JATROPHA CURCAS L. FOR REHABILITATION OF DEGRADED LAND OF GILGEL GIBE WATERSHED, SOUTH WESTERN ETHIOPIA

M.SC. Thesis

Sisay Assefa

May, 2015

Jimma, Ethiopia

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Submitted to the Jimma University, School of Graduate Studies, College of Agriculture and Veterinary Medicine, Department of Natural Resources Management

In Partial Fulfillment of the Requirements for the Degree of Master of Science in Natural Resource Management (Watershed Management)

May, 2015

Jimma, Ethiopia

DEDICATION

This piece of work is dedicated to the memory of my late brother Bahiru Assefa. Because he was everything for my success until he passed away in 2011. Brother, my hope was only you! But I do nothing rather pray to God to sanctify your soul in the heaven and give him peace rest.

DECLARATION

This thesis is my original work it has never been submitted in any form to other university and it has never been published nor submitted for any journal by another person and all sources of materials used for the thesis have been appropriately acknowledged.

Name___________________________________

Signature________________________________

Place ___________________________________

Date of submission_______________________

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BIOGRAPHICAL SKETCH

Sisay Assefa was born September 01, 1985 in Kersa Woreda of Jimma Zone, Oromia region. He attended his elementary at Dilfere Elementary school from 1993-1998 and junior secondary school from 1999-2000 at Seto Semaro school in Jimma Town. He attend his secondary school at Jimma Academic and Vocational Training Institute (JAVTI) from 2001-2004. He joined Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) in September 2005 and graduated with BSc Degree in Natural Resource Management (NRM) in July 2007. After graduation, he was employed in Jimma Zone, Omo Nada Woreda Agricultural office where he served as an expert of natural resource management and coordinator of sustainable land management project (SLMP) at Woreda level from 2008-2009. Besides, from 2010-2012, he served as head of the land and environmental protection office and sustainable land management project (SLMP) coordinator. The author joined the school of graduate studies of JUCAVM in 2013 to study his Master of Science in watershed management.

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LISTS OF ABBREVIATIONS

GHG	Green House Gas
GTZ	German Technical Cooperation
FAO	Food and Agricultural Organization of the United Nation
LWJ	Land with Jatropha
LWOJ	Land without Jatropha
SAS	Statistical Analysis Soft ware
SPSS	Statistical Package for Social Science
PA	Peasant Association
RCBD	Randomized Complete Block Design
SWOA	Sokoru Woreda Office of Agricultural
EC	Electrical Conductivity
SMC	Soil Moisture Content
OM	Organic Matter
OC	Organic Carbon
PBS	Percentage Base Saturation
USDA	United States Department of Agriculture
GEXSI	Global Exchange for Social Investment
TSDF	Treatment, Storage, and Disposal Facility
ANOVA	Analysis of Variance
Ha	Hectare

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ABSTRACT

Decline in soil fertility has become a serious problem affecting all spheres of social, economic and political life of the Ethiopia population. This problem is continuing and natural resource base is deteriorating at alarming rate. As the result agricultural productivity has been declined from years to years. Some tree/shrubs species are integrated to the farming system to rehabilitate degraded land. One of such Species which are commonly integrated with farming system is Jatropha. Therefore, the study was conducted to assess the role of Jatropha curcas to rehabilitate soil fertility. ***.*** *In order to achieve the objective, Melka Leku sub watershed from the Gilgel Gibe catchment was selected from south western Ethiopia.* ***.*** *Soil samples were collected by using stratified sampling method at depth of 0-30cm from land with Jatropha and adjacent land without Jatropha plant. For each land use, sites were divided into three slope categories; at each slope three replicates were used. The result of the study shown that, all selected soil physic-chemical properties (texture, BD, MC, pH, EC, OC, OM, TN, AvP, CEC, basic cations and PBS) measured under land with Jatropha was significantly different ($p < 0.05$) from land without Jatropha. Soils under land with Jatropha were superior for all selected soil fertility indicators than adjacent land without Jatropha except BD, sand and silt fractions. The mean values of soil clay, pH, OM, TN and AvP of land with Jatropha and adjacent land without Jatropha site were 54.44 and 37.67%, 6.58 and 5.67, 6.91 and 3.17%, 0.41 and 0.27%, and 18.93 and 14.18 ppm, respectively. Moreover, land use interaction with slope positions had a significance ($p < 0.05$) difference for all measured soil parameters except for bulk density and silt fractions. These mean values soil properties (except BD and silt) under land with Jatropha of slope position on upper area were significantly ($p < 0.05$) lower than foot slope positions of the same land use type. While topographic position and nature of the land also contribute to enhance soil fertility, Jatropha plantation has promising potential to play a decisive role on rehabilitating degraded soil fertility of the study area.*

Keywords*:* Land degradation, Soil Fertility, land rehabilitation and *Jatropha curcas L.*

1. INTRODUCTION

Land degradation is a global environmental problem that threatens the survival of more than 250 million people living in the dry lands of the developing world. A total of more than 1 billion people, mostly in Sub-Saharan countries, are at risk (FAO, 2011). In Ethiopia, almost half the population (41%) was living in very severely degraded land which forms 10% of the overall area of the country (FAO, 2005). In our country, land degradation has been recognized to be one of the chronic problems and many efforts have been made against it. However, the problem of land degradation is continuing and natural resource base is deteriorating at alarming rate (Yohannes, 1999; Genene, 2006). These problems are primarily caused by soil erosion; soil erosion is one of root cause for land degradation and the most dangerous ecological process in the in Ethiopia. About 1.5 billion tons of soil is lost from Ethiopia alone per year and 2 million hectares of land in has been severely degraded due erosion (Alemayehu, 2007). As a result of this an annual yield reduced by 1-2 %. Soil fertility decline is one of the major challenges to agricultural development and food security of the country. Approximately 90 % of the population lives in reduced agricultural productivity due to low soil fertilities (Simon, 2012). Erosion removes the most productive portion of the soil, that is, the chemically active part such as organic matter and clay fractions. It also causes a deterioration of soil structure, moisture holding capacity through lowering soil depth, increasing bulk density, soil crusting, and reducing water infiltration (Rachel *et al*., 2012). Eventually, the soil loss its fertility and lead to the decline the productive capacity of the land (Nsabimana *et al*., 2008). The study area Melka Leku watershed is located in southwestern Ethiopia, and is one of the severely affected areas by soil erosion, and where practicing the rehabilitation program.

Jatropha curcas Linnaeus is a multipurpose perennial plant that originated from Central America and South America. In recent years, this plant has become popular in the Philippines and many other countries in Asia and Africa (Victor *et al*., 2009). Many claims have been made about *J.curcas* as potential measure for soil and water conservation and it has been hailed as a “miracle” plants that can resist drought and grow well on marginal land (FAO, 2008). This plant has been well-known on contour ridges, hilly slopes and gullies land which help to stabilize slope of land that contributed for reducing soil erosion possibility (Adem, 2011). The potential of

Jatropha for reclamation of marginal land and degraded land soil is backed up by scientific literature (Spaan *et al*., 2004).Jatropha has the potential of retaining a marginal and degraded soil by re-anchoring the soil with its substantial root and reducing possibility of erosion and increase the fertility of soils (Agbogidi *et al*., 2013). Its plantation not only serves as an environment functions in degraded ecosystems but also can act as a nutrient pump for the rehabilitation of degraded lands and improves the fertility of the soil by adding plant material to the soil which is easily decomposed. Indeed, it has been stated that Jatropha used for enhancement of rural development in semi-arid and arid regions without depleting natural carbon stocks and ecosystem services (Francis *et al*., 2005; Fargione *et al*., 2007; Divakara *et al*., 2009). Cultivation of *Jatropha* increased macro-aggregate turnover in degraded soils, enhanced the recovery of the soil structure, and showed considerable potential to increase carbon sequestration rates, soil moisture retention and soil chemical properties (Ogunwole *et al.*, 2008). Soils under Jatropha hedgerows showed high amounts of organic carbon and organic matter compared to neighboring soils (Soulama, 2008). India over a ten year period, the reduction of the total soil loss amount was nearly 50% due to Jatropha cultivation (Sunil *et al.*, 2008). Jatropha benefits developing countries like Ethiopia includes degraded lands recovery, and soil fertility improvement; provide huge opportunities from sustainable and renewable land resources. For instance, in Ethiopia, Jatropha not only increasingly used as a hedge or living fence but also as a soil and water conservation technology (Simon, 2012).

