# Impacts of *Eucalyptus* Plantations on Soil Physiochemical Properties and its Economic Implications of Jarso Woreda, West Wollega Zone of Oromia

**Dessalegn Etana[1]*, Shabu Jemal[2]**

[1] Department of Natural and Environmental Science, Wollega University, Oromia, Ethiopia
[2]Deapatment of Forestry, Wollega University, Oromia, Ethiopia

Research Article

**Received:** 19-Feb-2022, Manuscript No. JEAES-22-52608; **Editor assigned:** 20- Feb-2022, Pre QC No. JEAES-22-52608 (PQ); **Reviewed:** 03- Mar-2022, QC No. JEAES-22-52608; **Accepted:** 07-Mar-2022, Manuscript No. JEAES-22-52608 (A); **Published:** 10-Mar-2022, DOI: 10.4172/ 2347-7830.10.02.006

***For Correspondence:**
Dessalegn Etana, Department of Agriculture, Woldia University, Amhara, Ethopia;
Tel:251910069023;
**E-mail: desalagnetana@yahoo.com**

**Keywords:** *Eucalyptus* tree, Natural Forest, Soil properties

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## ABSTRACT

Different tree species are blamed to have negative effects on soil ecosystems by changing soil physicochemical properties, and hence soil quality. However, few researches to verify this statement in Ethiopia. This study investigated the effect of *Eucalyptus* plantations on selected soil physical and chemical properties in Jarso wereda west wollega of Oromia regional states. To conduct the study three land-uses (*Eucalyptus* plantations, croplands and natural forests) were used for comparison. Each experimental plot was sub-divided into three sub-plots for soil sampling. Sampling was done to 30 cm depth with soil auger for soil sample except soil moisture content which the sample was taken from 0-30 cm and 30-60 cm. The soil samples were dried and analyzed while following standard procedures. One way anova test result indicated that *Eucalyptus* plantations have significantly different effect on soil parameters such as texture (sand, silt and clay), soil moisture contents, pH level, total nitrogen, and organic. However, the three land uses/covers did not significantly differ from each other in influencing the soil bulk density, Avp and CEC.

Due to the less decomposition rate of the *Eucalyptus* leaves and debris collection for fuel could result in lowest soil organic carbon of *Eucalyptus* plantation soils. The presence of highest, cation exchange capacity and in cultivated land soil was related to application of artificial fertilizers. Natural forest soil soils have highest soil pH values, total nitrogen and organic carbon which can be related to the leave and debris return and less surface run off on natural forest.

## INTRODUCTION

*Eucalyptus* is among the most widely cultivated forest trees in the world. The major *Eucalyptus* growing countries are: China (170 million ha); India (2.5 million ha) and Brazil (3.7 million ha) [1-4]. In Africa, South Africa has the largest area under *Eucalyptus* plantations of about halfa million hectares [5].

The term *Eucalyptus* has been derived from two Greek words, “eu” meaning “well” and “kaluptos” meaning “covered”, a botanical reference to the trees, flowers and fruits [6-8]. Globally, *Eucalyptus* comprises more than 900 species and unknown number of hybrids and varieties [9]. Most *Eucalyptus* species (eucalypts) occur naturally in Australia. A few species are naturally found in Philippines, Papua New Guinea, Indonesia and Timor. *Eucalyptus* grows in diverse ecological conditions with some hardy species growing in semi-arid areas, while others are able to grow on marshy and swampy sites. *Eucalypts* also grow under a variety of soils including fertile loamy soils, infertile sands and heavy clays [10]. The major planting of the eucalypts, outside its native environment of Australia, the Malaysian region and the Philippines, started in 1904 in Brazil [8,11].

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. A dramatic decline in forest cover in eastern Africa along with a growing population means that timber; poles for building and wood for fuel are in short supply. To overcome this shortage, the region is increasingly turning to *Eucalyptus* plantations [12].

