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The impacts of post plantation management practices on growth and survival rate of selected tree species in Mirab Abaya District, Southern Ethiopia: An experimental approach

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The impacts of post-plantation management practices (urea, farm yard manure, and combinations of urea and farmyard manure) on the growth and survival rates of selected indigenous and exotic tree species *Cordia africana, Olea europaea, Grevillea robusta, and Cupressus lusitanica* at Sutte micro-watershed, Morode kebele in Mirab Abaya district, South Ethiopia were investigated. Soil samples were collected from the experimental site by the zigzag method at 10 m intervals from a 40 m by 80 m plot of land and analysed in Arba Minch University for their physical and chemical properties. Results showed that the mean soil texture was 94.12% sand, 4.66% silt and 1.19% clay, pH (6.95), and total nitrogen and available phosphorous were low, with corresponding results of 0.04% and 2.1 mg/L, respectively. Similarly, soil organic matter, available potassium and cation exchange capacity (CEC) were 2.8%, 1.33 mg/L and 13.2 mg/L, respectively. On the other hand, micronutrients like copper and zinc were 1.18 and 3.2 mg/L, respectively. The concentration of iron was 1.95 mg/L which no longer hampered the growth of planted tree seedlings. The growth of height and root collar diameter (RCD) of planted tree seedlings was measured, and the survival rate was calculated for each tree species for twelve months. Tree seedlings that received the combination of urea and farmyard manure (FYM) showed the longest height, RCD and the highest survival rate in *C. lusitanica* compared to other three planted seedlings species. The lowest growth in height and survival rate was recorded in *O. europaea*. The major limiting factors of the study included experimental site due to the presence of sandy soil and the toxicity of copper and zinc. However, these limitations were avoided by testing the soil before planting tree seedlings on selected sites and preparing plantation pits during dry seasons 2 to 3 months before the plantation period.

Key words: Farmyard manure, growth, Mirab Abaya, post plantation management, survival rate, tree species, urea.

INTRODUCTION

Deforestation causes the world's natural forest area to shrink from time to time (Moges et al., 2010). As a result, forest goods are in short supply, and the ecology is deteriorating. Many of these issues are addressed by forest plantations. Every year, 4 million hectares of plantations are planted around the world (Brown, 2009; Cossalter and Pye-Smith, 2003). Plantations that are intensively managed are profitable and provide their owners with competitive financial returns (Siry et al., 2005). Forest plantings relieve strain on surviving natural forests, restore degraded regions, and boost soil fertility (Tesfaye et al., 2016). Plantation forests help many people in developing countries better their livelihoods by providing raw materials for wood-based processing industries and customers in both developed and developing countries (Chamshama et al., 2009). *Eucalyptus* and *Acacia* species are the most common fast-growing and short-rotation plantation species in the tropics and subtropics (FAO, 2009).

The change of land use from forest cover to cultivated land may delay addition of litter, losses nutrient content in soils (Ozgoz et al., 2013), increases rates of erosion (Kassa, 2003; Biro et al., 2013), loss of soil organic matter and nutrient (Saha and Kukal, 2015) and accelerate rate of soil degradation (Barua and Haque, 2013). According to Ogeh and Osioman (2012), decline in organic matter and nutrient lead to decline in soil fertility if replenishment with inorganic or organic fertilizer is inadequate. In Ethiopia, rapid population growth and environmental factors lead to the conversion of natural forest and grass land into cultivated farmland (Gebreyesus, 2013). Such human-caused factors have contributed to soil degradation and loss by deteriorating soil physical and chemical properties, making the ecosystem more delicate and vulnerable to land degradation.

As a result, forest cover of Ethiopia has been decreasing since 1990. Even though, massive reforestation, afforestation, soil, and water conservation activities were launched in the country, their growth and survival rate were poor (Reusing, 2000; Mehari, 2005). According to Tadesse (2012), since 2007, massive tree planting campaigns have been undertaken in connection with the celebration of the country's Millennium, and about 2.21 billion seedlings were planted in 2009 in four regions: Oromia, SNNP, Amhara and Tigray. Reforestation goals were set in terms of number of seedlings to be planted rather than their ecological requirements (Mehari, 2005). As a result, reforestation impacts could not match with the deforestation rates in which poor implementation and follow-up of plantations have limited their success.

Most plantations in Ethiopia are carried out in harsh circumstances due to a lack of accessible land (Zobel and Talbert, 1984; Evans and Turnbull, 2004). Adverse environments are sites that are marginal for growing economic crops due to their extreme climate and poor soil conditions (e.g. nutrient deficit, acidic and alkaline soils). Moreover, the soils of Ethiopia highlands are shallow due to erosion. Every year, the region losses about 1500 million tons of its topsoil (Hurni, 1993). As a result, most of the soils of highlands of Ethiopia are acidic and their pH ranges between 3 and 5.3 (Tadesse, 2013). According to the study of Reusing (2000), forest cover of Ethiopia during 1990s was 35 to 40%. In 2010 it was decreased to 11.2% (FAO, 2010) due to the conversion of forest lands into agricultural lands, settlements and increment of demand for construction and fuel wood. Recently, forest coverage of Ethiopia stands at 15%, but through the new program it is expected to grow to 20% by 2020, while 22 million hectares of degraded land is expected to be rehabilitated by 2030. The forest sector's contribution to national GDP is also expected to grow from 4 to 8% by 2030 (UNDP, 2019).

Establishing forest plantation on degraded land can play a key role in harmonizing long-term forest ecosystem of rehabilitation or restoration goals (Lamb, 1998). Warren et al. (2005) state that successful seedling establishment and growth are dependent on soil condition and stored soil moisture to ensure survival into the following growing season.

Application of organic manures on planted tree seedlings is one of the post plantation management activities that can improve growth and survival rate of planted tree seedlings (Mohammad et al., 2012). In addition, Totey et al. (1986), reported that the adequate quantity of farmyard manure can improve both growth and survival rate of planted tree seedlings better than chemical fertilizers. In addition, seedling quality can also affect the growth and survival rate of tree seedlings (Chavase, 1980). Sorecha (2017) reported that the survival rate of *Olea europaea* Mill P.S Green was 38% due to lack of after care (post management practices). On the other hand, this tree species can resist harsh environment with some management interventions. According to Kitaba et al. (2017), the survival rate of *Cordia africana* was poor and accounted 40% due to the shortage of soil nutrients in degraded watersheds. In addition, farmers prefer *Eucalyptus* spp. rather than indigenous tree species due to short rotation income and their capacity to grow rapidly even after harvesting. However, the growth and survival rate of indigenous and exotic tree species can be improved by applying soil amendments like inorganic, organic manures and

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watering (Amha et al., 2020). The primary goal of this study is to evaluate the effects of farmers' post-management practices, such as soil amendments, on the growth and survival rate (growth of height, root collar diameter, and survival rate) of planted tree seedlings, to identify the tree species with the highest growth rate of root collar diameter and height among selected tree species, and to describe some physical and chemical properties of the soil in the study area.

MATERIALS AND METHODS

Description of the study area

Mirab Abaya is found in Gamo Zone, North of Arbaminch Zuria, and Northeast of Chencha Woreda, Southeast of Boreda and South of Humbo Woreda. It is located at 6°6‘44“N-6°31‘12“N latitude and 37°35‘9“E-37°59‘23“E longitude (Eshete, 2019). Birbir is the administrative town and located at 455 km south of Addis Ababa, 230 km from Hawasa and 50 km from Arbaminch (Figure 1).

The district has three agro ecological zones: Dega (high altitude area of land), Weina dega (mid altitude area of land) and Kolla (low altitude area of land). Out of 24 kebeles, 16 (62%) are in low land, 6 (27%) are located in mid lands and 2 (11%) are found in high lands. According to the Ethiopian National Meteorology Agency, the average annual rainfall is between 700 and 1600 mm and means maximum and minimum temperatures of 22, and 7°C, in Chencha Woreda and Mirab Abaya areas, respectively. The Woreda experienced a bimodal pattern of rainfall regimes (belg from March to May and meher from July to September). The main cropping season in Kolla agro ecology is belg that is from March to May, but high land areas receive the highest rainfall during the meher (June to August) (Figure 2).