However, despite the apparent advantages of growing *J. curcas*, there is inadequately established knowledge currently on the effect of Jatropha could have on land reclamation through soil fertility improvement, especially on the physico-chemical properties of the soil of study area. This information can also be used to forecast the likely effects of any potential changes in land use types and slope position on soil properties. Therefore, taking the above problems under consideration, systematic and focused research on effect of Jatropha that have on soil physico-chemical properties was essential and may play a significant role for policy maker, academic purpose, research institution, rural communities and for Gilgel Gibe watershed development.

1.1. Objectives

1.1.1. General Objectives

To understand the role of *Jatropha curcas* on rehabilitation of degraded soil fertility of Gilgel Gibe Watershed

1.1.2. Specific Objectives

The following specific objectives was addressed in this study

1. To investigate the effects of *Jatropha curcas* on selected soil physico-chemical properties that are used as indicators soil fertility

2. To assess the combine effects of land use and slope on selected soil fertility indicators

2. LITERATURE REVIEW

2.1. Description of Jatropha (*Jatropha curcas* L.)

The complete scientific denomination of *Jatropha* is *Jatropha curcas* Linnaeus. *J.curcas* belongs to the families *Euphorbiaceae,* and its genus name derives from the Greek word Jatrós (doctor) and Trophé (food), which implies medicinal uses. Brueck (2008) classified Jatropha in 175 species and gave it the botanical name *J. curcas.* These plants are a small tree or large shrub, up to 5–7 meter tall, with a soft wood and a life expectancy of up to 50 years (USDA, 2000; Achten et *al.*, 2010). Common names for *J. curcas* are physic nut, Barbados nut, fig nut, pig nut, purging nut. It is a deciduous monoecious perennial shrub meaning it carries separate male and female flowers on the same plant. Jatropha is a succulent plant that sheds its leaves during the dry season (Achten *et al.*, 2008a). It can grow on any type of soil whether gravelly, sandy or fairly saline and thrives even on the poorest stony soils (Singh *et al.*, 2011).

The origin of *J. curcas* is estimated to be from Central America and South America mainly occurs at lower altitudes. In Africa or Asia, Jatropha can only be found in cultivated form (Henning, 2006). Jatropha can resist wide range of climatic and edaphic conditions. The area covered by plantations of Jatropha curcas estimated as 936.000 ha in the world in 2008. Out of these 85 % is in Asia, 13 % is in Africa and 2 % is in Latin America .Globally, plantation area increased dramatically to 4.72 million ha in 2010 and is predicted to reach 12.8 million ha in 2012(GEXSI, 2008).This plant has been promoted globally as used to make biodiesel and carries the added advantage of helping to rehabilitate degraded lands. Similarly, in Bati region of Ethiopia, the dual use of Jatropha to provide energy and to rehabilitate land has been practiced to some extent for at least 40 years. For instances, farmers in Ethiopia mainly used Jatropha plants as living fences and as a structural means of soil and water conservation (Brigitte *et al*., 2014). Similarly, farmers in Sokoru Woreda of Jimma Zone were traditionally using *Jatropha curcas* as living fence and medicinal value, especially for snack bit since 1990. However, the use of Jatropha for soil and water conservation practice is not much known in the study area before introduced by GTZ (GTZ, 1998).

2.2. Socioeconomic and other Uses of Jatropha (*Jatropha curcas* L.)

Most of the small farms in the developing world cultivate 20–30 % of their land with inadequate management practices which are the reasons for the decline productive capacity of their land. It is recommended to plant perennial plants like Jatropha, on this portion of land. The positive influence of this vegetation was helped to reclaim land in a relatively short period of time which makes it again suitable for staple crop production .This system of agronomic practices seems to be especially suited for small-scale farms in our global world that are the most advantaged ones (Harinder et al., 2009). Jatropha ranks first among all possible plant after considering the social and economic aspects (Sarijeva, 2007; Achten et al., 2010; Reubens *et al*., 2011). It is economically viable not only to the growers but also to the processors, end users and to the rural society; the plants can create regular employment opportunities, as it provides never ending marketing potential(WAC, 2006).

The Jatropha system is an integrated approach of rural development which characterized by its multiple uses in slope stabilization, erosion control, livestock control (used as a hedge), as a natural fence, farmers can be served by the plant Jatropha in restraining conflicts with imperiled wildlife. Additionally, by providing physical barriers, Jatropha can control grazing and demarcate property boundaries (the plant acts as cost effective biofence compared to wire fence) at the same time improving water retention and soil conditions of the farmers' and income generation among other uses makes it a valuable pathway to the improvement of livelihoods (Silva *et al.,* 2010). Increasing in the planting of Jatropha, there could be substitution of fire wood by plant for household cooking of rural areas to reduce the current rate of deforestation as well as promoting the health of rural women subjected to indoor surface pollution from cooking by insufficient fuel. Furthermore, Jatropha is known to increase food production in third world countries where non cultivated land has been developed mainly because the communities are able to use the stable income derived from Jatropha to plough into the planting of sustenance crops. Trees should be grown at wide spacing on degraded common property resources so to enable the local farmers to inter-crop food crops in-between the trees (Tigere *et al.,* 2006).

2.3. The Role of Jatropha (*Jatropha curcas L.*) for Erosion Control

Jatropha hedges are a potential conservation technology in early stages of erosion as a mitigation measure before erosion started, since Jatropha hedges are implemented in a short time and with very little work input (Simon, 2012). Jatropha is seen as contributing to the restoration of degraded land in at least two ways: first, according to its planting method, for example, when cultivated as dense hedges that form contour lines across slopes in gullies and the second, Jatropha's root structure featuring one vertical root and four lateral roots is believed to naturally stabilize slopes and help control soil erosion (Spaan *et al.*, 2004). The rapid growth and the huge ramification capability of the root system allow *J. curcas* to be quoted among plants that contribute to preventing soil erosion leads to improve soil fertility status (Behera *et al.*, 2010). Jatropha cuttings simply have to be put into the soil and the spacing between each cutting has to be filled with litter. As soon as the plant has rooted it is flexible enough to even sustain heavy runoff (Islam *et al.,* 2011). Because of the above reason, some authors are called Jatropha are earth friend plants.

The Jatropha's roots grow close to the ground surface, anchoring the soil like miniature dikes or earthen bunds. These dikes, effectively slows surface runoff during intense downpour, thus causing more water percolation into the soil (Achten *et al.,* 2008b). The taproot attaches the plant in the ground while the profusion of lateral and adventitious roots near the surface binds the soil and keeps it from being washed out by heavy rains, afterward responsible for 30 % of soil degradation (Becker and Francis, 2010). The lateral roots could decrease soil erodibility through additional soil cohesion while the tap root and sinkers may enable exploitation of subsurface soil moisture and enhance vegetative cover, even in very dry environment. Jatropha has capacity to recycle nutrients from deeper soil layer, providing shadow to the soil (Spaan *et al.,* 2004). Average daily run-off intensity decreased by 12 % for the current Jatropha plantation, compared to the degraded condition (Kaushal *et al*., 2009).