In Ethiopia the genus was introduced during the reign of Emperor Menilek II (1868-1907) in 1894/95(Von Breitenbach [13]. The purpose was to supply fuel wood and construction timber to the new and growing capital city, Addis Ababa. In the 1970s, the plantation area around Addis Ababa was about 15,000 ha while in other parts of the country approximately 76,000 ha of plantations had been established.

Currently, about 55 species of eucalyptus have been grown in Ethiopia, of which between five species are widely planted. In Ethiopia, the most widespread species include *E.camaldulensis, E.citriodora, E.globulus, E.regnans, E. saligna* and *E.tereticornis; E.globulus* and *E. Camaldulensis* are the major species planted in the highlands of Ethiopia [14].

In recent years, single rows of *Eucalyptus* species planted along field borders, along the road side and expansion of *eucalyptus* plantation on previous crop land have become a dominant feature of the western Ethiopia including the Jarso district. Expansion of *Eucalyptus* plantations would create competition between agricultural crops, grazing land and other native tree species for land area major resources (water and soil nutrients). The study was conducted to access the impact of *Eucalyptus* plantation on soil physicochemical properties and factors contribute the massive plantation of *Eucalyptus*.

## Statement of the problem

*Eucalyptus* spp. (*Eucalyptus camaldulensis, E.citriodora, E. globulus*) remains part of the dominant tree species planted in the study area. It is planted in various parts of the area to meet the demand for fuel wood, building construction, timber, electricity poles, charcoal production and cushion farmers when the markets for their agricultural produce fail or are low, reports such as drying up of water sources, affecting the soil properties, tendency to deplete soil nutrients and fertility, suppression of other vegetation, reduction of forest biodiversity and reducing crop yield in agro-forestry systems have been made.

To safeguard and maintain the sustainability of the economic and environmental resources in the area, it is vital to assess the effects of *Eucalyptus* species soil physo-chemical properties.

## Objectives of the study

### General objectives

- To investigate the impacts of *eucalyptus* plantation on the environment and its economic implication.

### Specific objectives

- To determine *Eucalyptus* plantation on soil chemical properties
- To assess the impacts of *Eucalyptus* plantation on soil physical properties
- To assess factors influencing *Eucalyptus* plantation

### Significance of the study

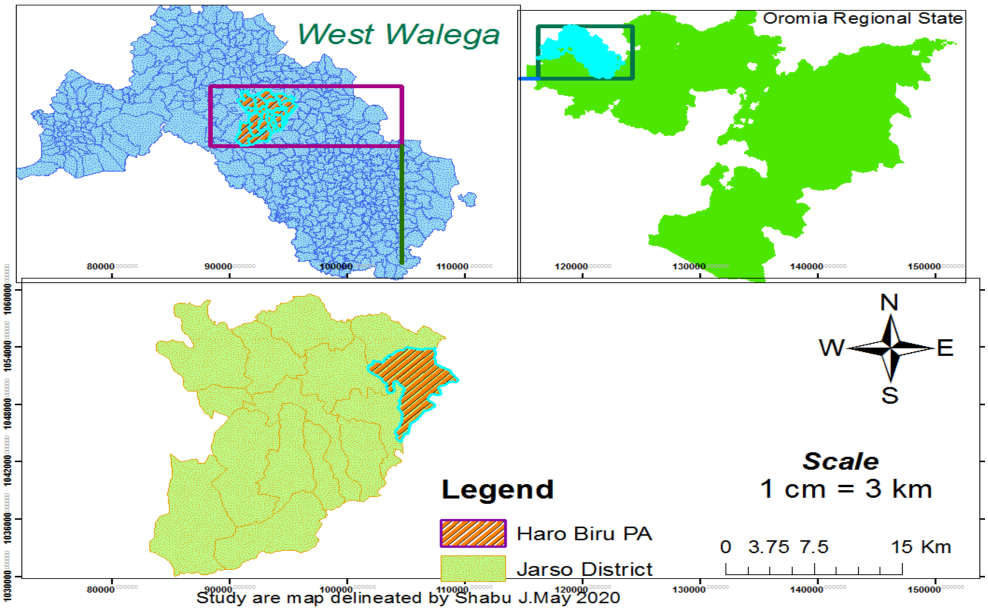
The outcome of this research would be beneficial the local community, experts at district, zone, and region and national level. The findings was also facilitate monitoring and evaluation of *Eucalyptus spp*. plantations by regarding their effects on the soil properties in Jarso District, west Wollega, Ethiopia (Figure 1).

