 18.45±3, 16.33±4.4 and 21.5±3.3 (c mol kg-1) from wider to narrower spacings (Table 4), the figures were also statistically significant. Spacing regimes 1m x 0.75m were founded to be significantly different with respective spacing of 0.5m x 0.5m and 0.5m x 0.25m. But failed to see significant difference within the rest of spacings. The cation exchange capacity of the soil has correlated directly with; OM, OC, N, P and clay particles and this might be the variation in the vegetation which would have significantly contributed to the CEC recorded in the soils. This might be why the wider spacing (1m x 0.75m) could have higher CEC value and significantly higher and provided with enough space for mineral nutrient replenishment at the exchangeable site that led better yield of the crop in test (E. globulus woodlot plantation).

4.3.2.3. Available soil nitrogen (N %). Nitrogen availability increased significantly under different spacings of E. globulus woodlot. Available N content was maximum 0.55±0.13 under spacing 1m x 0.75m followed by 0.44±0.12 in 0.75m x 0.5m and 0.38±0.07 and 0.32±0.08 in 0.5m x 0.5m and 0.5m x 0.5 x 0.25m respectively. That means a decreased spacing led to lower N availability. As like organic carbon, available nitrogen was significantly influenced by spacing because amount of available Nitrogen depends upon organic matter added in to the soil or increased N content of soil in wider spacing (1m x 0.75m compared to 0.5m x0.25m narrow initial spacing) is attributed to addition of organic matter in soil in the form of litter fall and fine root biomass. This proofs the intention of smallholder farmers to prefer wider spacing if they had no reserve OM added to the soil on which they intend to plant Eucalyptus woodlot; assuming wider spacing may provide space for undergrowth and decomposition of leaf litter that increase yield. Nitrogen concentration in soils is reflected in part by the rate of decomposition of the plant material (19) and (16); (20), (19) and (12), had also reported that under lower soil pH, Eucalyptus species produce slowly decomposing low nutrient concentrations containing nutrients and considerably lowers N mineralization from this process. Similar to the report that higher quantities of N cycled through litter fall of N-fixing trees and non-N-fixing than non-leguminous monoculture Eucalyptus species plantations alone (21) and (22).

4*.3.2.4. Available phosphorus (ppm).* Soil P also exhibited similar trend like that of soil nitrogen (Fig. 5). The highest available soil P was recorded under 1m x 0.75m (10.62ppm) spacing while it was lowest (3.8ppm) under 0.5m x 0.25m in surface soil (0-25cm depth). Statistical value from ANOVA table showed that available P has significant effect on initial spacing regimes and significantly different between 1m x 0.75m and 0.5m x 0.25m spacing regimes. However, left insignificant within the rest spacings. Therefore, as density was increased available P was decreasing and yield from the woodlot plantation were recorded reducing. Similar result from (16), reported that Eucalyptus species have a higher capacity of immobilizing phosphorus under lower soil pH value and make them inaccessible for plant use. (18) also added that at soil pH of below 5.5, soil trace nutrients like Aluminum (Al) availability increases to levels that are unsuitable for most plant growth and soil soluble compounds may form insoluble compounds with Al and Fe in acidic soils, which are inaccessible to native plants. (16) on the other hand reported that available phosphorus was low (below 5µg g−1) in soil under Eucalyptus species plantation in both the 0–10 and 10–20 cm depths of soil in Botswana.