In India, the cumulative soil loss generated at the watershed outlet over a ten year period showed that Jatropha cultivation resulted in a reduction of the total soil loss amount of nearly 50 % compared to the degraded land (Sunil *et al.,* 2008). Jatropha has the potential to alleviate soil degradation, increase carbon stocks and soil organic matter content (Simon, 2012). While the plant is said to be drought tolerant, rural and remote areas in Ethiopia could benefit from it to improve their access to sustainable energy as well as for reclamation of marginal or degraded soils as well (Spaan *et al*., 2004).

2.4. Effect of Jatropha (*Jatropha curcas* L.) on Soil fertility

Soil fertility is the capacity of the soil to supply nutrients to the plants in proper amounts and proportions. It greatly determines agricultural production especially in upland environments where subsistence farmers do not have the means to buy the expensive fertilizers (Volckaert*et al.,* 2009). Chaudharry *et al*. (2007) and Ogunwole *et al*. (2007) reported that soil structure improved significantly after *Jatropha curcas* was grown for 18 months under semi arid conditions and macro-aggregates increased by 6.30%, whereas soil bulk density was decreased by 20% and total nitrogen increased by an average of 33 %. Aggregated silt and clay, which is an index of micro aggregate stability was higher and increase the soil moisture retention. Nevertheless, does a Jatropha mine soil nutrient rather create favorable condition for other crops to appear on degraded land (Chaudharry *et al.,* 2007). Makkar and Becker (2009) stated that, the increase in soil fertility would quickly lead to a much better vegetation growth on the former barren land. For instance, comparison of the different land management scenarios shows that more than 50 % of the non-productive soil evaporation in the degraded land is shifted into productive and ground water recharges doubles in the in the two years Jatropha plantation scenario compared with the degraded scenario (Bailis and Baka, 2011). According to Soulama (2008) reported that amounts of soils organic carbon beneath Jatropha hedgerows has significantly increased from 4.55 to 8.41 g /kg in compared to neighboring soils, confirming the importance of Jatropha for carbon sequestration.

Moreover, changes in soil properties were significantly higher beneath the canopy than outside canopy of Jatropha (Henning, 2006). It is estimated that three-year old Jatropha plants return about 21 kg/ha of nitrogen back to the soil. Besides, it is a well-documented fact that Jatropha plantation not only improves the condition of the soil on the degraded land by fixing nitrogen but also the leaves fall off in winter and creates mulch which brings life to dead soil (Behera *et al*., 2010). According to Asselbergs *et al.* (2006) finding showed that the percentage of soil Ca^{2+},

Mg^{2+}, Na^{+} and K^{+} beneath Jatropha was higher than the adjacent soil. Similarly, the presence of Azotobacter in relatively larger number in the rhizosphere of Jatropha also increased nitrogen level in the soil as compared adjacent soil. Increasing microbial activity including earthworms is an indication of ecological improvement of the site (Makkar and Becker, 2009).

2.4.1. Jatropha (*Jatropha curcas L.*) seed cake as Organic Fertilizer

Jatropha seed cake is refers to the remains of the Jatropha seed after oil extraction, are in the form of cake, and there are possibilities that could be used as fertilizer, because it is rich in nitrogen, phosphorus and potassium, equal or even richer than chicken manure or used as cattle feed (Openshaw, 2000; Prueksakorn *et al.,* 2010). The production of good quality fertilizers as a by-product of oil production acts to improve soil fertility and agricultural productivities. Due to this value of organic fertilizer is being acknowledged (Achten *et al*., 2008b). According to Agbogidi *et al*. (2013) who reported that Jatropha seed cake makes an excellent organic fertilizer with high contents of nitrogen 3.93 % compares with, chicken manure 2.5 % .In the same way Tigere, (2002) indicated that the Jatropha seed cake has higher organic matter content 88 % compared to chicken manure 15-80 % and cattle manure 20-70 %. When Jatropha seed cake compared with commercial fertilizer the yield of maize and millets increased up to 179 to 120 % respectively (Gubitz, 1998).

2.4.2. Effect of Jatropha (*Jatropha curcas L.)* on selected soil physical properties

The physical properties of soils determine their adaptability to cultivation and the level of biological activity that can be supported by the soil. It also largely determines the soil's water and air supplying capacity to plants. The physical properties of a soil profile, particularly texture, structure and moisture regime can be used to determine the effect of movement of water into and through the soil (Eldershaw, 1999).

2.4.2.1. Texture

Soil texture can have a profound effect on many other properties and is considered among the most important physical properties. It is the proportion of three mineral particles, sand, silt and clay, in a soil. Further, determines a number of physical and chemical properties of soils. For example texture affects the infiltration and retention of water, soil aeration, absorption of nutrients, microbial activities, tillage and irrigation practices (Gupta, 2004). Moreover, it is also an indicator of some other related soil features such as type of parent material**,** homogeneity and heterogeneity within the profile, migration of clay and intensity of weathering of soil material or age of soil (Lilienfein *et al*., 2000). Soil particle size distribution varied across different land use systems as Alemayehu *et al.* (2010) reported high percentage of clay content in forest land than grazing land. According to Shehu (2013) indicted that apart from clay, sand and silt content were significantly affected by the land uses .The highest silt content was observed in control land 39.04, Fallow land 36.36, followed by land with Jatropha plantation 35.12 % respectively. The sand content significantly decreased in the following order, control land, Fallow land and land with Jatropha accordingly. However, Clay content significantly increases from control to Fallow land and followed land with Jatropha respectively. Pedogenic processes such as erosion, deposition, eluviations and weathering can bring the textures of various soils (Forth, 1990; Brady and Weil, 2002).

The highest proportion of sand and lowest proportion of clay content in the cultivated land compared to grazing and Enset *(Enset ventricosum)* farm land. A relative variation in proportion of sand and clay content in the cultivated land could be due to soil erosion. Erosion resulted in removal of a smallest soil separates of clay which was easily transported by water erosion. Therefore, contributed lowest proportion of clay in the cultivated and in opposite highest proportion of sand that could be due to it is not easily transportable relative to silt and clay (Bahilu *et al.,* 2014). Significant difference in percentage of sand, silt and clay contents among soils of different land use types. The mean value of sand fraction was lowest 18% under the natural forest and highest 34.76 % in grazing lands. Soils in plantation forest had clay texture while crop and grazing lands had clay loam texture (Yihenew *et al*., 2015).

2.4.2.2. Soil Bulk Density and Moisture Content

Measurement of soil bulk density is required for the determination of compactness, as a measure of soil structure, for calculating soil pore space and as indicator of aeration status and water content (Barauah and Barthakulh, 1997) stated that values of bulk density ranges from < 1 g/cm^3 for soils high in organic matter, 1.0 to 1.4 6 g/cm^3 for well- aggregated loamy soils and 1.2 to 1.8

g/cm^3 for sands and compacted horizons in clay soils. Soils having low and high bulk density exhibit favorable and poor physical conditions (Brady and Weil, 2002; Gupta, 2004). Jatropha plantation improves the soil bulk density and creates suitable conditions to other crop productions by adding the organic matter to the soil in the area with high bulk density. Bulk density recorded under Jatropha plantation was 0.311 and adjacent land without Jatropha was 0.373 g/cm3 as reported by Kumar *et al*. (2009).