Seeds collection of selected tree species

Seeds collection of selected tree species, *C. africana and O. europaea* were collected from home gardens, *Cupersus lusitanica* seeds were collected from communal plantation site that is located at an altitude of 1100 masl and *Gravilea robusta* seeds were obtained from a project plantation. Finally, each of tree seeds were sown based on the nursery calendar. Sowing, transplanting and out planting of selected tree seedlings were presented (Table 1).

Seedlings preparation

About 800 seedlings of four multipurpose tree species: *C. africana, O. europaea, C. lusitanica* and *G. robusta* were prepared, graded and out planted in early June in experimental site in Morode kebele. 1600 kg of FYM was collected on 04 - 06 January, 2019 from the study kebele near the study area stored and well decomposed for 5 months before plantation period of the selected tree seedlings in the temporary shed in the experimental site (Bradshaw, 1997). A 2 kg farmyard manure FYM was applied on 400 seedlings (that is, 200 seedlings received only FYM and 200 seedlings received both urea and FYM).

12.5 kg urea was brought and 10 kg of it was applied to 400 seedlings (that is each seedlings received 25 g urea based on the result of soil test). Spacing of plantation for selected tree seedlings was presented (Table 2).

Soil sampling methodology

In experimental site, Sutte microwater shed, Morode kebele, random selection of points was chosen to withdraw soil samples from three successive depths (0-15, 15-30 and 30-45 cm). Soil samples were taken using soil auger following zigzag method of soil sampling in 10 m distance intervals (Bradshaw, 1997). The soil cores from 10 depths were mixed to make 3 soil composites (1 kg from each successive depth). Soil samples were taken to Arba Minch University for analysis of bulk density, pH, total nitrogen (TN), available nitrogen (N), available phosphorus (P), available potassium (K), cation exchange capacity (CEC) and soil textures and micronutrients like Copper (Cu), Zinc (Zn) and Iron (Fe).

Randomized Complete Block design with four blocks with two replications and three treatments (Urea alone, Farmyard manure (FYM) and Farmyard manure and urea (FYM + Urea) and Control were applied to those selected tree species in the study experiments. The blocks were constructed from east to west along the contour and divided into 8 plots. Totally 32 experimental units or plots have 25 seedlings planted in 2 m by 2 m spacing and total of 800 seedlings in experimental site. A species was represented by 200 seedlings randomly planted in these 32 experimental units.

Qualitative data collection

Qualitative data were collected, using purposive sampling method in which focus group discussion with twelve farmers who are involved in tree planting, three agricultural development agents and seven experts of plant science and natural resource management or key informants (that is, from agricultural and natural resource management office).

Quantitative data collection

Initial tree seedlings height and root collar diameter were measured using meter tape before out planting. Growth of height, root collar diameter and survival rate were taken each month by non-destructive method (Van et al., 1998) using systematic sampling technique (Kindu et al., 2006).

Data analysis

Survival rate was calculated for each tree species planted in the experimental site using the formula (Megan, 2013):

Mortality rate = Number of seedlings dead during study period/Total number of saplings planted in each period × 100

Survival rate = 100 - Mortality rate (1)

Survived seedlings were counted, and their survival rate was calculated within month starting from August 2019 to June 2020 for 12 months.

Mean and multivariate analysis of variance were used for data analysis using SPSS version 20 at 5% level of precision was applied to know whether height growth, root collar diameter and survival were significantly different. Soil sample results were analyzed using different methods. Total nitrogen (TN) using Kjeldahl method, followed by calculating available nitrogen from total nitrogen or the concentration of nitrate nitrogen that accounts only 2% of TN (Bremner and Mulvaney, 1982). Finally, the quantity of urea-nitrogen in kg per hectare was calculated (Karuku and Mochoge, 2018) using the following formula:

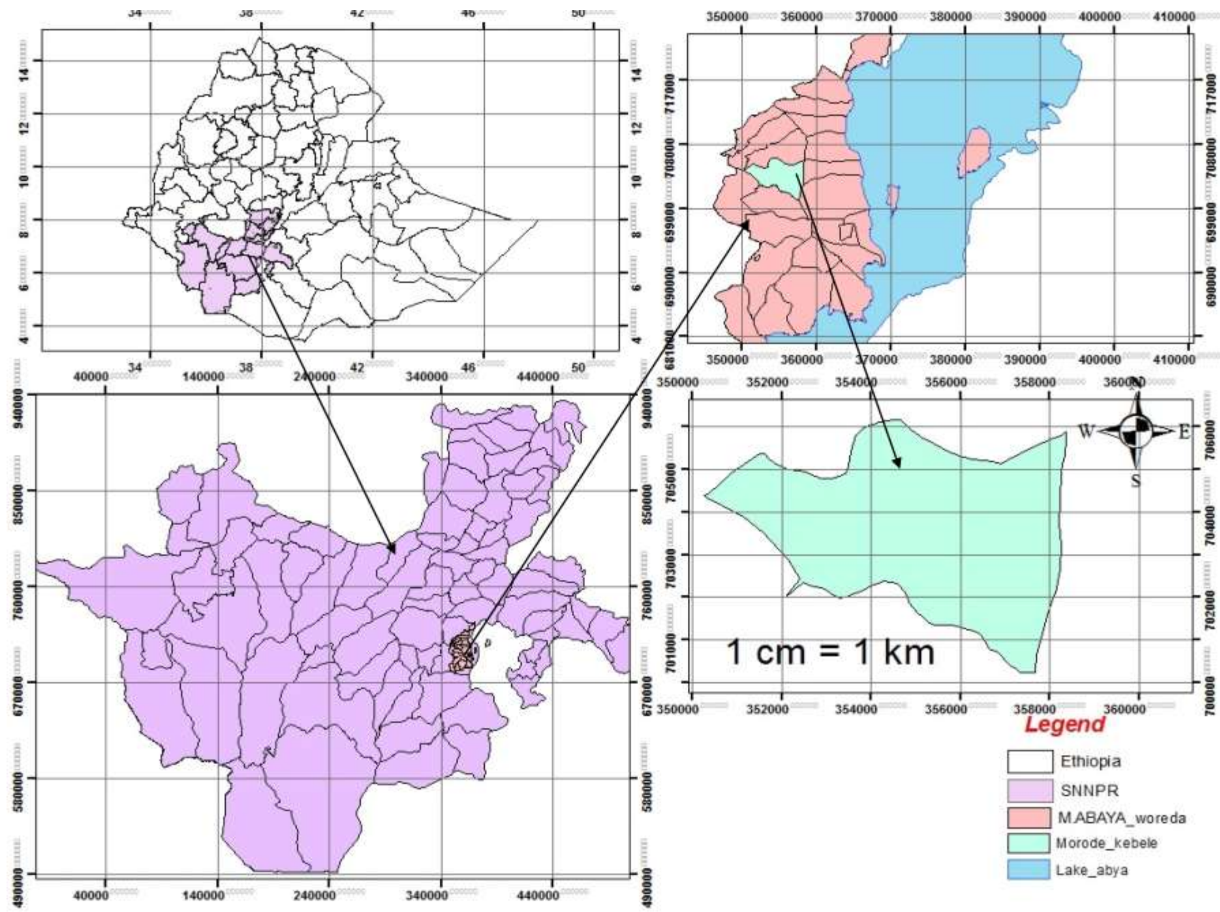

Figure 1. Map of the study area. Location of Morade Kebele of Mobaya Woreda Zone in SNNPR, Ethiopia.
Data Source: Ethio-GIS collected by ECSA (Ethiopian Central Statistics Authority, 2014), software Arch-GIS 9.2 was used.

kg N/ha = Soil depth × Bulk density × Conc. (μg N) × Area (cm^2) / Weight of soil × 10^9 (2)

where kg N/ha is the total nitrogen in kg in study experimental area (40 × 80 m) area and Conc. (μg N) is the concentration of total nitrogen in microgram (400 μg) using conversion factor 1% = 10000 ppm or 10000 μg N.

Finally, total fertilizer need for planted tree seedlings was analyzed using Oldham (2017) formula as follows:

Total nitrogen need = Recommended nitrogen in lbs / Nitrogen content fertilizer × Area in square feet /1000 square foot (3)

Available phosphorus (P) according to Olsen and Sommers (1982), organic carbon (OC) by Walkley and Black (1934), cation exchange capacity (CEC) by Rhoades (1983). Soil pH was analyzed using a potentiometric measurement method on the supernatant suspension of 1:2.5 water to soil ratio (Rhoades, 1995). The moisture content of soil samples was estimated after an immediate sampling of soil based on oven-dry method.