e-ISSN: 2347-7830
p-ISSN: 2347-7822

## MATERIALS AND METHODS

### Description of study area

**Figure 1**. Map of the study area. Note: ( ) Haro Biru PA; ( ) Jarso District




### Location of study area

The study was conducted at Jarso district of west Wollega zone which is far away 103 km from Gimbi town and 514 from Addis Ababa to the West direction. The study area is located at 9° 20' N-9° 40' N latitude and 35° 20'E-35° 40'E longitude. The district is enclosed by LataSibu district in the North east, Najo district in the south east, BaboGambel district in west and Gulliso in south west.

### Topographic features

Jarso is generally gentle plains from the East to west, and there are few very steep slopes around northern part to Aleltu River and southern part to Dila River. The altitude ranges from 1420 meters above sea level at the lower zones to about 1878 meters above sea level in the east and North Eastern part. (Jarso irrigation development authority office Report, 2017).

### Climate and temperature

The Jarso District is experiences an annual average rainfall ranging between 1000 and 1350 mm which vary along the agro-ecological zones with three distinct peaks in June to August (Asossa Meteorological Department, 2016).

The temperature in the study area varies from humid to semi-humid characteristics. The mean annual temperature in the humid zone varies between 16° C to 22° C; while in the sub-humid to semi-humid zones the mean annual temperatures vary between 24° C and 28° C. The annual maximum temperatures range from 25° C to 31° C in the months of February, March, and April respectively, while the minimum temperatures range from 16°C and 22°C in the months of December and January respectively (Asossa Meteorological Department, 2012).

### Farming system

The main economic activities in the District are subsistence and commercial farming. Commercial farming mainly involves the growing of coffee, Guizotia abyssnica (noug) and other food crops. Subsistence farming involves the growing of maize, sorghum, millet, beans, potatoes, Yams, bananas, orange, mango, sugar cane, sweet potatoes, and vegetables. Almost all farmers in the district plant *Eucalyptus* for fuel wood and construction as well as commercial purpose. Most typical type of farming practiced in the District is mixed cropping. Livestock rearing cattle, goats, and sheep is another important activity in the Jarso district. Donkeys and mule are an important form of transport, particularly for firewood, water and other goods for the market (Jarso agricultural office report 2017, Jarso animal and fish production and marketing office report, 2017).

### Experimental design

The effects *Eucalyptus* on selected soil physical and chemical properties was studied by collecting soil samples from three different land use types. The experimental design for this study was Randomized Complete Block Design (RCBD) in which the land use types were considered as treatments. Three land use types, namely, *Eucalyptus* woodlot, cultivated land, and forest, were selected for comparison as treatments. Forestland was considered as control treatment in the study. The three adjacent land use types, which shares similar biophysical condition such as soil and slope, are grouped in a block. Four replications of each land use type were used in the four deferent sites forming at total of twelve sample plots.

### Soil sampling

The soil samples were collected from three land use types at three deferent sites in Haro Biru of Jarso district. From each site, three soil sampling locations were systematically selected with having three adjacent land use types. The three land use types within each site have similar topography and other conditions. The soil samples were collected at twelve points with four replications of land use types in the study area. Plot with square dimension (20 m × 20 m) was laid at the middle of each land use types. The pits were dug at four corners and center of the plots using auger, and two soil samples were taken from the pit at two soil depths (0-30 cm and 30-60 cm) for soil moisture while the other samples taken from 0-30 soil depth.