Similarly, Shehu (2013) indicated that the mean value soil buck density under land with Jatropha, adjacent land without Jatropha and fallow land were 1.48, 1.53 and 1.63 g/cm3 respectively. This situation also able to enhance the fertility of the soil along slope of the land. Moreover, Makkar and Becker (2009) stated that Jatropha plantations have a possibility to reclaim marginal soils and prevent erosion by exploiting the soil with adequate root system and the leaf fall during the winter season increases the soil organic matter level plus reduce the bulk density of the soil.

The soil moisture contents recorded under Jatropha plantation was 15.4 and under control soil was 11.3 % respectively. The high moisture content was recorded under Jatropha plantation due to higher input of organic matter from the plants. As result of this there is increasing of water holding capacity into soil and root ramifications (Kumar *et al*., 2009). Soil moisture holding capacity under land with Jatropha was higher by 35 % when compared with the soil under the adjacent land without Jatropha (Suhas *et al.*, 2012).

2.4.3. Effect of Jatropha (*Jatropha curcas L.)* on soil chemical properties

Soil chemical properties are the most important among the factors that determine the nutrient supplying power of the soil to the plants and microbes. The chemical reactions that occur in the soil affect processes leading to soil development and soil fertility build up. Minerals inherited from the soil parent materials overtime release chemical elements that undergo various changes and transformations within the soil. Several Jatropha were planted on sodic soil to assess soil amelioration potential of the plant. After six years of plant growth, seed yield was not economically viable; however, soil properties improved significantly when compared to initial (0-year plantation). For instance, soil bulk density, pH, electrical conductivity and exchangeable sodium percentage decreased and soil organic carbon, total nitrogen, available phosphorus, microbial biomass increased significantly (Srivastava, 2013). As result the physico- chemical properties of the soil significantly changed lead to land productivities incensement

2.4.3.1. Soil pH and Electrical Conductivity (EC)

The pH scale is logarithmic expression of hydrogen ion [H+] concentration in the soil solution rather than linear; the difference in acidity between each pH value varies by a factor of 10, not 1. Therefore, a soil with a pH of 5.0 is 10 times more acid than a soil with a pH of 6.0. A soil with a pH of 4.0 will be 100 times more acid than a soil with a pH of 6.0 and 1,000 times more acid than a soil at pH 7.0. The pH can affect cation exchange capacity and electrical conductivity by altering the surface charge of colloids (Brady and Weil, 2002). pH affects humus formation in two ways: decomposition, and biomass production. In strongly acid or highly alkaline soils, the growing conditions for micro-organisms are poor, resulting in low levels of biological oxidation of organic matter. Soil reaction (usually expressed as pH value) is the degree of soil acidity or alkalinity, which is caused by particular chemical, mineralogical and/or biological environment (Gebeyaw, 2007)**.** This soil reaction affects nutrient availability and toxicity, microbial activity, and root growth. Thus, it is one of the most important chemical characteristics of the soil solution because both higher plants and microorganisms respond so markedly to their chemical environment (Lilienfein *et al*., 2000). Among soil proprieties, pH, electrical conductivity, organic carbon and clay significantly affect the availability of nutrients, thus soil conditions reflect the effect of Jatropha cultivation practices on a degraded soil. From the perspective of both soil structures, carbon and nitrogen sequestration, Jatropha cultivation under minimal soil disturbance can serve environmental functions. It improves soil resistance to wind erosion and enhanced macro-aggregate stability to water erosion. Under cultivation of Jatropha, increased potential carbon sequestration rates are possible as stable micro-aggregates can offer protection to organic carbon. Therefore, Jatropha programmers will not only serve as a source of income-generation to resource-poor farmers but will also improve the quality of their soils in the long run (Ogunwole *et al.*, 2008).

According to Habtamu (2011) reported that the mean pH-H2O value obtained underneath of the Jatropha was 7.9 while that obtained from adjacent soil was 8, both soils were alkaline. The important point here is that Jatropha plantation brings soil pH into neutral condition in both side.

Meaning that when the soil becomes acid soil it increase its pH value into neutral whereas, when the soil becomes alkaline soil it reduced the pH value into neutral again. For instance, the mean value of soil under land with Jatropha was 7.1 and under adjacent land without Jatropha were 7.4. The result was statistically significance difference at ($p< 0.01$) and ($p<0.05$) levels of significance (Shanker *et al.,* 2006). Kumar *et al*. (2009) also reported high pH values (5.7) for land with Jatropha as compared to land with natural vegetation 5.2. This was statistically significance difference at 0.01. Faizabad (2013) finding showed that on the alkaline soil after Jatropha plantation the mean value of soil pH value 9.9 and before Jatropha plantation the value was 11.2.

Soil electrical conductivity (EC) is a measurement that correlates with soil properties that affect crop productivity, including soil texture, cation exchange capacity (CEC), drainage conditions, organic matter level, salinity, and subsoil characteristics. It is an important indicator of soil health. However, too much or too low amount of salt, it can affect/harm crop yields, crop suitability, plant nutrient availability, and activity of soil microorganisms which influence key soil processes including the emission of greenhouse gases such as nitrogen oxides, methane, and carbon dioxide (TSDF, 2008). Although electrical conductivity does not provide a direct measurement of specific ions or salt compounds, it has been correlated to concentrations of nitrates, potassium, sodium, chloride, sulfate, and ammonia. For certain non-saline soils, determining electrical conductivity can be a convenient and economical way to estimate the amount of nitrogen available for plant growth.

The mean electrical conductivity value of the soils under land with Jatropha was (0.279 dS/m) and adjacent land without was (0.177 dS/m). This showed that there was a statistically significant difference ($P < 0.01$) between the two soils (Habtamu, 2011). Similarly, Mahesh and Nandita (2011) stated that electrical conductivity under canopy of Jatropha was 0.14 and outside the canopy of Jatropha was 0.11 ds/m respectively. Based on the above information it is possible to say Jatropha plantation can have ability to improve the soil electrical conductivity from time to time in long run. According to Srivastava (2013)reported that the value of electrical conductivity recorded before Jatropha plantation was (1.1ds/m) and after Jatropha plantation for twenty month the value recorded was (0.9 ds/m). The study indicates that Jatropha could reclaim sodic soil without applying chemical amendment.

2.4.3.2. Organic Carbon and Organic Matter

It has been claimed that cultivating Jatropha increases the carbon stock when grown on marginal Land. In a case study in India, Ogunwole *et al*. (2008) observed that the cultivation of Jatropha increased macro-aggregate turnover in degraded soils, enhanced the recovery of the soil structure and showed considerable potential to increase the soil carbon and organic matter. The leaves and branches are used as manure for coconut trees and to provide plant with organic matter thereby increasing microbial activities that help in decomposition. Jatropha removes carbon from the atmosphere (carbon sequestration), store it in the woody tissues and assist in the building of soil carbon (Agbogidi and Ekeke, 2011).

The soils under Jatropha hedgerows is showed high amounts of organic carbon compared to neighboring soils, confirming the importance of Jatropha for carbon sequestrate (Soulama, 2008). Jatropha plantations older than four years added as much as 1,450 kg/ha per hectare of organic carbon per year through leaf fall. Moreover, carbon additions by Jatropha during 4 years increased organic carbon content in the degraded surface soil layer by 19 %, resulting in about 2500 kg/ ha organic carbon sequestered. Huge organic carbon additions and live root activity under Jatropha increased microbial population, respiration rate and microbial biomass organic carbon and nitrogen in soil. Along with organic carbon additions, 4000 kg/ ha per year plant biomass recycled into the soil. Increased by 85.5 kg/ha nitrogen 44.9 kg/ha phosphorus and 5.20 kg/ha potassium (Suhas *et al.*, 2012). The organic carbon additions improved water holding capacity of the soil under Jatropha as compared with the adjacent control soil which increased by 35 %. The concentration of soil organic carbon has increased 53 % from the degraded site after about 10 years of Jatropha plantation which was even 73 % higher than that of agro ecosystem in the present study **(**Mahesh and Nandita, 2011).