Among many of soil physical properties, soil texture, soil moisture content and bulk density were studied. Soil texture was determined by sieve method (Yitbarek et al., 2016) and bulk density by the core method from the oven dry at 105°C (Landon, 1991). Soil moisture content was determined by gravimetrically through oven drying at 105°C to a constant weight from known mass and volume of soil sample collected using soil moisture cans.

RESULTS AND DISCUSSION

Growth of height, root collar diameter and percentage rate of survival

C. africana

An initial average height of seedlings of *C. africana* was 28 cm and average root collar diameter was 0.51 cm, respectively. The seedlings *C. africana* treated with urea, FYM and combination of FYM and urea increased growth of height and root collar diameter dramatically over control (Table 3). Over a period of seven months, plots previously received urea alone and the combination of urea and FYM showed poor growth of height and root

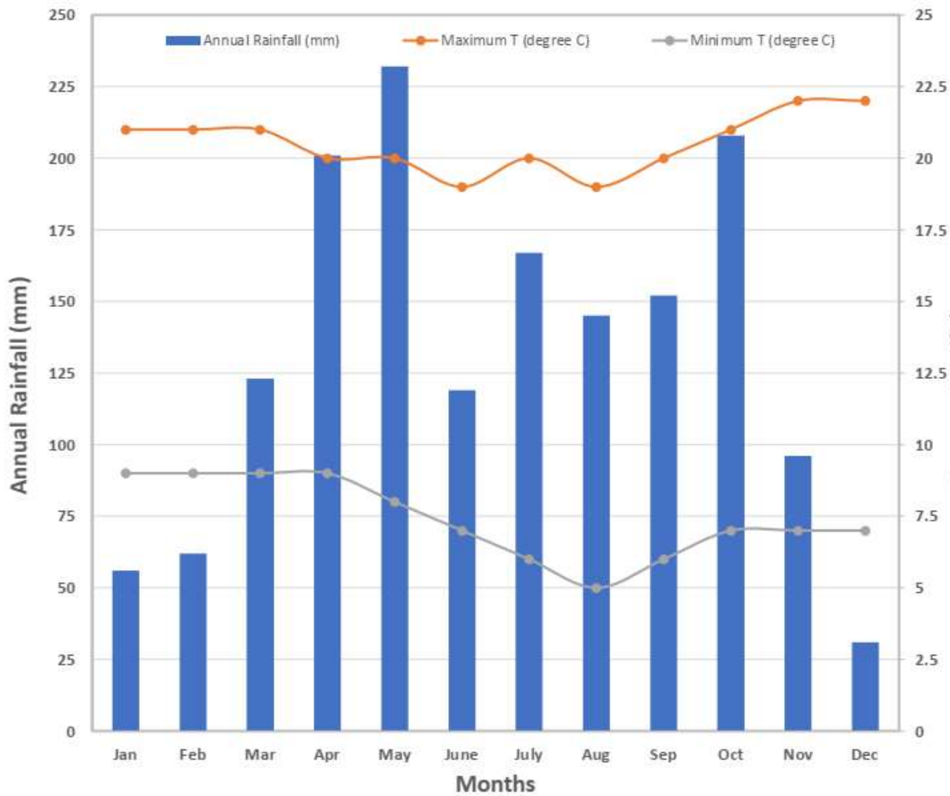

Figure 2. Monthly rainfall and annual maximum and minimum temperature of the study area in Chencha, Mirab Abaya from 1990 to 2021 according to Ethiopian National Meteorology Agency.

Table 1. Nursery calendar based on tree species.

Species	Nursery calendar (Dates)		
	Sowing	Transplanting	Out planting
Cordia africana	October 10,2018	January 02, 2019	June 30, 2019
Olea europaea	August15, 2018	October 12, 2018	June 30, 2019
Grevillea robusta	October 06, 2018	January 06, 2019	June 30, 2019
Cupressus lusitanica	August15, 2018	October 15, 2018	June 30, 2019

Source: Supported with Nabu Project Office (2016). Training Manual Awareness Creation, Nursery Establishment, and Plantation and Agroforestry practices: Bahir Dar.

collar diameter, low biomass production (all the leaves were yellow), due to the shortage of available nitrogen, phosphorus and toxicity of copper and zinc (Marschner, 2011) On the contrary, only seedlings received both urea and FYM showed deep green color and significant growth within a month. During the application of the second term, 10 g of urea at the seventh month, the growth of both for height and RCD for control, urea, FYM and the combination of FYM and urea were 43.1, 54.2, 58.1 and 64.3 cm and 0.7, 1.4, 1.7 and 2.1 cm, respectively. Similarly, during twelve-month period, measuring the average growth of height and RCD for control, urea, FYM and the combination of FYM and urea were 55.9, 54.8, 78.9 and 94.1 cm and 1.8, 2.1, 3.7, and 4.7 cm, respectively (Table 3 and Figure 3A) and growth of height and RCD was highly significant at P=0.05. The height growth and root collar diameter of Cordia was highly stunted in plots that received no fertilizer and urea. This might be associated with leaching of urea during the period since there was high rain fall, toxicity of Cu and Zn (nutrients may vary even in small distance) and coarse sand (texture may also vary in small distances). These

Table 2. Tree species selected for the study and their spacing of plantation.

Species name	Family	Spacing (m)
Cordia africana	Boraginaceae	2×2
Olea europaea	Oleaceae	2×2
Grevillearobusta	Proteaceae	2×2
Cuperessulusitanica	Cupressaceae	2×2

Source: *Cordiaafricana* (Amanuel Mehari (2005), *Cupersuslusitanica* (World Agroforestry Center, 2018), *Grevilearobusta* (Fact 98, 1998): https://www.winrock.org/fact net.

results were related to the findings of Tefese (2007) in that the mean height and RCD of *C*. *africana* in clay loam soil and Gebeyehu (2017) in nitosoils, respectively. *C. africana* seedlings treated with FYM and the combination of FYM and urea showed better growth of height and root collar diameter as farmyard manure reduced the toxicity of Cu and zinc by binding them from the soil (Davis, 1984). In contrast, the lowest height gains of native species in the range of 0.52 m in *Albizia gummifera* up to 1.20 m in *C. africana* (Amaha et al., 2020)

At the end of the second month count, survival rate for control, urea, FYM and the combination of FYM and urea were 92, 92, 96 and 96%, respectively. Contrary to other tree species, the survival rate was reduced rapidly in control and urea plots from third to the seventh month. From the eighth to twelve-month count, the survival rate was also continuously decreased in all plots. The performance of *C. africana* during the record of the twelve months for control, urea, FYM and the combination of urea and FYM were 44, 44, 68 and 72%, respectively (Table 3).

As can be seen from the survival rate in each treatment, the least survival rate was recorded in control and urea plots and the higher and the highest survival rate were recorded in plots that received FYM and the combination of FYM and urea. This showed that FYM might improve the water holding capacity that was being affected by sandy texture (Tadesse et al., 2014). Similarly, in clay loam soil, the survival rate of *C*. *africana* was 98% in eight months growing period (Tafese, 2007). Likewise, there was a significant effect shown by the application of moringa leaf juice on the field condition on the parameters of height on *C. africana* tree (Kassa et al., 2020). There was no significant difference in mean survival rate for seedlings that received FYM, the combination of FYM and urea and control but there was significant difference between mean survival rate of seedlings that received only urea at *P*=0.05.

Olea europaea

The growth of height and root collar diameter for control, urea, FYM and combination of FYM and urea were increased drastically after forty-five days in planted seedlings, respectively. Starting from the second month of observation, the mean height for control, urea, FYM and combination of FYM and urea were 28.3, 28.4, 35.4 and 37.3 cm, and that of root collar diameter was 0.48, 0.54, 0.64 and 0.67 cm, respectively. This made the growth of height and root collar diameter lag, as a result there was no much change on growth over a period of seven months. Thus, the recorded height was 30.2, 34.7, 44.2 and 46.9 cm and root collar diameter 1.00, 1.01, 1.08 and 1.2 cm, respectively. Twelve months after seedlings planted, the recorded height and root collar diameter for *O. europaea* in control, urea, FYM and the combination of FYM and urea were increased dramatically in each plot showing better growth in height and RCD in both FYM and urea, respectively (Table 3 and Figure 3B). In addition, according to Amaha et al. (2020) both *Acacia saligna* and *Sesbania sesban* achieved the highest root collar diameter growth, while the lowest root collar diameter growth of *A. gummifera* and *O. europaea*. Results suggested that *O. europaea* may be well suited to fine textured soils like loamy, sand, and loamy clay silt loam (Sibbett and Ferguson, 2019). The majority of species relative growth did, however, slow down with time. These findings were consistent with Kindu et al. (2006) who noted an earlier height and biomass increment than a later age. According to the result of analysis of variance, there was significant difference in growth of both height and RCD at *P*=0.05. However, due to their modest growth rates, *A. gummifera* and *O. europaea* have the lowest height and root collar diameter growths (Sorecha, 2017). Furthermore, some of these native tree species, the root collar diameter and height in growth tended to be better when planted together than when planted separately.