4.3.2.5. Soil Total Organic Carbon (%). The concentration of soil organic carbon were 5.75±0.62, 4.62±4.62, 3.68±0.44 and 2.73±2.7 (in %) in 1m x 0.75m, 0.75m x 0.5m, 0.5m x 0.5m and 0.5m x 0.25m respectively (Table 4.2). Organic Carbon in soils was significantly affected by spacing and also significantly different within spacing regimes except those between 0.75m x 0.5m and 0.5m x 0.5m. It increased as density were decreasing and this may be due to the fact that under wider spacing as compared to the closest spacing regimes, nutrient competition were reduced and better decomposition of organic matter added to the soil by soil microbes that also induced better yield. As the report of (23), Organic matter contents are considered low if it is less than 4 %, medium if it is between 4 % and 8 %, and high if it is above 8% . Organic carbon in soil decreased with the decrease in tree spacing and the relative amount of soil total organic carbon in the study area were generally decreasing with increase in tree density. On the other hand organic carbon was correlated strongly and directly with OM, TN, P, CEC and others. This associations and relatively lowering total organic carbon in the woodlot might be, due to the differences in the amount and rates of plant litter decomposition under the Eucalyptus plantation with decreasing spacings. Report from (12) also notified that 83 % of the soil samples under Eucalyptus species plantation areas were found low (< 1%) in organic matter (25). Furthermore (24) reported that organic carbon levels under 5 to 10-year plantations of Eucalyptus species plantation, near Pointe Noire, Congo, were below the level in a savanna control plot, suggesting that there was no substantial build-up of organic carbon in soil under the Eucalyptus plantation during the first 10 years following plantation establishment.

4.3.2.6. The Soil Organic Matter. The concentrations of soil TOM were significantly affected by initial spacing between trees (Figure 7). Yield from the woodlot plantation were decreased as spacing was decreased/or density were increasing and recorded low to medium. Except those between 0.5m x 0.5m and 0.5m x 0.25m; all spacing regimes showed a significantly different amount of total available organic matter. A relatively minimum yield from narrower spacing and the strong associations of SOM with soil pH might be raised from the principle of intense competition under high density planting, lower undergrowth, limited addition of mineral nutrient and OM from litter fall and minimum space for evapo-transpiration/ low decomposition due to higher acidity level. Similar finding were reported by (26), limited availability of vegetation in the ground and litter fall which resulting lower availabilities of organic material decompositions. Another finding from (27) reported that the lower pH value lowered the microbiological activity of the soils leads to slower breakdown of litters.

5. Conclusions

In general, the soil texture results showed that spacing had significantly higher effect on soils and increased the sandy and lowered the clay contents. The one way ANOVA result showed significant different between spacing regime of 0.25m x 0.5m and 1m x 0.75m in sand and clay content of soil. However, there were no significant difference seen in sand and clay fraction between 0.5m x 0.5m and 0.5m x 0.25m spacing regime. Spacing also affected the soil bulk density; significantly differ between; 1m x 0.0.75m and 0.5m x 0.5m as well as between 0.75m x 0.5m and 0.5m x 0.25m spacings regime. The soil moisture content of the soil was significantly affected by the spacing regimes. It was significantly different between 1m x 0.7m and 0.5m x 0.25m spacing regime but there were no statistically significant different between 0.75m x 0.5m and 0.5m x 0.5m spacing regimes. The pH of the soils was numerically different between spacing regimes (between 3.48 and 5.65) and statistically insignificant. Cation exchange capacity of woodlot plantation was found statistically significant between 1m x 0.75m; with 0.5m x 0.5m and 0.5m x 0.25m spacing regimes. However, there was no significant difference between other spacing regimes. Nitrogen availability and organic Carbon also increased significantly under wider spacing of *E. globulus* woodlot and it decreased with the increase in the spacings.

6. Recommendations

Most of the soil nutrients were lower/unavailable for the plant as spacing were coming closer and closer, so farmers could add fertilizers (like, Organic fertilizer.) which enhance soil fertility in their woodlots to increase yield especially in closer spacings.

Finally it could be better to look at effect of spacing regime on physico-chemical properties of soil that were not part of this study and as long as in different soil depth.