Most cultivated soils of Ethiopia are poor in Organic matter contents due to low amount of organic materials applied to the soil and complete removal of the biomass from the field and due to severe deforestation, steep relief condition, intensive cultivation and excessive erosion hazards (Eylachew, 1999). Jatropha sheds its leaves in winter which form mulch around the plant base, thereby provides plentiful organic matter and increasing the microbial activity including earthworms around root zone of the plants, which improves soil fertility and soil quality. This is an indication of ecological improvement of site (Singh *et al.*, 2011).

Soils with different depths and sites, under Jatropha had a significantly higher soil organic matter 3.588 % than natural vegetation 2.5 % (Abugre *et al.*, 2011). Organic matter level in the soil leads to an enhanced cation exchange capacity and also a better soil structure. This has been demonstrated in a number of trials that Jatropha responds positively to a high organic matter level (Vimal Chandra *et al.*, 2012). The average organic matter under land with Jatropha and away from Jatropha plantations were 7.15 and 2.48 % respectively (Jhonnah, 2009). According to Habtamu (2011) reported that the mean value of soil organic matter under land with Jatropha was 3.71 % and under adjacent land without Jatropha was 2.69 %. Moreover, soil microbial respiration increased with Jatropha cultivation as the microbes acted on the increased organic matter, there was slight increase in pH value on land with Jatropha (Jhonnah, 2009).

2.4.3.3. Total Nitrogen and Available Phosphorus

Nitrogen is the forth plant nutrient taken up by plants in greatest quantity next to carbon, oxygen and hydrogen, but it is one of the most deficient elements in the tropics for crop production (Mesfin, 1998). Wakene (2001) stated that there was a 30 % and 76 % depletion of total nitrogen from agricultural and abandoned land in compared to the virgin land in Ethiopia. According to Bailu *et al*. (2014) reported that total nitrogen (TN) was relatively higher under Enset (*Enset ventricosum*) and grazing land than cultivated land. This probably happened due to continuous mulching of Enset (*Enset ventricosum*) garden with organic matter which is the potential source of soil N.

Average total nitrogen increased from cultivated to grazing and forest land, which again declined with increasing depth from surface to subsurface soils (Nega, 2006). The considerable reduction of total nitrogen in the continuously cultivated fields could be attributed to the rapid turnover (mineralization) of the organic substrates derived from crop residues (root biomass) whenever added following intensive cultivation (Donagh *et al*., 2001). The decline in soil organic carbon and total nitrogen , although commonly expected following deforestation and conversion to farm fields, might have been exacerbated by the insufficient inputs of organic substrates from the farming system (Mulugeta, 2004).

It is a well-documented fact Jatropha by fixing nitrogen can have the ability to improve the status of degraded land. The Jatropha's leaves fall off in winter create mulch on the soil which helps to bring life to dead soil by improving the total nitrogen contents in the soil. This contributes towards the rehabilitation of severely eroded and degraded soil from time to time. According to Kuma *et al*. (2009) reported that the total nitrogen content under the Jatropha plant was 0.122 % and adjacent land with no Jatropha plantation was 0.053 % respectively. Jatropha cultivation has positive effect on the nitrogen contents of the soil. The average value of total nitrogen under and away from Jatropha was 0.226 % and 0.168 % respectively. As Habtamu (2011) reported the mean value of total nitrogen of the soil under land with Jatropha was higher than the soil away from the plant. Available phosphorus is known as the master key to agriculture because lack of available phosphorus in the soils limits the growth of both cultivated and uncultivated plants (Foth and Ellis, 1997). Following, nitrogen, phosphorus has more wide spread influence on both natural and agricultural ecosystems than any other essential elements. The main sources of plant available phosphorus are the weathering of soil minerals, the decomposition and mineralization of soil organic matter and commercial fertilizers. Most of the soils in Ethiopia particularly nitisols and other acid soils are known to have low phosphorus contents, not only due to the inherently low available phosphorus content, but also due to the high phosphorus fixation capacity of the soils (Eylachew, 1999). The average value of phosphorus from the soil under Jatropha was 32.75 ppm and 21.73 ppm for the soil away from the plant respectively. Generally as per the result of soil analysis, Jatropha improved fertility of the soil by improving the soil macro nutrenties in the soil (Habtamu, 2011). According to Suhas *et al*. (2012) explained that the mean value of available phosphorus under land with Jatropha was 4.7 mg/kg and under adjacent land without Jatropha was 0.7 mg/kg) respectively.

2.4.3.4. Cation Exchange Capacities (CEC), Exchangeable Bases and PBS

The Cation exchange capacity (CEC) of soils is defined as the capacity of soils to adsorb and exchange cations (Brady and Weil, 2002). Also cation exchange capacity is an important parameter of soil because it gives an indication of the type of clay minerals present in the soil, its capacity to retain nutrients against leaching and assessing their fertility and environmental behavior. According Habtamu (2011) reported that the average cation exchange capacities of the soil under *Jatropha* and away from Jatropha plantation were 45.57cmol (+)/kg and 41.22 cmol

(+)/kg respectively. Comparing the cation exchange capacity mean value of the two group of soil, Jatropha had increased the cation exchange capacity of the soil by 10.5 %. Soils clay minerals and organic matter tend to be negatively charged, thus attracting positively charged ions (cations) on their surfaces by electrostatic forces. As a result, the cations remain within the soil root zone and are not easily lost through leaching. According to Munyinda *et al.* (2009) report shown that calcium, magnesium and potassium increases with Jatropha cultivation. Jatropha has a deep reaching tap root; it is able to "pump "minerals from the depth of the soil to the surface, then recycle back to the soil through leave shed and plant litter. This encourages degraded land to be rehabilitated.

Potassium is the third most important essential element next to total nitrogen and available phosphors that limit plant productivity. Its behavior in the soil is influenced primarily by soil cation exchange properties and mineral weathering rather than by microbiological processes. Exchangeable magnesium commonly saturates only 5 to 20 % of the effective CEC, as compared to the 60 to 90 % typical for calcium in neutral to somewhat acid soils (Brady and Weil, 2002). Research works conducted on Ethiopian soils indicated that exchangeable calcium and magnesium cations dominate the exchange sites of most soils and contributed higher to the total percent base saturation (Eyelachew, 2001). According to the Hazelton and Murphy (2007) the concentration of sodium ion was low for the soil away from Jatropha and it was moderate for soil under Jatropha. Additionally, this plant could reclaim sodic soil completely. Cultivation of Jatropha is an effective and more sustainable way to manage sodicity (Mangkoedihardjo *et al*., 2008). Nutrient loss across the slope positions can be dramatically decreased through the presence of Jatropha plants on a site (Kellman, 2002).

Percent base saturation is the percentage of the CEC occupied by the basic cations Ca^{2+}, Mg^{2+} and K^{+}. Habtamu (2011) finding showed that PBS under land with Jatropha and adjacent land without Jatropha was 95.25 and 89.88% respectively. Soils with high percent base saturation have a higher pH; therefore, they are more buffered against acid cations from plant roots and soil processes that acidify the soil (nitrification, acid rain, etc.). They have little or no acid cation Al^{3+} that is toxic to plant growth rather they contain greater amounts of the essential plant nutrient cations K^{+}, Ca^{2+} and Mg^{2+} for use by plants (Biyensa, 2011). Thus, soils with a high percent base saturation are generally more fertile.