### Soil laboratory analysis

Composite soil samples was collected for homogeneity of soil from all plots at 0-30 cm using Auger and the selected physical and chemical properties including texture by Bouyoucos hydrometer method (Day, 1965), organic carbon using Walkely and Black method (Neilsan and Sommers, 1917) and total nitrogen using Kjeldahl digestion and distillation method (Bremner and Mulvaney, 1982), available phosphorous (Olsen and Dean (1965), Soil pH was determined at soil: water suspension ratio of 1:2 using a conventional glass electrode pH meter at Bedele Soil Research Center of Oromia Agricultural Research Institute (OARI)[15].

**Texture:** Texture determination was carried out using the hydrometer method (Day, 1965).

## Data analysis

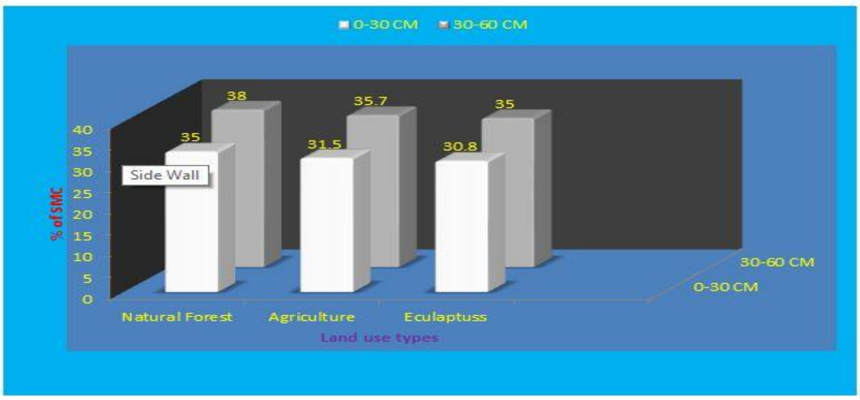
The collected data were subjected to Analysis of Variance (ANOVA) using General Linear Model (GLM) procedures in SAS version 9.2.3 (SAS Institute, 2002). Means that were significantly affected by the treatments were separated using the Least Significant Differences.

# RESULTS AND DISCUSSION

## Soil physical properties

Soil moisture contents the three land use. The data of the soil moisture contents of the study area presented in Figure 2 showed that plantation of *Eucalyptus* was significantly influence the soil moisture content. The higher mean value of soil moisture content of plots with of natural forests was 38% at 30-60 cm and 35% at 0-30 cm soil depth. On the plots of agricultural land, the mean value of soil moisture content were 35.4% at 30-60 cm and 31.53% at 0-30 cm soil depth in the plots with while 30.75% at 0-30 cm and 34.5% at 0-60 cm soil depth in the plots of *Eucalyptus* woodlots. The results exposed that natural forest improve soil moisture content since the land was almost all covered by litter fails on the grounds and other plant materials mulching the grounds. In contradiction to the above findings had estimated that the *Eucalyptus sp*. had high water holding capacity in the soil (Figure 2) [16].

**Figure 2**. Soil moisture content affected by level soil bund at 0-30 and 30-60 cm.




## Soil bulk density and texture

Soil Bulk Density (BD) (g $cm^{-3}$) was affected by different land uses. As the present study, the soil bulk density was ranges from 0.92 g $cm^{-3}$ (natural forest) to 1.06 g $cm^{-3}$ (plots of eucalyptus woodlots) (Table 1). Cultivated land had the higher bulk density value when compared with, while forest had the lowest bulk density as compared to others. The lower mean soil bulk density value of the natural forestmight is the subsequent effects of reduced soil loss and leaf fail from the natural forest. As reported by Mongia and Bandyopadhyay [17] the replacement of virgin forest with highly valued plantation species likes *S. robusta, T. grandis* and *Elaeisguinensis* plantation in Andaman led to a rapid deterioration in soil physical properties and found that bulk density of the surface soil increased to (1.30 gm/cc), (1.49 gm/cc), (1.35 gm/cc) and (1.28 gm/cc) in plantations respectively, compared to bulk density of 1.05 gm/cc in the virgin forest (Table 1).