Tables

Table1. Pearson's correlations of different soil parameters studied in the woodlots.

	pH	**% OC**	**% OM**	**CEC (cmol/kg)**	**P (ppm)**	**%N**	**% MC**	**BD**	**% Sand**	**% Clay**	**% Silt**
pH	1										
OC	.81	1									
OM	.66**	.64*	1								
CEC	.53	.61**	.79	1							
P	.57	.78**	.41	.74	1						
N	.73**	.63**	.84**	.86*	.75**	1**					
MC	.40	.41	.54	.39	.68	.69	1				
BD	-.40	-.47	-.54	-.32	-.21	-.27	-.86	1			
sand	-.32*	-.71	-.80	-.53	.35*	-.76	-.55	.68	1		
clay	.47	.31	.77	.58	.207	.34	.43	-.36	-.61	1	
Silt	.29	.25	-.65	.64	.51	.77	.28	-.50	-.68	.38	1

Notes: pH − power of hydrogen; OC − soil organic carbon; OM − organic matter; N − total nitrogen; P − available phosphorous; MC − moisture content; BD − bulk density; CEC − cation exchange capacity; ** Correlation is significant at the 0.01 level (two-tailed); *Correlation is significant at the 0.05 level (two tailed).

Table2. Laboratory analyzed results of on soil physical and chemical properties of woodlot plantation:

spacing	**%OC**	**%OM**	**P^H**	**CEC(cmol/kg)**	**P(ppm)**	**N**	**%MC**	**BD**	**%SAND**	**%CLAY**	**%SILT**
1X 0.75M	5.75±0.6	10.5±1	4.52±0.67	21.5±3.3	10.62±3.3	0.8±0.13	27.17±5.4	0.198±0.05	49.1±9.7	35.9±7.19	26.47±6.17
0.75X0.5M	4.62±4.6	9.4±1.4	4.4±4.4	18.45±3	8.5±4.1	0.49±0.12	24.4±5.5	0.242±0.05	52.3±7.5	29.79±5.5	23.79±7.5
0.5X0.5M	3.68±0.4	5.8±1.2	4.63±0.7	16.33±4	5.78±3.19	0.39±0.07	22.9±4.4	0.286±0.06	55.4±7	25.47±5.5	19.05±5.26
0.5X0.25M	2.73±1.7	4.3±0.9	3.48±0.63	21.5±3.3	3.8±1.5	0.32±0.08	20.54±3	0.34±0.07	62.05±6.2	20.1±3.4	15.79±3.1
CV	22	15	29	17.9	25	27	20	21.5	13.8	19.4	25.8