3. MATERIALS AND METHODS

3.1. Description of the Study Areas

The study was conducted in one of sub watershed of the Gilgel Gibe catchment known as Melka Leku at Sokoru Woreda, Jimma Zone; Oromia regional state. The study area is located 222 km from Addis Ababa, capital city of Ethiopia. Geographically the area is located at 8^{o} 6'6" - 8^{o} 7' 7" N latitude and 37^{o} 27' 21"- 37^{o} 29' 36" E longitude at an altitude ranges between 1700-2000 above sea level (m.a.s.l.). The mean annual maximum and minimum temperatures are $28^{o}C$ and $14.5^{o}C$ respectively. The relative humidity ranges from 41.82 to 93.1%. The mean annual rainfall of the study area varies between 900-1300 mm. About 86% of the annual rainfall is during the months of March to September. The total area of the watershed under investigation covers 918 hectare (GTZ and SWOA, 1998).

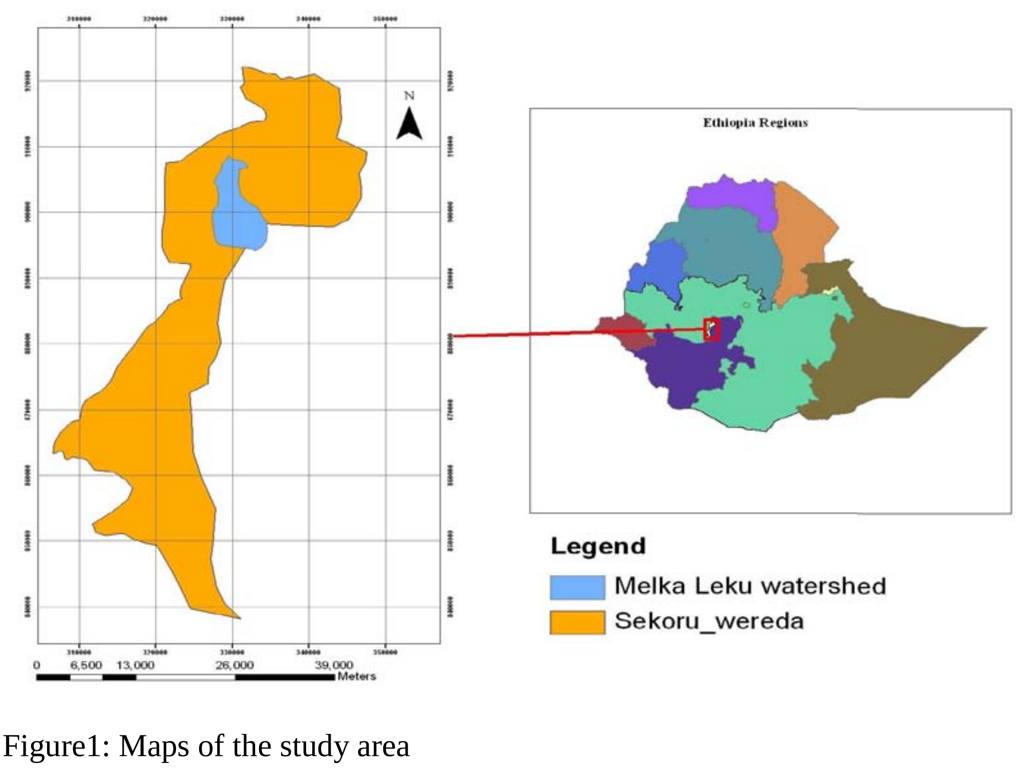

Figure1: Maps of the study area

The total population of the study area is 1443. Out of this, 548 were males and 895 were females. The area providing livelihood for a total of 389 households of which approximately 1 % are female headed and 99 % are male headed households out of which 25 % are landless (GTZ and SWOA, 1998). The people in the communities concerned with mixed agriculture where they integrated crops production with livestock husbandry, where crop production is about 55 %. The most common food crops produced in the areas are cereals, root crops and fruits. The current land use of the study area was categorized as 59 % is arable or cultivable cultivated land , 8 % covered by shrubs and forest ruminants, 28 % occupied by villages / homestead s, 1 % is grazing land and 4 % of the site was degraded /waste land which illustrated by Figure 2.

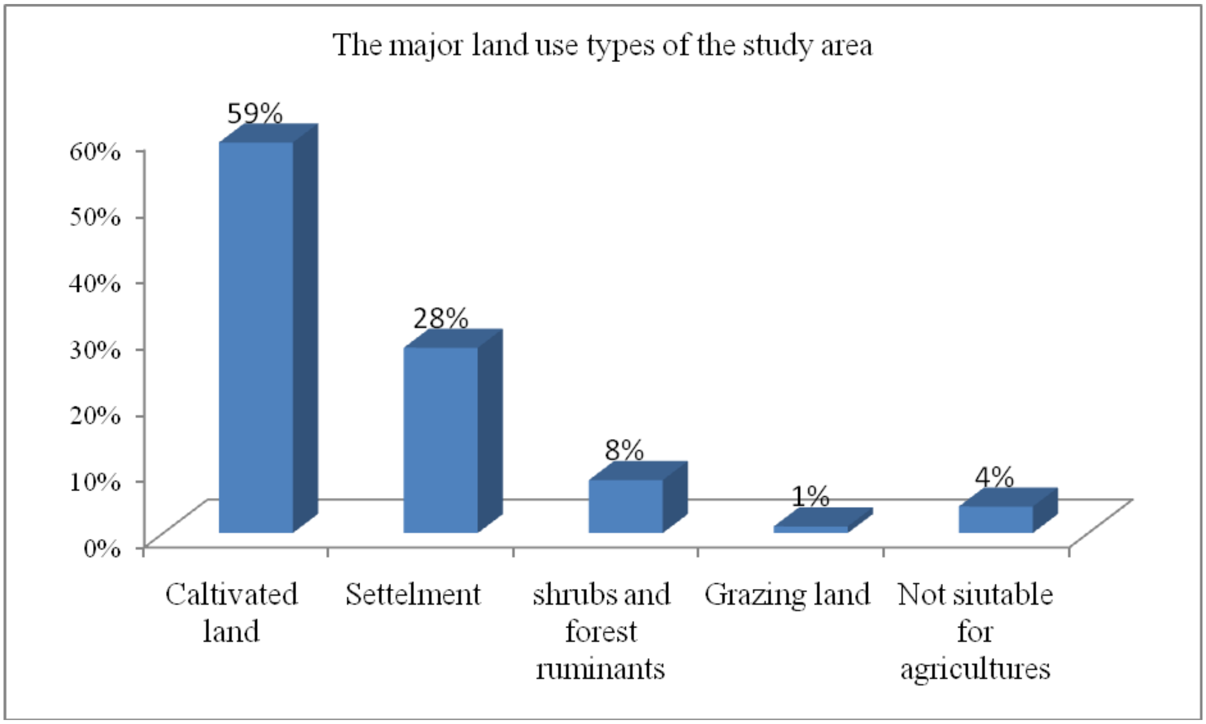

Figure 2: The major land use types of the study area

Source (GTZ and SWOA, 1998)

The land form belongs in the study area is 58 % flat, 19 % is characterized as moderate slope and the rest 23% is characterized as steep slope based on classification (FAO 2006). The major soil nature of area is deep red and gray, classified as Nitisols. However, the steep part of the study area is characterized as shallow and stony soil (GTZ and SWOA, 1998).