**Table 1**. Mean value of on selected soil chemical properties affected by soil bund.

| Treatment | BD (g cm-3) | Sand (%) | Clay (%) | Silt (%) | Textural class |
|---|---|---|---|---|---|
| Forest land | 0.92 | 26.28 | 31.72 | 37** | Clay loam |
| Agricultural | 1.03 | 29.5 | 33.72 | 33.5* | Clay loam |
| Eucalyptus | 1.06 | 25.48 | 3.79 | 32 | Clay loam |
| LSD | NS | 1.23 | Ns | 1.34 | |
| CV% | 4.32 | 4.68 | 5.96 | 9.57 | |

**Note:** *p<0.05, **p<0.01, ***p<0.001

## Soil chemical properties

**Soil (pH):** Soil pH was significantly affected by of eucalyptus tree when compared with natural forest. So that, the higher mean pH value obtained from the plots of natural forestland (5.8) while lower pH value and obtained from the plots of eucalyptus plantation(5.08) and agricultural land(5.03) respectively (Table 2). But there is no significant difference between agricultural land and eucalyptus land. There was significant deference ($p \leq 0.05$) in soil pH between natural forestland eucalyptus plantation lands (Table 2).The mean pH of soils in forestland>eucalyptus land>agricultural land.

The soils in cultivated land were more acidic than the other land use types in the area. This can be due to application of ammonium-based fertilizers, erosion, and improper ploughing direction. Both soil nutrient levels and soil pH tend to decrease after the first *Eucalyptus Coppice*, after the initial establishment of the *Eucalyptus* plantation. In comparison to other plantation type trees, like the indigenous *Juniperus Procera*, *Eucalyptus* species, specifically the species *Eucalyptus Globulus* that is commonly found in the Ethiopian Highlands, typically have lower soil nutrient contents as funding of Michelsen A [14]. Also the study conducted in our country by Lemenih showed that sites where *Eucalyptus* was grown showed increased soil acidity while the base saturation declined compared to native vegetation sites and adjacent agricultural lands [18].

**Total Nitrogen (TN):** The statistical significant difference was observed ($p<0.05$) in TN as a result of *Eucalyptus* plantations. The higher mean values of TN (0.66) observed in the plots of Natural Forests. According to the present study the plots of agricultural land and eucalyptus plantation gives the mean values of TN (0.32 and 0.25) respectively. In natural forest site due to higher the number of trees species and complex structure, there is higher amounts of the leaf nitrogen content that supports the existence of more nitrogen in the soil. As Janice Liang [19] Nitrogen and phosphorus levels were higher in the indigenous forest than in the *Eucalyptus* and agricultural areas, where there are also significantly higher amounts of organic matter Kindu [20] also showed that *Eucalyptus* species have lower soil N contentment when compared to other some tree species. For instance under *E. camaldulensis* and *E. globulus* 21.31 and 17.14 mg.g$^{-1}$ soil N was reported respectively. Many studies indicate the nutrient depleting ability of *Eucalyptus* species. For example, Forrester [21] reported that mixed plantations of *Eucalyptus* species with nitrogen fixing tree species have the ability to increase site productivity by maintaining the soil fertility as compared to monoculture plantations of *Eucalyptus* (Table 2).