Graphs

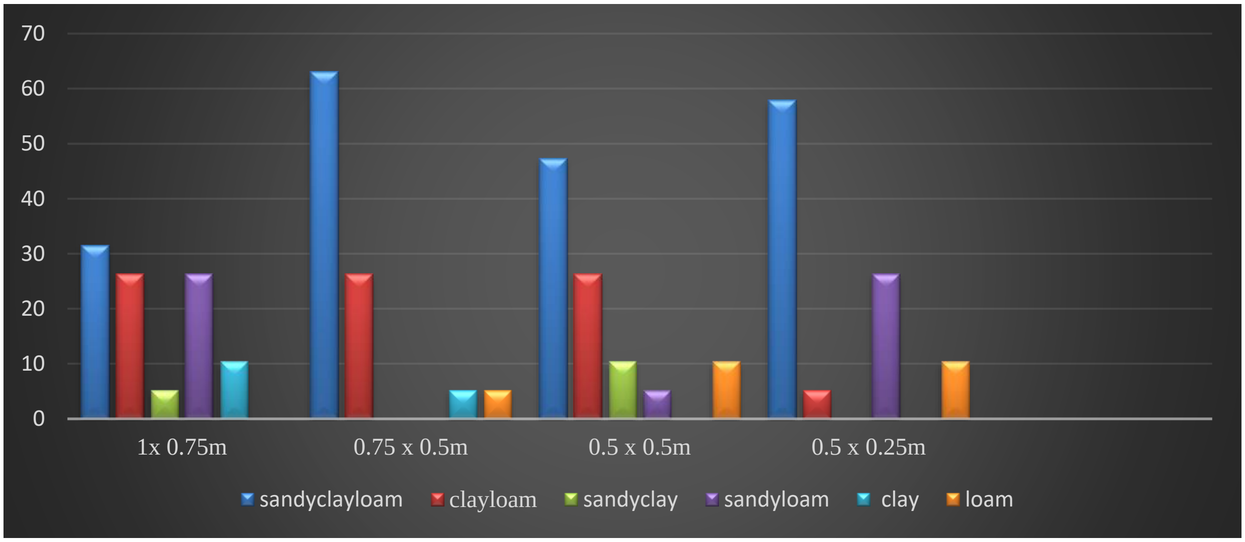
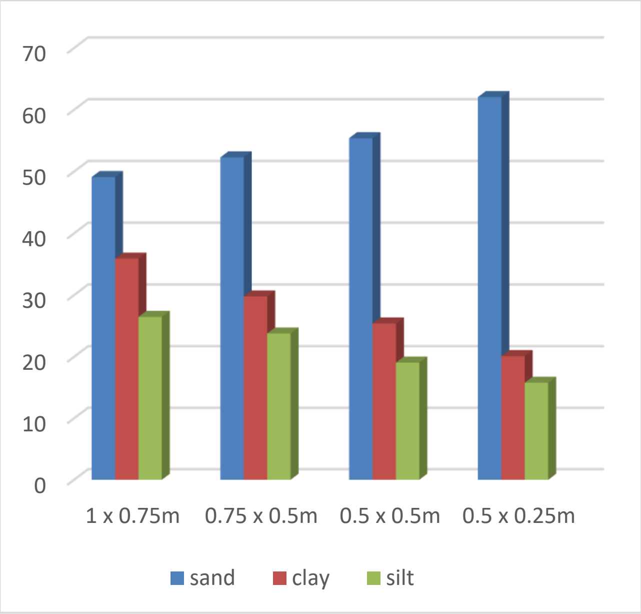


Figure2. Summary of the soil textural class results in each spacing regimes.



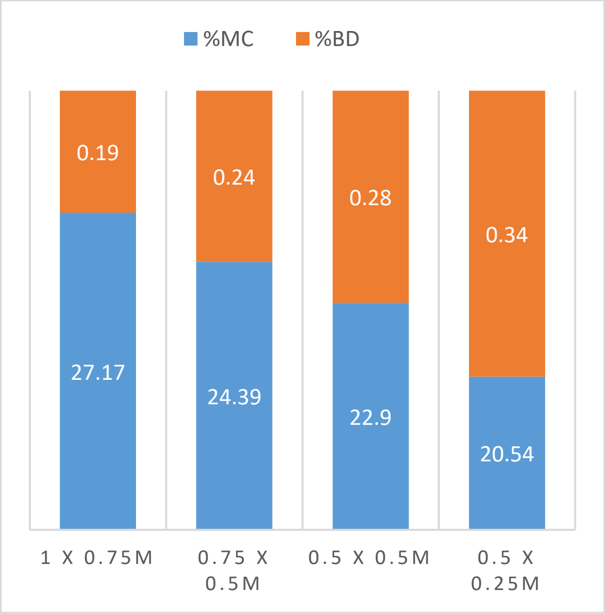
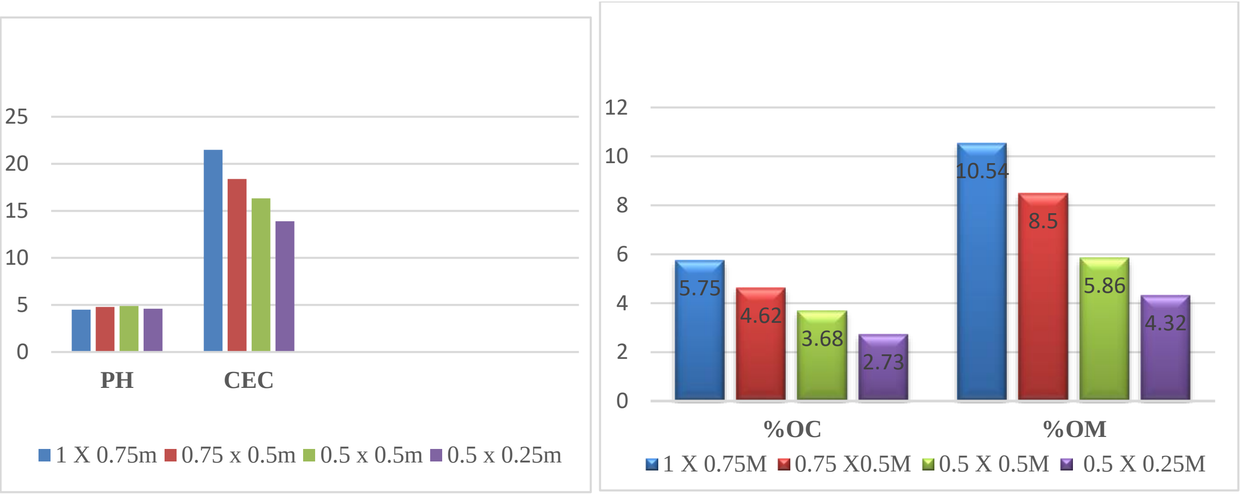