3.2. Methods

3.2.1. Data Sources

Before actual field data collection, survey and discussion with the Woreda agricultural experts was made in order to obtain information about the distribution of *J. curcas* plantation in the study areas and general information about the selected watershed. To understand the effect of *J. curcas* on the soil fertilities both primary and secondary data sources have been collected. Primary data was generated from the analysis of soil laboratories. Secondary sources of information was obtained from published materials such as official records, research papers and journal and articles

3.2.2 .Site Selection and Soil sampling

To investigate the impact of *J.curcas* on soil fertility, from Gilgel Gibe watershed, Melka Leku sub watershed was selected purposively because of this area is dominated by *J.curcas* as compare to other watershed. The sampled area was stratified into two land use types (land with *Jatropha* plantation, and adjacent land without Jatrophas). For each land use type, sites were divided into three slopes categories namely; upper slope (16-22 %), middle slope (6-15 %) and foot slope (0-5 %) by using clinometers. Three replicated soil samples were collected per treatment. Ten soil samples were collected to make one composite sample for each replication. These soil samples were collected from 0-30cm soil depth. A total of 18 samples (2 land use X 3 slopes X 3 replications) were collected.

3.2.3. Soil Sample Analysis

The sampled soils were air-dried in the laboratory and ground with mortar. The samples were passed through 2mm sieve. From theses samples soil texture, BD, SMC, pH, EC, OC, OM, TN, AvP, CEC, basic cations (Ca^{+2}, Mg^{+} K^{+} and Na^{+}) and PBS were determined. The physic-chemical analysis was carried out at the soil laboratory of the Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) following Standard laboratory procedures

3.2.3.1. Analysis of soil physical properties

Soil particle size distribution was determined by the Boycouos hydrometric method (Bouyoucos, 1962; Van Reeuwijk, 1992) after destroying OM using hydrogen peroxide (H_2O_2) and then sodium hexameta phosphate $(NaPO_3)_6$ was used to disperse the soil. The soil textural classes were determined using the international society of soil science system (Rowell, 1994), triangular guideline.

Moisture content was determined by Gravimetric method. Initially, weight the field samples and dry it at 105°C for 24 hours, then weighing them again. The percentage of water held in the soil was calculated as the weight difference of field and oven dried soils divided by weight of oven dried soil multiplied by 100 (Simkins, 2008);

$$Percent\ of\ moisture\,(wt\,\%) = \frac{(A-B)x100}{B-C}$$

Where A=air dry soil (g) + core weight (g), B=weight of oven dry soil (g) + core weight (g) and C=weight of the empty core (g), B-C= weight of oven dry soil (g).

Soil bulk density also determined by the undisturbed core sampling method after drying the soil samples in an oven at $105^{o}{}_{C}$ to constant weight and calculated by the following formula indicated by (FAO, 2007);

$$\mathrm{BD} = \frac{Wtof\ oven\ dry\ \ soil\ (g)}{Volume\ of\ the\ core(cm3)}$$

Weights of oven dry soils (g) and V is the volume of the cylindrical core (cm^3).

3.2.3.2. Analysis of Soil chemical properties

Soil pH was measured by using a pH meter in a 1:2.5 soil: water ratios (Van Reeuwijk, 1992) whereas electrical conductivity (EC) was measured in soil to water ratio of 1:5(Van Reeuwijk, 1992). The soil organic carbon was determined by the Walkley-Black oxidation method with potassium dichromate (K_2Cr2O_7) in a sulfuric acid medium then converted to soil organic matter by multiplying it by the factor of 1.724 following the assumptions that OM is composed of 58% carbon (Walkley and Black, 1934).The Total Nitrogen was determined by micro-Kjeldahl digestion method (Bremmer and Mulvancy, 1982) by oxidizing the OM in concentrated sulfuric acid solution (0.1N H_2SO_4) and the digest was distilled and about 50 ml of the distillate was collected which was then titrated with 0.05N H_2SO_4 to pink end point. Available phosphorus was determined using Bray II extraction method as described by Van Reeuwijk, (1992).Cation exchange capacity (CEC) was determined by the saturated ammonium acetate (1 Normal NH_4OAc at pH 7.0) method (Chapman, 1965). Exchangeable calcium (Ca^{2+}) and magnesium (Mg^{2+}) by ammonium acetate extraction and measured by the atomic absorption spectrometry (AAS) method. Exchangeable potassium (K^+) and sodium (Na^+) extracted by sodium acetate method and measured by flame photometer. Percent base saturation (PBS) was calculated by dividing the sum of the base forming cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) by the CEC of the soil and multiplying by 100 (Fageria, 2009):-

$$PBS = \frac{(Ca^{2+} + Mg^{2+} + K^{+} + Na^{+})}{CEC} x100$$

Where the values of CEC, Ca^{2+}, Mg^{2+}, K^+, and $Na^+$are expressed in cmol (+)/kg

3.2.4. Statistical data analysis

Two way analysis of variance (ANOVA) was performed to assess the significance differences in soil parameters between different treatments, using the general linear model (GLM) procedure of statistical analysis software (SAS) version 9.2. Means separation was done using least significant difference (LSD) after the treatments were found significance at P value of 0.05 (Gomez and Gomez, 1984). Simple correlation analysis was carried out with the help of SPSS version 16 in order to reveal the magnitudes and directions of relationships between selected soil fertility indictors. On the other side, relative change in soil properties was computed as:

$$\text{Relative Change} = \frac{(Pj - Pwj)}{Pwj} X\ 100$$

Where $P_j$is the soil property measured under the land with *J. curcas* site and $P_{wj}$is the soil property measured under the adjacent land without *J. curcas* site.

4. RESULTS AND DISCUSION

4.1. Effect of Jatropha (*Jatropha curcas L.)* on Soil Physical Properties

4.1.1. Soil Texture

The sand, silt and clay fraction of the soils were significantly (P<0.05) affected by land use systems (Table 1). The analysis result showed that the mean values of sand, silt and clay under land with *J. curcas* and adjacent land without *J. curcas* were sand 26.88 and 37.89 %, silt 18.44 and 23.97 %, clay 54.44 and 37.67 % respectively. The textural class of soil the under investigation was clay and clay loam based on the soil textural triangle of the international society of soil science system (Rowell, 1994). As compared to adjacent land, sand and silt content under land with Jatropha were reduced by 29 and 23 % respectively. However, the clay fraction was increased by 44.5 %. The higher clay content of the land with Jatropha was due to vegetation cover which reduces the clay fractions likely to be lost by selective erosion processes and slow clay movement down into soil profile. This indicated that *J.curcas* plantation has ability to lower soil erosion and keep normal soil condition. In contrast the lower clay in the adjacent land without Jatropha indicated that there was removal of the clay particles, thereby increasing the proportion of the coarser particles in the soil which leaves more sand particles. In line with this finding, Shehu (2013) reported that clay particles are lighter than sand particles, and once detached by erosion they are easily transported. According to Brian (2007) rating, the proportion of sand, silt and clay categorized as moderate, low and high respectively in study site.

The results of sand and clay measured at different slope positions were statistically significance differences at p value of 0.05 but the silt fractions was not significant (Table 1). The highest mean value (37 %) of sand fractions was recorded on the upper slope positions while the lowest value (27.33 %) was recorded on the foot slope positions. On the contrary, the highest mean value of the clay fractions 52 % was recorded on the foot slope positions whereas the lowest mean value 40.66 % was recorded on the upper slope positions. Hence, the clay content significantly increases into the lower slope positions in the study area. The fine textured soil move faster than course particle to the lower slope positions may be the probable reason for the variation observed in this study. Similar report was done by Yihenew *et al*. (2015) who reported that the highest clay content on foot slope position and the lowest clay on upper slope positions.