From forty-five days to the end of the third month, no change on mortality was observed and each planted seedling in experimental site was becoming deep green continuously due to, there was continuous rain fall, however only one seedling was dead in control plot. On the same manner, from fourth to seventh month count, *O. europaea* showed no change on survival rate such that

Table 3. Mean ± standard deviation of the four different tree seedlings growth of height, root collar diameter and survival rate of tree seedlings using urea, FYM and combination of urea and FYM.

Plant Species	Treatment	Height (cm)	RCD (cm)	Survival rate (%)	Height (cm)	RCD (cm)	Survival rate (%)	Height (cm)	RCD (cm)	Survival rate (%)
		45 days			210 days			360 days		
Cordia africana	Control	34.2±0.8	0.70±1.2	92	43.1±1.2	0.74±0.03	72	55.9±1.2	1.8±0.1	44
	Urea	34.7±0.9	0.83±0.2	92	54.2±1.2	1.49±0.07	76	54.8±0.8	2.1±0.3	44
	FYM	36.2±1.1	0.97±0.2	96	58.1±1.3	1.7±0.07	84	78.9±0.8	3.7±0.2	68
	FYM+Urea	41.1±1.3	1.10±0.6	96	64.3±1.4	2.14±0.21	96	94.1±1.2	4.7±0.2	72
Olea europaea	Control	28.3±0.7	0.48±0.02	96	30.2±1.2	1.0±0.07	92	43.1±0.8	1.03±0.052	74
	Urea	28.4±0.8	0.54±0.03	100	34.7±1.1	1.01±0.05	100	45.2±0.5	1.4±0.04	80
	FYM	35.4±1.2	0.64±0.03	100	44.2±1.2	1.08±0.06	100	46.3±0.6	2.06±0.04	84
	FYM+Urea	37.3±1.1	0.67±0.03	100	46.9±1.3	1.21±0.09	100	58.2±0.8	1.93±0.52	88
Grevillea robusta	Control	30.1±0.7	0.44±0.03	100	32.2±1.2	0.52±0.02	96	45.1±0.6	0.78±0.04	56
	Urea	30.3±0.8	0.44±0.03	100	32±1.1	0.64±0.03	100	51.2±1.4	0.8±0.03	58
	FYM	31.2±0.7	0.71±0.04	100	34±1.2	0.76±0.04	100	72.6±1.4	1.06±0.03	94
	FYM+Urea	33.5±0.9	0.73±0.05	100	36±1.3	0.83±0.04	100	78.3±1.6	1.15±0.04	88
Cupressus lusitanica	Control	36.1±0.9	0.31±0.01	100	54±1.6	0.75±0.05	86	94.2±3.4	0.97±0.085	76
	Urea	37.2±1.1	0.62±0.03	100	58±1.5	1.1±0.04	100	124.1±2.3	1.22±0.085	94
	FYM	40.4±1.3	0.78±0.03	100	76±1.9	1.33±0.05	100	144.4±2.4	1.64±0.06	94
	FYM+Urea	43.2±1.2	0.92±0.04	100	87±1.8	1.35±0.08	100	158.3±3.4	2.27±0.085	100

Source: The average values are represented as ±SE. Further details are described in Materials and methods.

the least survival was even better 92% and the highest survival was 100% for seedlings that received FYM and the combination of FYM and urea. During the twelve-month count, the survival rates recorded for *O. europaea* on each treatment were 74, 80, 84 and 88%, respectively for growth of height, RCD and survival rate (Table 3). Furthermore, according to Amaha et al. (2020), the survival rates of all tree/shrub species decreased considerably over time due to extended dry seasons and termite incidences and reported that the lowest survival percentage (4%) among indigenous species was *A. gummifera* while the highest (51%) was by *O. europaea* subsp. *cuspidate*.

G. robusta

The performance of *G. robusta* during the period of out planting shows the longest and shortest height was 29 and 27 cm and the highest and lowest root collar diameter were 0.64 and 0.38 cm, respectively. Even though, the fourth month growth was affected by heavy rain fall, *G. robusta* continued to grow in both height and root collar diameter on all the treatments provided. At the end of the year after plantation, the growth of height and RCD for seedlings received urea, FYM and the combination of FYM and urea were 51.21, 72.64, and 78.31 cm over the control (45.16 cm) and 0.79, 1.06 and 1.1 cm over the control (0.8), respectively (Table 3 and Figure 3C). According to the results recorded from experimental site, seedlings received FYM and the combination of FYM and urea showed the highest growth of

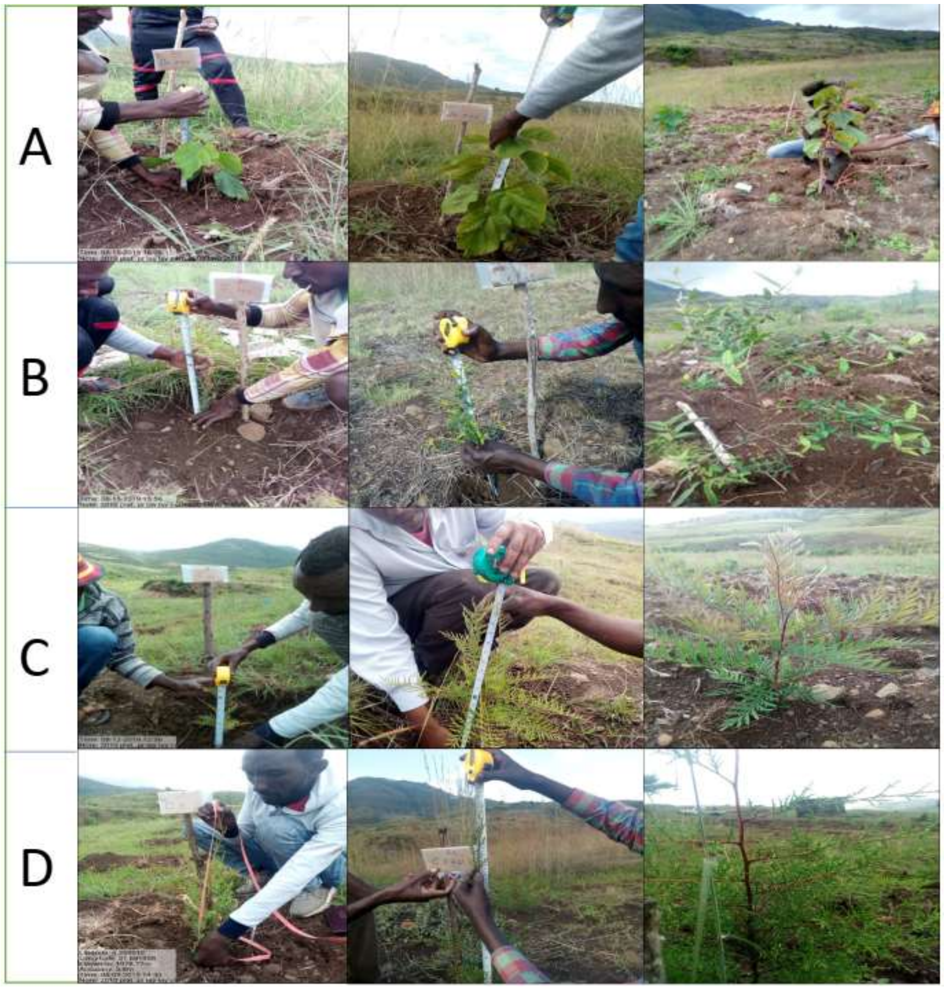

Figure 3. Measurement of height and (root collar diameter) RCD of growth of (A) *C. Africana*, (B) *O. europaea*, (C) *G. robusta,* and (D) *C. lusitanica* at 45, 210, and 360 days, respectively.
Source: Further details are described in Materials and methods.