**Table 2.** Mean value of on selected soil chemical properties affected by soil bund.

| Treatment | TN (%) | AvP (ppm) | PH(1:2$H_2O$) | OC (%) | CEC(meq/100g) |
|---|---|---|---|---|---|
| Natural Forest | 0.66 *** | 6.31 | 5.8 ** | 6.87 *** | 32.12 |
| Agriculture | 0.32 ** | 2.5 | 5.03 ** | 4.57 ** | 28.74 |
| Plantation | 0.25 ** | 3.75 | 5.08 ** | 3.92 ** | 26.54 |
| Lsd | 1.12 | ns | 1 | 1.1 | ns |
| CV% | 30.98 | 18.97 | 7.67 | 23.26 | 13.75 |

**Note:** *$p$<0.05, **$p$<0.01, ***$p$<0.001

### Ns represent no significance difference were observed between the three land uses

**Available Phosphorus (AvP):** The mean values of available phosphorus of the soils sampled from the Natural Forest plots were higher than that of *Eucalyptus* plantation and agricultural plots. Therefore the higher mean value (6.31 ppm) and the lower mean value (2.5 ppm) of AvP were observed under the plots of Natural forest and *Eucalyptus* plantation plots, respectively [22]. The mean values AvP agricultural land was low when compared with the other land uses due the loss of nutrients by continuous cultivation and low land management practice in the study area. The results was supplemented by finding of Singwane S [23] that statues the more degraded status of the soils in agricultural fields and eucalyptus plantations in comparison to natural forests may also be indicative of the varying management practices of these different sites. Constant tillage and continuous cultivation for food crops and similarly the frequency of cultivation and harvest of plantation species such as *Eucalyptus* can negatively impact the quality of soils [24] also found that the phosphorus content was lower in mature leaves than young ones for tree species of *A. mearnsii, E. globulus, E. fraxinoides E. grandis and P. radiate*.

**Cation Exchange Capacity (CEC):** The numerical values, the higher mean value of CEC (32.12 meq/100 g) and the lower mean value of CEC (26.54 meq/100 g) were observed under the plots of natural forest soil and plantation forest, respectively (Table 2). So, as the present studies soil CEC of the study site ranges from 32.12-26.54; this could indicate that it is grouped into the soil salinity class of non-saline soil. The CEC of the soils could depend on the amount of moisture present in the soil. The agricultural soils had the highest CEC value, while *Eucalyptus* land soils had the lowest CEC value as compared to others. The higher CEC can be related with the presence of higher exchangeable sodium and potassium in the soils that can be related to the application of fertilizer. The CEC of a soil is strongly affected by the amount and type of clay, and amount of OM present in the soil Curtis and Courson [23] and Soils with CEC less than 16 meq/100 g are considered not to be fertile. Based the Curtis and Courson category the soil of the study area categorized under fertile soil.

Adugna and Abegaz [25] have found higher CEC in grass land soils than cultivated land soils. As their report CEC can be related with soil carbon, clay content, and pH value of the soil. The lower CEC value in *Eucalyptus* woodlot soils can be related with the lower soils' pH value (more acidic soil). After the study of soil carbon and nutrient accumulation under forest plantations in southern Rwanda, Nsabimana [26] reported lower level of CEC under Eucalyptus than most native and exotic tree species. For instance, under *E. grandis* plantation site 7.0 cmol $kg^{-1}$ has been observed. Variations in cation exchange capacity are controlled by leaching of exchangeable ions coming from top soils [26]. In forest plantations, these exchangeable ions are probably increased by high levels of litter fall from tree species, shrubs and herbs. They might be also related to the activities and symbiosis of mycorrhizal fungi that reinforce the decomposition rate [27-29]. Application of fertilizers, which can initiate the presence of cations on cultivated land, can also affect the CEC of cultivated land soils.

