Innovations

Effects of Eucalyptus (*E. camaldulensis*) tree plantation on the soil properties on Didessa Woreda, South Western Ethiopia

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Abstracts

Eucalyptus camaldulensis are widely planted all across Ethiopia including on large areas of land previously allocated to food production. In recent decades eucalyptus has also increasingly been planted on lands around and within "church forests," sacred groves of old-aged Afromontane trees. Due to the fast-growing nature of eucalyptus combined with its widely recognized socio-economic benefits (as fuel wood, charcoal, construction wood, etc.), this introduced species has been widely planted around and inter cropped on the agricultural lands in almost all parts of Ethiopia. In some cases even replacing native tree species with eucalyptus becomes common types of land use practices throughout the country. In many developing country contexts the introduction of exotic eucalyptus has been shown to have ecological impacts ranging from soil nutrient depletion, to lowering water tables, to allelopathic effects. In this study, I have collected a total of 5 composite soil samples from eucalyptus stands at four radiuses (1m, 5m, 10 and 15m) and from the adjacent agricultural plots with one depth (0-30cm) to investigate the effects of eucalyptus (E. camaldulensis) on the fertility of the soil comparatively with the adjacent agricultural plots. To achieve these objectives Didessa district was purposively selected based on the abundance of eucalyptus (E. camaldulensis) plantation. Minitab version 16 was used for statistical analysis of soil properties. The result of the experiment revealed that all the investigated soil physico-chemical properties (texture, BD, TP, MC, OM, TN, and Av.P) under both land use types (Eucalyptus stand and adjacent agricultural plots) were significantly different ($p \leq 0.0$ and $p>0.01$) except the pH values measured at all levels. Except sand and silt fractions, the soils under the stand of eucalyptus had the higher mean values for all the selected soil physico-chemical properties than the adjacent agricultural plots. Therefore, planting eucalyptus trees on a carefully selected site with continuous management may has a promising potential for biomass and forest area coverage enhancement.

Keywords: 1.Eucalyptus; 2.Agricultural land; 3.soil properties; 4.Strata

INTRODUCTION

Historical Background

Eucalyptus is a kind of evergreen and fast growing tree species, which was indigenous to Australia, Indonesia and Philippines, and is grown to provide paper pulp, wood, gum, and oil used in medicines [1]. Eucalyptus has 945 species, subspecies or varieties, among which 100 species (or subspecies or varieties) are economically important. Eucalyptus plantation forests have exceeded 18 million hectares around the world and they distributed mainly in Brazil with a plantation area of 3.1 million hectares and China with plantation area exceeded 2.5 million hectares by 2010 as the first and second largest countries of the world's [2]. Today *Eucalyptus* plantations cover at least 12 million ha throughout the tropical zone, 90% of which have been established since 1955

Europeans introduced *Eucalyptus* to eastern Africa during the second half of the 19th century and at the beginning of the 20th century. The introduction of the eucalypts to East Africa seems to have followed the serious forest decline and emergence of wood deficit in these countries [3]. At the moment Ethiopia has the largest area of *Eucalyptus* plantations in the east Africa and is one of the 10 pioneer countries that introduced the eucalypts. *Eucalyptus* is an efficient biomass producer, it can produce more biomass than many other tree species as we have concerned with empirical literature so far. *Eucalyptus* was introduced to Ethiopia in 1895 during Emperor Menelik II (1868-1907) from different countries, mainly from Australia. Seedlings were raised in the palace nursery and planted in the city. To assure its fast dissemination, seeds and seedlings were distributed freely to landowner with tax relief as incentive. People were also encouraged to protect the major indigenous forests. The Emperor also employed expatriates to set up the first forestry law in which all forests were declared state property. Accordingly, 'Crown Forest Land' was set aside to conserve natural forests [4]. About sixty kinds of *Eucalyptus* have been introduced to different regions of Ethiopia. Out of these the well adapted species such as *E. camaldulensis, E. globulus, E. grandis* and *E. saligna* are widely planted and have offered versatile multipurpose uses of economic importance [5].