height and RCD. This result relates to the finding of Karanja et al. (1999) in that annual height and root collar diameter of *G. robusta* was 77 and 1.8 cm, respectively and Gebeyehu (2017) 80 and 1.02 cm, respectively. In addition, Yakob et al. (2017) reported that *G. robusta* showed 80 cm height growth in deep dark reddish clay soil and Yeshiwas et al. (2018) reported that farm yard manures and nitrogen fertilizers played an important role on plant growth and development in sandy soil. Growth of height and root collar diameter of *G. robusta* without treatment was affected by shortage of soil nutrients such as phosphorous, potassium, and nitrogen as well due to toxicity of Copper and Zinc, for successive twelve months (Maliondo et al., 1999). The average DBH and height of the trees showed significant difference under different spacing regimes (Sanjith et al., 2020). Accordingly, the average height and mean annual diametric increment of *G. robusta* did not exceed when grown in different locations of Uganda (Okorio and Peden, 1992). In addition, Otieno (1992) found that in the Shiaya district, the average height at age 5 ranges from 8.8 to 10.6 m and the height of mean annual diametric increment ranges from 1.8 to 2.1 m, depending on the location and spatial arrangement of the trees. Similarly, *G. robusta* showed that fertile soil, cover crops, and growing between trees significantly improved growth performance. However, growth was negatively correlated with height above sea level, showing weak growth (Kalinganire, 1996).

The numbers of seedlings of *G. robusta* during the second month in control, urea, FYM and combination of FYM and urea, were all equal survival rate of 100%, respectively. From second to the fifth month count, the number of seedlings of *G. robusta* recorded for control was 96% compared to treatments 100%, respectively. During this period, there was continuous rain fall at the study site, however, in control and urea plots, two seedlings were dead. Similarly, in line with the survival rate of *G. robusta,* the highlands of Uganda were maintained at 100% (Okorio and Peden, 1992). By the time of twelve-month period, the mean % survival rate was decreased from 96 to 56% in control, and this reduction of survival is seen in treatments as well (Table 3). In agreement with Kalinganire (1996) the survival rate was between 47 and 68% at the age of two years in *G. robusta*. The reason might be associated with the domination of sand texture that resulted in low water holding capacity and consequently death of planted seedlings. There was no significant difference ($P > 0.05$) in mean survival rate of *G. robusta* that received different treatments as observed for survival and other studied growth characteristics (Madadi et al., 2009).

C. lusitanica

During plantation period, the longest height was 43.2 cm and the smallest height was 36.1 cm. Following this problem, 10 kg of urea was applied to the plots received urea alone and the combination of urea and FYM in *C. lusitanica*, respectively. From this it is easy to conclude that application of farmyard manure and urea may favour the vigorous growth of height and root collar diameter in *C. lusitanica*. Twelve months after plantation, growth of height for control, urea, FYM and the combination of FYM and urea was 94.2, 124.1, 144 and 158 cm, respectively and root collar diameter was 0.97, 1.22, 1.64 and 2.27 cm, respectively (Table 3 and Figure 3D). Furthermore, it is easy to understand that FYM together with urea improved the growth of height and RCD of *C. lusitanica* by over 100 and 1.3 cm faster than planted seedlings compared to control plots, attributed to heavy rains from July 2019 to June 2020, except February 2020 which was partially dry during the study period. Similar range of dominancy in height for *C. lusitanica* was also observed in the Ethiopian lands (Mamo and Sterba, 2006) and certain areas of Kenya (Ngugi et al., 2000).

The survival percentage of seedlings planted in each experimental unit for control, urea, FYM and combination of FYM and urea was 100%, respectively, but the survival rate for control plots up to the seven months was 86%. From the eight to twelve months count, the survival rate for control, urea, FYM and the combination of FYM and urea were 76, 94, 94 and 100%, respectively. This might be due to the toxicity of zinc and copper in addition to the deficiency of nitrogen, phosphorous and potassium. In accordance with the study of Gill et al. (2009), farmyard manure not only increases growth but also improves soil fertility in soils like sand. The decrease in survival rate in control compared to treatment was caused by nutrient competition or plant death as a result of no thinning (Luoga et al., 1994). There was no significant difference in mean survival for seedlings that received FYM, the combination of FYM and urea and control but there was significant difference between mean survival rate of seedlings that received only urea at p=0.05.

Soil texture, moisture content and bulk density

The current observation indicated that the variation in soil texture was more of sand with 94% compared to clay and silt (Table 4), and the results were compared to soil textural class standards and related to the range of 85 to 100% are sandy soil for the characterization and classification of high land soils in Western and Northern Ethiopia (FAO, 2006; Deressa et al., 2018). The increased percentage of sandy soil in highlands is due to high rain fall, which causes sheet and hill erosion, resulting in fine particles of clay and silts being easily detached and transported, and finally the coarser texture (sandy soil) remaining in the study area. Due to the presence of macropores, this soil diverts more water into the soil profile, has high nutrient leaching: nitrogen (70%), phosphorus (80%), and potassium (63%), tends to have low moisture levels, and affects plant growth (Kebede and Charles, 2009). Because of the presence of macro pores, this soil drains more water down into the soil profile, has high nutrient leaching: nitrogen (70%), phosphorous (80%), and potassium (63%), is prone to low moisture content, and affects plant growth (Kebede and Charles, 2009). The study site had a moisture content of 25.59%, which was compared to the critical levels of soil moisture for sandy soil reported (Table 4) in some degraded areas of Ethiopia (Nyssen et al., 2006). The bulk density of the study site was 0.77 g/cm^3, when compared with the standard bulk density, which no longer affects plant root penetration, particularly when the bulk density is less than 1.46 g/cm^3 (Hunt and Gilkes, 1992; USDA, 2006).

Soil chemical properties

According to the result of soil test, the concentration of TN was 4% or 400 ppm showing the concentration decreases as the depth of the soil increases (Table 4). This result was in line with the finding of Ayalew et al. (2014) that the concentration of TN was low due to degradation of total nitrogen coupled with little nitrogen fertilization that occurred in the area. In addition, Hailu et al. (2015) reported that the concentration of TN below 0.1% is taken as very low and as a result the soil was poor in quality on the bases of TN which was compared to the standard TN where the level is less than 2% (Landon, 1991). In view of the fact that the plant available form of nitrogen in the soil is dependent on total nitrogen accumulation, where the four tree seedlings planted in

Table 4. Physical and chemical properties of the soil taken at different soil depth in the study site and their Mean ± standard deviation.

Soil properties	Soil depth (cm)			
	0-15	15-30	30-45	Mean
Total nitrogen (%)	0.051	0.039	0.032	0.0406±0.009
Cation Exchange capacity(mg/L)	13.2	13.3	13.1	13.2±0.09
Available phosphorus (mg/L)	2.12	2.081	2.075	2.09±0.02
Available potassium	1.52	1.31	1.16	1.33±0.17
Soil texture				
Sand (%)	97.2	95.28	89.9	94.12±3.5
Silt (%)	2.42	7.54	4.04	4.66±1.51
Clay (%)	0.34	2.56	0.68	1.19±0.69
pH	6.82	6.91	7.12	6.95±0.14
Organic carbon	1.45	1.4	1.4	1.41±0.027
Organic matter (%)	2.88	2.81	2.77	2.82±0.052
Bulk density (g/cm^3)	0.78	0.78	0.76	0.77±0.011
Soil moisture content (%)	27.3	25.6	23.87	25.59±1.63
Fe (mg/L	2.17	1.9	1.78	1.95±0.19
Zn (mg/L)	3.91	3.1	2.6	3.20±0.628
Cu (mg/L)	1.66	1.17	0.71	1.18±0.451

Source: The average values of 3-5 experiments are represented as ±SE. Further details are described in Materials and methods.

this experiment will no longer have enough available nutrients unless additional nitrogen is provided. For the sake of nitrogen recommendation as fertilizer for plants, converting the total nitrogen into the plant available nitrogen form is crucial and important (Karuku and Mochoge, 2018). However, according to Angus (2001), the available form of nitrogen in the soil accounts for only 2% of total nitrogen (98% is the unavailable form of nitrogen). Furthermore, the established rule of thumb for available nitrogen or the plant utilizable form of nitrogen in tropical countries ranges from 1 to 3% of total nitrogen. According to the results, available phosphorus in the soil was 2.09 mg/L which demonstrated that concentration is very low for the tree seedlings planted (Table 4), where the soil test result was compared to the standard level of available phosphorus which is less than 3 ppm (USDA, 2001; Landon, 1991). Unlike nitrogen, phosphorous cannot be leached down the soil profile, but it can be washed from the soil by water and runoff (USDA, 2001).