Figure3. Soil physical properties of different spacing regime in E. globulus woodlots plantation.



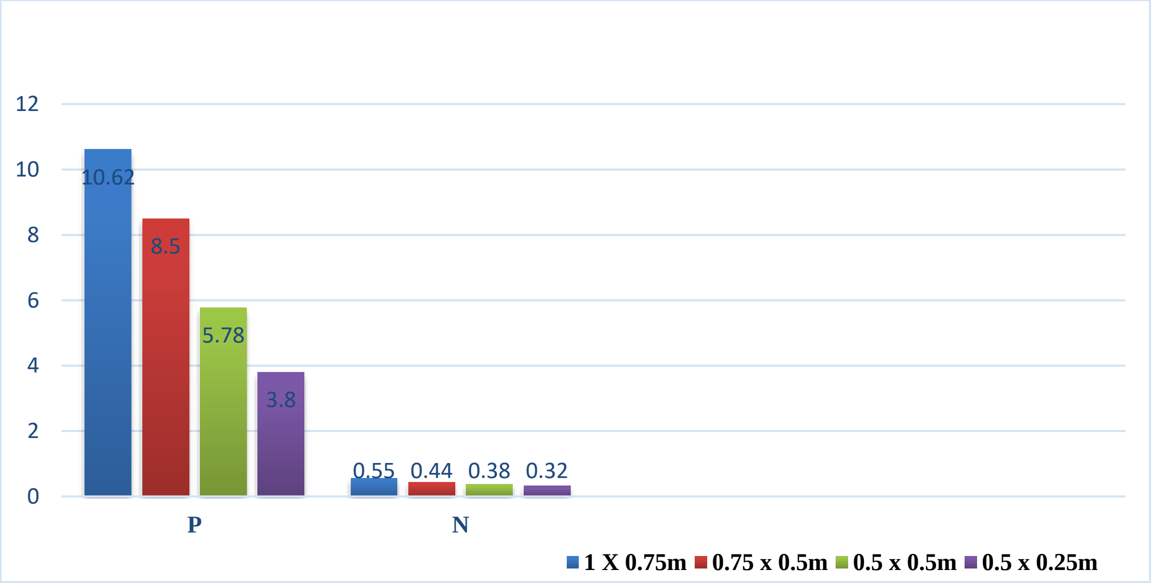


Figure4. Soil chemical properties of different spacing regime in E. globulus woodlots plantation by smallholder farmers.

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