The effects of Eucalyptus forest management on soil properties are not completely understood because the literature often reports contradictory results and conclusions. Although some authors have found significant loss in soil nutrients under Eucalyptus plantations as compared to native trees [6], others found no significant change [7] or even increases in SOC [8]. Currently the expansion of non-native species that are being used for fuel wood and construction materials is undermining the conservation of indigenous trees and is one of the major problem affecting the density and diversity of indigenous trees in farming communities particularly at Bunno Bedele Zone. The expansion of *Eucalyptus tree* plantation mainly *E. camaldulensis* is currently under taken both on farm lands and intercropped without considering its effects on the fertility of the soil that causes decline in yield and water availability. Due to its commercial values the people in the study area prefer and intensively expanding *Eucalyptus* (*E. camaldulensis*) trees plantation towards some remnant patches of natural forest through removing the native trees which is causing the degradation of species diversity in the area.

This activity has been practiced for long period of time in Didessa Woreda. Despite the long time practice of *Eucalyptus tree plantaion in Didessa Woreda*, information on the impact of this practice on the fertility of the soils and native tree diversity was not recorded so far. Therefore, this study will be aimed to investigate the long term effects of *Eucalyptus* tree on selected soil fertility indicators as compared with adjacent farm land soil.

MATERIALS AND METHODS

Description of study area

The study was conducted in Didessa woreda, Buno Bedele zone, Oromia region. The woreda is bordered by Gechi and Borecha woredas in north, Limmu Korsa in east, Sattama in west and Gumay Woredas in south. It is found to south western part of Ethiopia at the distance of 420 km from Addis Ababa. The land features of this woreda is characterized by plateaus of central and western plains of Didessa valley. The main river for this woreda is Didessa and the tributaries for this main river at this study area are Mulade, Asha and Dibo. Didessa is the smallest district among the nine Woredas of Buno Bedele zone with area of 615 km^2. The elevation varies in this area from 1360-2340 meter above sea level. The annual mean temperature for most part of the district is 13°C-28°C and annual rain fall is about 900-1000 mm.

The climatic condition of the area includes: Dega, woina Dega and kola cover 16%, 64%, and 20% of the district respectively. According to the report of Woreda's Agriculture and Natural Resource Office report of 2011, the land use systems of the Woreda were 4719.57 hectare for cultivation, 9848.45 hectare for grazing, 10682.7 hectare for forest, and 724 hectare for other types of use.

DATA COLLECTION METHODS

Soil sampling techniques

Before collecting soil samples reconnaissance survey was carried out to identify the abundant site in the presence of Eucalyptus trees. Stratified sampling technique was used to collect the composite soil samples at the radius of 1m, 5m, 10m and 15m from the stem of the tree (Eucalyptus). The purpose of stratifying the spaces in to four positions (1m, 5m, 10m and 15m) was to evaluate distance and shade effects on the selected soil fertility indicators and 1m distance from stem was to reduce root and microbial effects. Following this stratified sampling procedure five (5) composite soil samples were collected from randomly selected five to ten (5-10) points using augur from each distances at the depth of 0-30cm. The core sampler was used to collect undisturbed soil samples for bulk density and soil moisture content determination.

In order to minimize the effect of elevation deference and surface-erosion the samples were collected from nearly similar slope and similar soil types. Following these procedures a total of 5 composite soil samples 4 strata **(at 1m, 5m, 10m & 15m) x 1 depths + 1 control)** were collected and mixed. The sub-samples were thoroughly broken to make a uniform mix in clean plastic bucket for laboratory analysis to understand the effect of Eucalyptus trees on soil fertility in relation to its depth and spacing.

Soil laboratory analysis

The collected soil samples were air dried at room temperature then homogenized and passed through a 2mm sieve. The laboratory analyses were conducted using the following standard procedures at Bedele soil laboratories. Soil particle size distribution (texture) was be determined by hydrometer method [9]. Soil bulk density was calculated using core method through drying it to constant weight in an oven at a temperature of 105°c for 24 hours, whereas moisture percent was measured using gravimetric method [10]. Soil bulk density (BD gcm^{-3}) and soil moisture content (*MC %)* was estimated as:

$$\mathbf{BD} = \frac{W3-W1}{V}, \text{ and } \mathbf{MC} = \frac{W2-W3}{W3-W1} x100$$ (Craze, 1990)

Where,

W1 = Weight of core (g)