The lower level of available phosphorous was caused by a lower concentration of organic carbon in the study site. This, in turn, may influence the growth of planted tree seedling in the area.

Soil pH and soil organic matter

The pH of the surface and subsurface soil profiles analyzed did not differ significantly (Table 4). The mean soil pH of the study site was 6.95 which shows, the soil was neutral that may no longer affects growth of planted tree seedlings when compared with the standard pH range of 5.5 to 7studied by Landon (1991).

This could be due to the increased organic matter in the topsoil, which may have increased the soil's buffering capacity and thus resistance to changes in soil pH. Despite a significant difference in cations between soil layers (Table 4), there was no significant change in pH, which could affect the planted tree seedlings.

The result of organic carbon was 1.41% in some parts of Ethiopia, the concentration of organic carbon shows great variation between degraded lands and forested lands. According to the finding of Amare et al. (2013), in heavy rain fall areas of Ethiopia like Anjeni the lowest organic carbon recorded was 0.2% in cultivated field and 13.68% in top soil of old forest. In addition, in areas like Wondogenet (Agroforestry based farming system) and Bale (Bale mountain National Park) both having high rain fall and soil organic carbon obtained was 3.37 in the study site which is low due to lack of vegetation cover with poor in quality as a result it may hinder plant health and growth.

The soil organic matter was 2.82% which was related to the findings of Corral-Nunez et al. (2014) in some protected and restored Northern parts of Ethiopia over 20 years. Similar findings were seen according to Olsenand Sommers (1982) where the concentration of soil organic matter was 5.6%. However, in cultivated areas its

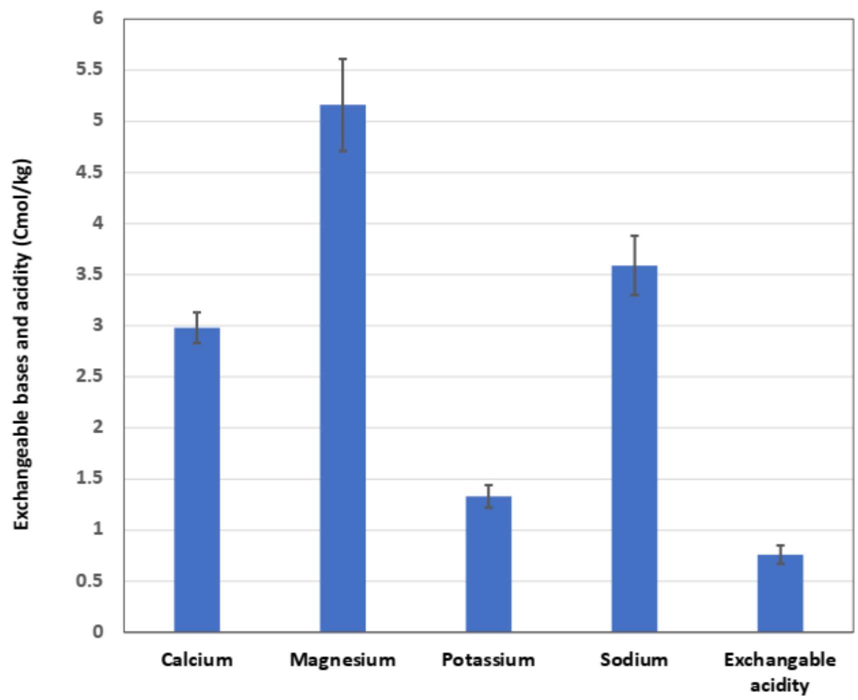

Figure 4. Average values and standard deviation of the exchangeable bases (Ca, Mg, K, and Na), and exchangeable acidity influenced at study experimental site.
Source: The average values of 3-5 experiments are represented as ±SE. Further details are described in Materials and methods.
Source: The average values of 3-5 experiments are represented as ±SE. Further details are described in Materials and methods.

concentration was very low (2.1 to 2.9%) as presented (Table 4). From this, it is easy to understand that study area is affected by shortage of soil organic matter that might result in poor soil quality to reduce growth and survival rate. The concentration of soil organic matter was higher at the surface than in the subsurface soil due to the higher amount of organic carbon at the surface than in the subsurface soil of the study area. This could be due to increased organic matter deposition (leaf litter, root) under trees and in the topsoil, as well as increased biological activities that promote organic matter decomposition and subsequent mineralization (Nega and Heluf, 2009).

Cation exchangeable capacity (CEC)

Cation exchange capacity is a useful indicator of soil fertility because it shows the soil ability to supply three important plant nutrients: calcium, magnesium and potassium. The result of cation exchange capacity was 13.2 mg/L which is medium (Mojiri et al., 2012), while comparing with the standard level of CEC that is the range between 5 and 15 mg/L (Table 4). The decrease in soil CEC values in farmland uses was primarily due to a decline in organic matter content (Nega and Heluf, 2009). According to the exchangeable cation and acidity test results, calcium and potassium were much lower than magnesium and sodium (Figure 4). However, Nicholas (2004) research found in line with that of exchangeable cation levels, such as potassium and sodium, were higher than normal.

The soil test results showed that the concentrations of Cu, Zn, and Fe at the experimental site were 1.18, 3.2, and 1.95 ppm, respectively (Table 4). These results were compared to the critical levels of the nutrients in the soil (Lanyon et al., 2004), where the concentration of Cu and zinc were high compared to concentration of Fe which was adequate (Jones, 2003). Hence, the level of Fe in the study site was suitable for planted tree seedlings growth but the elevated concentration levels of Cu and zinc might be one of the reasons for stunted growth of planted tree seedlings because the toxicity of zinc resulted in symptoms like chlorosis and low production of biomass (Marschner, 2011). According to authors, it was observed that increased organic matter may improve soil structure, aeration, and protect micronutrient oxidation and precipitation. Additionally, soluble chelating agents may help also to increase the solubility of micronutrients.

Conclusion

The preliminary evaluation that the *C. lusitanica* outperformed in terms of height, RCD and survival rate for twelve months after planting suggested that *C. lusitanica* is suitable for forest rehabilitation in the study area, and that this reforestation effort could yield positive results in the long run. Another possible reason for the significant growth rate in height and diameter associated with the high survival rate of *C. lusitanica* could be the adaptability of planted trees to grow in specific soil conditions (sandy soil). In addition, the ability of FYM to continuously release soil nitrogen, phosphorus, and potassium and similarly improve soil water-holding capacity was also compared to *C. africana*, which has the lowest survival rate. This could be due to the low resilience of sandy soil during the growing season, particularly in control plots where seedlings were damaged by nitrogen, potassium, phosphorus deficiencies, and copper and zinc toxicity. Similarly, urea had poor growth and survival rates, although they did better than control plots. Since there has been heavy rainfall throughout the year except in the month of February, this could be due to leaching of urea during the growing season. Fertilizer recommendations for tree species based on soil test must be a prerequisite issue not only to improve growth and survival rate, but also to reduce problems of over application (soil acidity) and underapplication (poor growth and survival rate) of planted tree seedlings. Well-prepared farmyard manure can boost growth in height, root collar diameter, and survival rate. As a result, more research is needed to determine the soil plant relationship of these tree species as well other edaphic factors that may affect the growth and survival of tree species under line planting technique.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Amare T, Hergarten C, Hurni H, Wolfgramm B, Yitaferu B, Selassie YG (2013). Prediction of Soil Organic Carbon for Ethiopian Highlands Using Soil Spectroscopy. International Scholarly Research Notices, Soil Article ID 720589 https://doi.org/10.1155/2013/720589.

Amha Y, Tesfaye MA, Kassa Z (2020). Growth and biomass production of some selected native and introduced tree/shrub species under severely degraded landscapes of West Showa Zone of Oromiya Regional State, Central Highlands of Ethiopia. Forest Research and Engineering International Journal 4(1):28-34.