## Organic carbon

The values of soil organic carbon in the study area was significantly ($p<0.05$) affected by plantation of eucalyptus tree. As the result numerically the higher mean value of OC 6.87 % and the lower value OC 3.92 % recorded in the plots of natural forest and eucalyptus plantation respectively. In several findings, natural soils can accumulate higher soil carbon than other land use types. The decomposed humus from roots and above-ground biomass in the upper layer of the natural forest especially the titter fails soils increase the carbon content. But, on the cultivated land the accumulation of organic carbon was law due to the repetitive cultivation of the land. Also on the eucalyptus land the composition of organic carbon was law since the leaf of eucalyptus was low decomposition rates. According to Reganold J [30] agricultural fields, which are cultivated and harvested more frequently than eucalyptus plantations, can lose a lot of additional nutrients and organic matter in its top soil. Another study by Turner and Lambert [31] in Brazil showed that the soil organic carbon content was less in *Eucalyptus* plantations compared to the adjacent native vegetation site. Concentration of soil organic carbon (14.6 mg $^{g-1}$ soil) and the size of soil microbial (246 µg of C and 44 µg of N $^{g-1}$ soil, respectively) and micro fungal biomass (243 µg $g^{-1}$ soils) was also the least in the plantation site compared to natural and regenerating forest [32].

Other studies indicated that variations in soil organic carbon are influenced by the litter fall added to the soil from trees and shrubs dead roots, and biochemical activities of mycorrhizal fungi as well [33,34]. Actually, the richness in soil organic carbon is very important for soil ecosystems. Soil organic carbon was also appreciated to supply nutrients in soil, facilitates soil exchange of cations, soil aggregation, and increases the capacity of soil to hold water.

### Factors influences *Eucalyptus* plantation

According the idea derived during data collection at the construction, fire wood, farm implements are primary values of *Eucalyptus*. *Eucalyptus* has several desirable economic benefits since it generate income at household. The eucalyptus are great contribution to increasing the household incomes through the purchasing *Eucalyptus* by products likes charcoal, pools and the likes These idea was supported by the study of Mekonnen [35-40] finding on the eucalyptus plantation factors driving farmers to plant *Eucalyptus* are: increasing demand for wood products in the market, the unavailability of wood on farm, its high rate of biomass production, its ease of cultivation and wider adaptability, its non-palatability to livestock, the decline in land productivity for agricultural use, the decline in off-farm employment opportunities *Eucalyptus* generates substantial income to rural households [41-43]. In addition to income generation several factors encourage the community to plant more eucalyptus tree on their lands. The increased cost of fertilizer and the reduction of land productivity are the majors

## CONCLUSION

It is concluded that *Eucalyptus* tree plantation have negative impacts on soil physio -chemical properties since the high mean value of soil moisture contents, soil structures, soil pH values, total nitrogen and organic carbon observed on the plots of natural forests Especially, the existence natural forest in a relatively high rainfall area of western Wollega has improved soil properties which affected by soil acidity that related with poor land management, high rainfall and rugged topography. This study confirms that natural forest did increase the soil moisture content than the plots of agriculture and eucalyptus plantation sites at the soil depth of depth of 0-30 cm and 30-60 cm since the soil covered by litter fall and other plant materials.

## RECOMMENDATIONS

Based on the finding the following recommendations are forwarded,

- The establishment of fast growing *Eucalyptus* tree for longer periods of time can lead the soil into insufficient nutrient content and more acidic character. Such consequences should be accepted at the local and national level when dealingwith *Eucalyptus* species. Therefore, it is recommended to maintain site productivity for long production periods protection and management of natural forest and plantation of endogenous forest tree species
- As the results of study conducted the *Eucalyptus* tree species great value for inco me generation. Even if it has great contribution for income generation, these tree species many negative impacts on the environments. So, Eco-friendly indigenous plants which increase soil fertility is to plant by mobilizing the community in continuous manner in and sounding the crop land which can give dual benefit.

## ACKNOWLEDGEMENT

First and foremost, I would like to thank Lord God Almighty for giving me the strength and courage to go through all this work. In addition, I would like to be grateful for Wollega University for immense provisions rendered to me fund.

I would like to acknowledge Jarso District Agricultural Office and Development agents for their remarkable help during my fieldwork in Jarso district HaroBiru site for their support in providing necessary data, information and materials needed for the research work during data collection in the study area. I am also grateful to the farmers of the study area who responded to my numerous questions with remarkable patience. The help rendered by all the laboratory technicians of Bedele Soil Research Laboratory are highly appreciated for their collaboration.

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