W2 = Weight of moist soil + core (g)

W3 = Weight of dried soil + core (g)

V = volume of core (cm^{-3})

Total soil porosity will be calculated as;

$$\text{Porosity} = 1 - \left(\frac{Bulkdensity}{Particledensity}\right)$$ by assuming particle density 2.65 gcm^{-3} (Warrick, 2002)

Soil pH was determined by pH meter with combined electrode in 1:2.5 soils: water ratio [11]. Organic matter content of the soil was computed by multiplying OC with a factor of 1.724. Total Nitrogen and available phosphorus was determined by Kjeldahl digestion procedure [12] and Bray II extract method [13], respectively. Exchangeable bases were determined after leaching the soils with ammonium acetate (1N NH40AC) (pH 7.0).

Statistical analysis

Laboratory analytical results on soil physicochemical properties was subjected and analyzed using statistical software Minitab version 16 and excel. Analysis of variance (ANOVA) was performed to assess the significance differences in soil parameters between the land uses, using the general linear model (GLM). Following significance variation Duncan's multiple range method (DMRT) was done for the computation of pair wise mean separation for both land uses at $\alpha = 0.05$.

RESULTS AND DISCUSSIONS

Soil Physical Properties by Sampling Locations

Soil Textures

The result presented in table 1 showed that the textural classes of the soil at (1m, 5m, 10m, and 15m) distance radius from eucalyptus and the adjacent agricultural plot showed clay loam. The analysis of variance revealed that the mean values of the clay fraction at 15m radius was significantly different from all three radius at 1m, 5m, 10m and the adjacent agricultural plot ($p \leq 0.01$). The sand (32%) and silt (37.8%) fractions was significantly ($P \leq 0.01$) affected by land use type where the highest were recorded under the adjacent agricultural land. The silt fraction also showed significant differences at 5m and 10m radiuses.

The highest clay content that observed at the 15m radius position may be due to slope transformation ability of the eucalyptus hedges that results in the accumulation of finer soil material that is being transported from the upper position to down slope. The highest sand and silt fractions recorded under adjacent agricultural plots might be as a result of intensive and regular cultivation which leads to the finer soil particle to be dislocated

Table 1: The mean values of Physical Properties of Soil

	Texture				BD (g/cm^3)	MC %	TP %
	Clay %	Sand %	Silt %	T.Class			
Control (Agriculture land)	33.6	32.00**	37.8**	C.Loam	1.11	19.5	56.9*
Strata One (at 1m)	36.0	30.03*	31.7	C.Loam	1.28**	23.87**	53.2
Strata Two (at 5m)	35.11	28.56	32.3**	C.Loam	1.21	18.82	54.0
Strata Three (at 10m)	34.7	30.13*	33.0**	C.Loam	1.34**	18.17	55.3*
Strata Four (at 15m)	38.6**	29.89*	30.3	C.Loam	1.1	17.3	58.7**

Means within a column with ** are significantly different at $p \leq 0.01$ and with * significantly different at $p > 0.01$.

Soil Bulk density, Moisture contents and Total porosity

The analysis of variance showed highly significant differences ($p \leq 0.01$) in mean values of soil bulk density at 1m (1.28%) and 10m (1.34%) radius, where there was no significant deference among the adjacent agricultural plots, at 5m and 15m radius. This is possibly due to the higher organic matter and clay content of the soil at the other locations than at 1m and 10m position. Several studied for example [14] indicated that relatively lower bulk density and higher total porosity are associated with the presence of higher OM and clay content. The soil moisture content showed highly significant differences at 1m radius which might be resulted from the shade values of eucalyptus that minimize evaporation of moisture from the soil. The highest total porosity of (56.9% & 55.3%) recorded at agricultural plot and 10m radius respectively showed significant differences at $p \geq 0.01$, and the value achieved at 15m radius (58.7%) showed highly significant differences. These significant differences on the soil BD and TP at different strata might be associated with the difference in the uniform distribution of SOM, clay fraction and erosion potential within those positions. However, during my soil sampling period I have interviewed some farmers about the effects of eucalyptus when inter-cropped and they have responded the crops grew under the shade eucalyptus becomes less productive and perform poorly. But due to its economic significances they regularly used the trees for sale and construction purpose, which mainly reduces the shade effects.