Angus JF (2001). Nitrogen supply and demand in Australian agriculture. Australian Journal of Experimental Agriculture 41(3):277-288.

Ayalew G, Selassie YG, Elias E, Van Beak C (2014). Soil classification in Yigossa water shed; Lake tana basin, highlands of North western Ethiopia. Journal of Agricultural Science 7(1):106-116.

Barua SK, Haque SMS (2013). Soil characteristics and Carbon sequestration potentials of vegetation in degraded hills of Chittagong, Bangladesh, Land degradation Development 24:63-71.

Biro K, Pradhan B, Makeschin F (2013). Land use land cover change analysis and its impact on soil properties in the Northern part of Gadrif region, Sudan. Land degradation Development 24:90-102.

Bradshaw AD (1997). Restoration of mined lands-using natural process. Ecological Engineering 8:255-269.

Bremner JM Mulvaney CS (1982). “Nitrogen-total” in Methods of Soil Analysis, Part 2, Chemical and microbiological properties. A.L. Page Ed, SSSA, Madison, Wisconsin pp. 595-641.

Brown JD (2009). Statistics Corner. Questions and answers about language testing statistics: Choosing the right number of components or factors in PCA and EFA. Shiken: JALT Testing & Evaluation SIG Newsletter 13(2):19-23.

Chamshama SAO, Nwonwu FOC, Lundgren B, Kowero GS (2009). Plantation Forestry in Sub Saharan Africa: Silvicultural, Ecological and Economic Aspects. Discovery and Innovation 21(3):42-49.

Chavase GR (1980). Planting stock quality. A review of the factors affecting performance. New Zealand Journal of Forestry 25:144-171.

Corral-Nunez G, Opazo SD, Gebre SG, Tittonell P, Gebretsadik A, Gebremeskel Y, Tesfay G, Van Beek CL (2014). Soil organic matter in Northern Ethiopia, current level and predicted trend: A study case of two villages in Tigray. Soil Use and Management 30(4):487-495.

Cossalter C, Pye-Smith C (2003). Fast-wood forestry: myths and realities. Forest Perspectives No.1. Bogor, Indonesia, CIFOR. 54p. ISBN:979-3361-09-3.

Davis JA (1984). Complexation of trace metals by adsorbed natural organic matter. Geochimica et Cosmochimica Acta 48679-691. UGGS Publications Ware house https://doi.org/10.1016/0016 50(10): 2153-2164.

Deressaa A, Yli-Hallab M, Mohamed M, Wogic L (2018). Soil classification of humid Western Ethiopia: A transect study along a toposequence in Didessa watershed. Catena 163:184-195.

Eshete G (2019). Forest Management plan for selected Afforestation/ Reforestation and Assisted Regeneration sites in Mirab Abaya.Mirab Abaya, Ethiopia.

Evans J, Turnbull JW (1992). Plantation Forestry in the Tropics: The role, Silviculture, and the Use of Plantation forests for Industrial, Social, Environmental and Agroforestry purpose. Department of Environmental Science, Oxford University.

Food and Agriculture Organization (FAO) (2006). Guidelines for soil description. 4thedition.Rome, Food and Agriculture Organization of the United Nations. 97 p.

Food and Agriculture Organization (FAO) (2009). Eucalyptus in East Africa: The Socio-economic and Environmental Issues. Addis Ababa

Food and Agriculture Organization (FAO) (2010). Global forest resources assessment 2010 country report: Ethiopia (FRA2010/065). UN: FAO.

Gebeyehu W (2017). Germination and early growth Performances of *Cordia Africana* Lam. In pouted vertisol and Nitosol in Buchan, Town east Gojam zone, Amhara Regional state: Thesis. Department of Zoological Sciences,Addis Ababa University, Addis Ababa, Ethiopia.

Gebreyesus B (2013). Soil quality indicators response to land use and Soil management systems in Northern Ethiopia’s catchment, Land Degradation Development, Published online, doi:10.1002/ldr.2245.

Gill J, Sale P, Peries R, Tang C (2009). Changes in physical properties and crop root growth in dense sodic soil following incorporation of organic amendments: Field Crops Research 114(1):137-146.

doi:10.1016/j.fcr.2009.07018.
Hailu H, Mamo T, Keskinen R, Karltun E, Gebrekidan H, Bekele T (2015). Soil fertility status and wheat nutrient content in Vertisol cropping systems of central highlands of Ethiopia. Agriculture and Food Security 4(19):1-10
Hunt N, Gilkes R (1992). Farm monitoring Handbook, The University of Western Australia: Nedlands, WA.
Hurni H (1993). Land degradation and Land resource Scenarios in Ethiopia. Univestat Ben, Swizerland. 27-61
Jones JB (2003). Agronomic Handbook: management of crops, soils, and their fertility. CRC Press, Boca Raton, Florida, USA.
Kalinganire A (1996) Performance of *Grevillea robusta* in plantations and on farms under varying environmental conditions in Rwanda. Forest Ecology and Management 80(1-3):279-285..
Karanja NK, Mwendwa KA, Zapata F (1998). Growth response of *Grevillea robusta* A. Cunn. Seedlings to Phosphorus fertilization in acid soils from Kenya: Biotechnology, Agronomy, Society and Environment 3(1):51-64.
Karuku G, Mochoge BO (2018). Nitrogen Mineralization Potential (No) in Three Kenyan Soils: Andosls, Ferralsols and Luvisols. Journal of Agriculture Science 10(4):69-78.
Kassa B (2003). Livestock and livelihood security in the Harar highlands of Ethiopia. Doctoral Diss., Dept. of Rural Development Studies, SLU. Acta Universitatis Agriculturae Sueciae, Agraria vol. 388.
Kassa G, Ferde T, Nigatu A (2020). Improving growth and productivity of *Cordia africana* trees using moringa leaf juice in Northwestern Ethiopia. Cogent Food and Agriculture 6:1762980
Kebede F, Charles Y (2009). Soil Fertility Status and Numass Fertilizer Recommendation of Typic Hapluusterts in the Northern Highlands of Ethiopia. World Applied Sciences Journal 6:1473-1480.
Kindu M, Glatzel G, Tadesse Y, Amha Y (2006). Tree species screened on nitosols of central Ethiopia: Biomass production, nutrient contents, and effect on soil nitrogen. Journal of Tropical Forest Science 18(3):173-180
Kindu M, Glatzel G, Yohannes Y, Amha Y (2006). Performance of eight tree species in the highland Vertisols of central Ethiopia: growth, foliage nutrient concentration and effect on soil chemical properties. New Forests 32(3):285-298.
Kitaba F, Mama T, Negese W (2017). Adaptation and Growth Performance of Multipurpose Trees Under Haro Sebu Condition. Journal of Biology, Agriculture and Healthcare 7(23):13-18.
Lamb D (1998). Large Scale Ecological Restoration of degraded tropical forest lands: The potential role of timber plantations. Restoration Ecolology 6:271-279.
Landon JR (1991). Booker tropical soil manual: A handbook for soil survey and Agricultural land evaluation in the tropics and sub tropics. Booker Agricultural International, Longman Scientific and Technical Publications, Harlon. London.
Lanyon DM, Cass A, Hansen D (2004). The Effect of Soil Properties on Vine Performance," CSIRO Land and Water Technical Report 34/04.
Luoga EJ, Chamshama SAO, Iddi S (1994). Survival, growth, yield and wood quality of a species and provenance trial of *Cupressus lusitanica*, *Cupressus lindleyi* and *Cupressus benthamii* at Hambalawei, Lushoto, Tanzania. Silvae Genetica 43:1990-1995.
Madadi LM, Mathias SC, Mugasha WA, Nshubemuki L, Mwihomeke ST (2009). Comparative growth performance of different Australian provenances and local land races of *Grevillea robusta* at Lushoto and Ubiri in the West Usambara Mountains, Tanzania. Southern Forests 71(3):201-206.
Maliondo SMS, Mbaga PD, Sabas E, Pederson A, Madoffe SS (1999). Growth and nutrients variation between *Grevillea robusta* provenances in Tanzania. South African Forest Journal 183:66-71.
Mamo N, Sterba H (2006). Site index functions for *Cupressus lusitanica* at Munesa Shashemene, Ethiopia. Forest Ecology and Management 237(1):429-435.
Marschner H (2011). Mineral Nutrition of higher plants. 3rd Ed. Academic Press, London pp. 10-20.
Megan K (2013). Assessing the Plant Species, Mortality Rates and Water Availability under the Canopies in the Million Trees NYC Plots. http://www.nybg.org/press/files/forest/MeganSummer2013 Research Paper pdf.
Mehari A (2005). Growth and suitability of some tree species selected for planting in adverse environments in Eritrea and Ethiopia, Doctor's dissertation ISSN 1652-6880, ISBN 91-576-69902.
Moges Y, Eshetu Z, Nune S (2010). Ethiopian forest resources: current status and future management options in view of access to carbon finances. Ethiopian Climate Research and Networking; the United Nations Development Programme.
Mohammad B, Sharif A, Mohammad K (2012). Effects of organic manure on seedling growth and nodulation capabilities of five popular leguminous agroforestry tree components of Bangladesh: Center for Research on land use Sustainability Noahali, 3800, Bangladesh.
Mojiri A, Aziz HA, Ramaji A (2012). Potential decline in soil quality attributes as a result of land use change in a hillslope in Lordegan, Western Iran. African Journal of Agricultural Research 7(4):577-582.
Nega E, Heluf G (2009). Influence of land use changes and soil depth on cation exchange capacity and contents of exchangeable bases in the soils of Senbat Watershed, western Ethiopia. Ethiopian Journal of Natural Resources 11(2):195-206.
Ngugi MR, Mason E, Whyte AGD (2000). New growth models for *Cupressus lusitanica* and *Pinus patula* in Kenya. Journal of Tropical Forest Science 12(3):524 - 541.
Nicholas P (2004). Soil, irrigation and nutrition. grape production, Series No.2. South Australian Research and development Institute. Adelaide, South Australia.
Nyssen J, Poesen J, Moeyersons J, Deckers J, Haile M (2006). Processes and rates of rock fragment displacement on cliffs and scree slopes in an amba landscape, Ethiopia. Geomorphology 81(4):265-275.
Ogeh JS, Osioman GE (2012). Evaluation of the some oil palm on some physical and chemical properties of the Rhodicpaleults, Niger Journal of Basic Applied Sciences 20(1):78-82.
Okorio J, Peden D (1992). The growth performance of *Grevillea robusta* in the Highlands of Uganda. In: Harwood CE (ed.), *Grevillea robusta* in agroforestry and forestry: proceedings of an international workshop held on August 28-31 1990, at ICRAF's headquarters, Nairobi. Nairobi: International Center for Research in Agroforestry, pp.87-98.
Oldham L (2017). Fluid fertilizers. Mississippi State University Extension. Mississippi State, MS. P1466, pp. 1-4, http://extension.msstate.edu/publications/P1466_web.pdf .
Olsen SR, Sommers LE (1982). Phosphorus. In "Methods of Soil Analysis, Part 2" (A. L. Page, et al., Eds.), 2nd edn. American Society of Agronomy and Crop Science. Soil Science Society, Madison, WI, USA, pp.403-430.
Otieno HJO (1992). Growth performance of *Grevillea robusta* in various agro-ecological zones of Siaya District, Western Kenya. In: Harwood CE (ed.), *Grevillea robusta* in agroforestry and forestry: proceedings of an international workshop held on August 28-31 1990, at ICRAF's headquarters, Nairobi. Nairobi: International Center for Research in Agroforestry, pp. 81-85.
Ozgoz E, Guna H, Acir N, Gokmen FM, Birol M, Budak M (2013). Soil quality and Spatial variability assessment of land use effects in a typic Haplustoll. Land Degradation Development 24:277-286.
Reusing M (2000). Change Detection of Natural High Forests in Ethiopia using Remote Sensing and GIS Techniques. The International Archives of the Photogrammetry. Remote Sensing 33:1253-1258.
Rhoades JD (1983) Cation Exchange Capacity. In "Methods of Soil Analysis: Part 2 chemical and microbiological properties, 9.2.2., Second Edition. American Society of Agronomy. Soil Science Society, Madison, WI, USA, pp.149-157.
Rhoades, J.D. (1995). Salinity: Electrical conductivity and total dissolved Solids. In: Sparks DL (ed). Methods of Soil analysis, Part 3: Chemical properties. SSSSA, Madison, pp417-435.
Saha SS, Kukal D (2015). Soil structural stability and water retention characteristics under different Land uses of degraded lower himalayas of Northwest India. Land Degradation and Development 26(3): 263-271. https://doi.org/10.1002/1dr.2204.
Sanjith DP, Hegde R, Manasa CPA, Supriya KS, Singh K,

Maheswarappa V (2020). Performance of *Grevillea robusta* A. Cunn.Ex R.Br. Under Different Farming and Spacing Regimes. Journal of Tree Sciences 39(1):53-60.

Sibbet G, Ferguson L (2019). Olive Production manual: Division of Agriculture and Natural resources. University of California. UCANR Publications.

Siry J, Cubbage F, Ahmed MR (2005). Sustainable forest management: Global trends and opportunities. Forest Policy and Economics 7(4):551-561

Sorecha EM (2017). Growth and survival rate of endemic trees of Ethiopia: *Olea africana* and *Hagenia abysinicca* in the degraded lake of Haramaya Watershed, Ethiopia. Journal of Degraded and Mining Land Management 4(4):863-871.

Tadesse G (2013). Biodiversity and livelihoods in southwestern Ethiopia: Forest loss and prospects for conservation in shade coffee agroecosystems (Ph. D. dissertation). Santa Cruz, USA: University of California.

Tadesse G, Zavaleta E, Shennan C (2014). Effects of land-use changes on woody species distribution and aboveground carbon storage of forest-coffee systems**.** Agriculture Ecosystem and Environment 197:21-30.

Tadesse W (2012). The Status of Forestry development in Ethiopia: Challenges and Opportunities. National Dialog on Sustainable Agricultural Intensification in Ethiopia.

Tafese M (2007). Growth Performance of Three Indigenous and One Endemic Tree Species of Ethiopia on Degraded Site in Central-West Ethiopia. Addis Ababa University.

Tesfaye MA, Bravo F, Ruiz-Peinado R, Pando V, Bravo-Oviedo A (2016). Impact of changes in land use, species and elevation on soil organic carbon and total nitrogen in Ethiopian Central Highlands. Geoderma 261:70-79.

Totey NG, Bhowmik A, K, Katri PK, (1986). Growth of Teak Seedlings in Nursery. Indian Forester 122(9):792-799.

UNDP (2019). National forest sector development of Ethiopia. A situation analysis. Vol 1: UNDP, New York, USA.

U.S. Department of Agriculture (USDA) (2006). Keys to Soil Taxonomy. 10th Edition, United States Department of Agriculture, NRCS Soil Conservation Service, Washington DC.

U.S. Department of Agriculture (USDA) (2001). Soil Phosphorous Guide. NRCS 142 p2-053254.

Van DR, Palmioto PA, Strimbeck GR (1998). Allometric equations for South American conifers: test of non-destructive method. Forest Ecology and Management 106:55-71.

Walkley AJ, Black IA (1934). Estimation of soil organic carbon by the chromic acid titration method. Soil Science 37:29-38.

Warren JM, Meinzer FC, Brooks JR, Domec JC (2005). Vertical stratification of soil water storage and release of dynamics in Pacific North west Coniferous forests. Agriculture Forestry Meteorology 130(1-2):39-58.

Yakob G, Gizachew K, Fikadu A, Kassa K (2017). Growth performance of some multipurpose trees species around the homesteads in Gimbo District, South western Ethiopia: Bonga. Agriculture Forest and Fisheries 6(1):1-5. doi:101648/j.aff.20170601.11.

Yeshiwas Y, Yikeber B, Zewdie B, Chekol A, Walle A (2018). Effect of nitrogen fertilizer and farmyard manure on growth and yield of lettuce (*Lactuca sativa L.).* International Journal of Agriculture Research 13(2):74-79.

Yitbarek T, Beyene S, Kibret K (2016). Characterization and Classification of Soils of Abobo Area, Western Ethiopia: Department of Natural Resource Management, College of Natural Resource Wolkite University, P. O. Box 07, Wolkite, Ethiopia.

Zobel BJ, Talbert J (1984). Applied forest tree improvement. John Wiley and Sons. New York, USA. 505 p. ISBN 0-4.