SOIL CHEMICAL PROPERTIES BY SAMPLING LOCATIONS

Soil PH and Organic Matter

The samples collected in the study location reflects a moderately weak acid range, with mean pH values of 4.9 at 1m radius, 4.7 but the value measured at all locations and at adjacent agricultural plot didn't show significant differences (table 2). The mean Organic matter content differed significantly between the strata one (1m) 7.0 and strata two (5m) 8.6 showed highly significant differences at $p \leq 0.01$ from both agricultural plots and at 15m strata, whereas the value recorded at 10m location also indicates significant difference at p>0.01. These indicated Eucalyptus stands had significantly higher organic matter content than agricultural soils. Thus, Eucalyptus stands had a greater abundance of organic matter than agricultural fields as indicated on table 2 below, suggesting that agriculture may be a less beneficial land use for accruing soil organic matter. There was no significant difference in pH between the eucalyptus and agriculture plots, suggesting that in comparison to agricultural practices, eucalyptus may have comparable effects on soil acidity, consistent with recent work [15].

Table 2: The mean values of Soil pH, Organic matter, and total nitrogen and Av. phosphorus

	PH	OM %	TN %	Av. P (ppm)
Control (Agriculture land)	4.9	4.5	0.2	5.51*
Strata One (at 1m)	4.9	7.0**	0.26*	6.92**
Strata Two (at 5m)	4.7	8.6**	0.3**	6.68**
Strata Three (at 10m)	4.7	5.9*	0.22	4.7
Strata Four (at 15m)	4.7	4.8	0.2	3.4

Means within a column with ** are significantly different at p≤0.01 and with * significantly different at p>0.01.

Total Nitrogen and Available Phosphorus

Similar patterns in significant differences were observed between the mean values of TN and Av.P recorded at strata one (1m) 0.26 and strata two (5m) 0.3 showed significant differences from the other strata and adjacent agricultural plot at p>0.01 and p≤0.01 respectively. There was also statistically highly significant difference between the mean values of phosphorus levels recorded at strata one (6.92) and strata two (6.68) at p≤0.01, where the adjacent agricultural plot also showed significant difference (5.51) at p>0.01

The higher in mean nitrogen and phosphorus levels in the eucalyptus plots in comparison to the agriculture plots could also be explained by the significantly different quantities of organic matter, due to the obvious difference in leaf litter. Agricultural fields, which are cultivated and harvested more frequently than eucalyptus plantations, can lose a lot of additional nutrients and organic matter in its topsoil [16]. Though fertilizers can add large amounts of nitrogen and phosphorus to the soil in agriculture lands, they are also being actively used by the crops and at times cannot compensate quickly enough for the amount of nutrients being taken up by the crops, and the soil can become impoverished. Soil acidity intensifies with exhaustive farming over a number of years with the use of fertilizers or manures [17, 18]. The agricultural land surrounding stands of eucalyptus sites have been cultivated for long periods of times, and where available, fertilizers and manure have been used to maximize crop production, potentially reducing acidic pH levels in agriculture plots.

CONCLUSSION AND RECCOMMONDATIONS

Smallholder eucalyptus planting on agricultural land can have great implications for larger development issues such as food security. The impacts of eucalyptus species on soil health remain hotly debated among scientists and development practitioners. Our results indicate that soils in eucalyptus stands exhibit higher organic matter and nutrient levels in comparison to nearby agricultural land, and no significant decrease in soil pH. In our analysis eucalyptus stands appear to be more favorable than agricultural crops in terms of the observed soil properties; this conclusion is not without significant caveats. There are other ecological effects of eucalyptus on agricultural land that are not tested in this study, but nevertheless are important considerations in eucalyptus systems, such as water use and the allelopathic impact of eucalyptus trees on neighboring crops and forests. Also it is better use eucalyptus on the recommended sites with regular management practices to enhance biomass production and minimize the intensive utilizations of native trees. Biomass production and minimize the intensive utilizations of native trees. Further research needs to be done to understand the roles eucalyptus planting might play as part of integrative strategies for soil rehabilitation and natural forest restoration in the degraded lands, and also Further research could be undertaken on the cooperative study with indigenous tree species.`

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