Table1: The main effect of land use and slope positions on selected physical properties of the soils and the value of their relative change

Treatments	Sand (%)	Silt (%)	Clay (%)	STC*	BD(g/cm3)	SMC (%)
			Land use types			
LWJ	26.88±7.23[b**]	18.44±3.9[b]	54.44±9.5[a]	Clay	1.12±0.08[a]	20.73±2.84[a]
LWOJ	37.89±6.13[a]	23.97±3.44[a]	37.67±5.24[b]	Clay loam	1.21±0.65[b]	15.78±1.59[b]
RC (%)	-29.1	-23.1	44.52		-7.4	31.4
LSD(0.05)	5.65	3.86	6.37		0.07	1.92
P-value	0.0009	0.091	0.0001		0.03	0.0001
			Slope positions			
US	37±8.27[a]	22±6.44	40.66±12.3[b]	Clay loam	1.18±1.18	16.55±2.91[b]
MS	32.83±9.17[ab]	21.5±3.01	45.5±11.1[ab]	Clay	1.15±1.15	18.31±3.35[ab]
FS	27.33±6.62[b]	20±4.1	52±9.5[a]	Clay	1.15±1.15	19.91±3.54[a]
LSD(0.05)	6.92	4.7	7.8		0.11	2.35
P-value	0.031	0.65	0.023		0.74	0.027
CV (%)	17.26	18.03	13.68		6.36	10.41

*STC = soil texture class; BD = bulk density; SMC = soil moisture content; LWJ = land with Jatropha; LWOJ = land without Jatropha; US (16-22%) = upper slope; MS (6-15%) = middle slope; FS (0-5%) = foot slope
**Main effect means within a column followed by the same letter are not significantly different at 5% level of significance

With regard to the interaction effects of the land use with the slope positions, the highest interaction mean value (42.67 %) of sand fractions was recorded on uppers slope positions on the adjacent land without Jatropha and the lowest value (21.33%) was recorded on foot slope positions on the land with Jatropha. Whereas, the highest interaction mean value (60.33%) of clay particles was recorded on land with Jatropha on the foot slope positions and the lowest value (23%) was recorded on adjacent land without Jatropha on upper slope positions.

Comparing different slope positions of the land with Jatropha and adjacent land without Jatropha with each other, the mean interaction value of sand fractions of upper, middle and foot slope of the land with *J.curcas* was decreased by 26.57, 33 and 25 % while the clay fractions at these slope positions were increased by 49, 48.6 and 38.21 % respectively. Sand fraction obtained at upper slope without Jatropha was significantly different (P< 0.05) from all land use interaction with slope positions except at middle slope without Jatropha (Table 2). The clay content under Jatropha of foot slope area was not statistically (P<0.05) different of middle and upper slope position of same land use. The highest amount of sand in the upper slope without Jatropha was due to combined effect of steep topography and bare land which trigger soil erosion to easily detach and transported fine particles to the lower slope positions and left large particles in upper area. Koulouri and Giourga (2006) also reported that soil erosion is significantly higher on steep slope gradient than on moderate steep slope gradient.

Table 2: The mean (±MSD) interaction effects of land use and slope positions on selected soil physical properties

Land Use type	Slope	SMC*(%)	BD(g/cm3)	Sand (%)	Silt (%)	Clay (%)
LWJ	US	18.83±1.95^{bc**}	1.14±0.08	31.33±8.1^{bc}	19.33±7	48.66±13^{abc}
	MS	20.34±3.64^{ab}	1.12±0.13	26.33±9.08^{c}	19.3±2.08	54.34±8.4^{ab}
	FS	23.03±1.24^{a}	1.10±0.03	23±3^{c}	16.66±0.6	60.33±3.5^{a}
LWOJ	US	14.26±1.31^{d}	1.23±0.05	42.67±3.1^{a}	24.66±5.8	32.63±3^{d}
	MS	16.27±1.52^{cd}	1.20±0.03	39.33±1.2^{ab}	23.67±2.1	36.57±1.5^{cd}
	FS	16.8±0.83^{bcd}	1.18±0.11	31.6±6.7^{bc}	23.33±2.9	43.65±2^{bcd}
P-value		0.005	0.47	0.01	0.18	0.006
LSD(0.05)		3.77	0.16	9.95	7.24	13.20
CV (%)		11.35	7.36	16.89	18.82	15.76

*STC = soil texture class; BD = bulk density; SMC = Soil moisture content; LWJ = land with Jatropha; LWOJ = land without Jatropha; US(16-22%) = upper slope; MS(6-15%) = middle slope; FS(0-5%) = foot slope
**Interaction effects means within a column followed by the same letter are not significantly different at 5% level of significance

4.1.2. Soil Bulk Density and Moisture Content

Soil bulk density was one of the major parameters used in this study to assess the fertility status of soil in terms of physical property. The analysis result shown that the mean values of the soil bulk density under land with *J. curcas* and adjacent land without *J. curcas* were 1.12g/cm^3 and 1.21g/cm^3 respectively. The statistical analysis revealed a significance ($P<0.05$) difference in bulk density due to *J. curcas* plantation on degraded land (Table 1). As compared to adjacent land without *J.curcas*, bulk density of land with *J. curcas* was reduced by 20.56 %. This is maybe due to higher Organic matter and clay proportion of the soil under land with Jatropha. Correlation matrix (Table 7) also shown a negative and significance relationships between bulk density and clay content ($p< 0.01$, $r=-0.48^*$), bulk density and organic matter ($p< 0.01$, $r =-0.59^*$).

This result agrees with earlier findings of Soumit *et al*. (2010) who reported that the soil bulk denisity of land with Jatropha was significantly reduced as compare to land not having this plant. Similarly, Kumar *et al.* (2009) and Makkar and Becker (2009). Reported that the plantation of Jatropha on degraded soil decreases the bulk density which is an indicator of the enhancement of the soil fertility. On the other side, the highest mean value of bulk density recorded on adjacent land without Jatropha was due to the removal of light weight soil particles by erosion.

Moreover, Frank(1990) stated that the bulk density of agricultural soil ranges from 0.9-1.2 gm/cm^3, and hence, the mean bulk density result obtained (1.12-1.21 gm/cm^3) under these two land use types (land with *J. curcas and* without *J. curcas*) studied were almost situated in the agricultural soil. This implies that both land use types are in good condition in their bulk density.

The variations in slope positions in the study area was not significantly ($P<0.05$) affected the mean value of soil bulk density. Besides, the interaction effects of land use with slope positions on bulk densities were also revealed that statistically non significance differences at 0.05 levels of significance (Table 2). Numerically, comparing the mean value of soil bulk density of the two land uses across the slope positions, the lowest mean value was observed under land with Jatropha at the foot slope positions whereas the highest was measured under the adjacent land without Jatropha of upper slope positions.

The analysis result indicated that the highest (20.74 %) and lowest (15.78 %) mean value of the soil moisture contents were recorded on land with *J. curcas* and adjacent land without *J. curcas* respectively. The variation was statistically significant ($P < 0.05$) (Table 1). The mean value of SMC was increased by 31.4 % in the land with *J. curcas* in contrast to soil without *J. curcas*. The higher organic matter buildup from plant residues and the higher clay percentage of the soil in the land with *J. curcas* might have contributed to the higher moisture retention of the soil. In line with this finding, Kumar *et al*. (2009) reported that the *J. curcas* can increase the moisture content of the soil due to higher input of organic matter into soil and root ramifications.

Comparing the mean value of the soil moisture content of the different slope (US, MS and FS) positions, the highest mean value was recorded on foot slope positions and the lowest value was recorded on the upper slope positions. The statistical analysis revealed a significant difference (P

< 0.05) of moisture contents at different slope ranges. The variations in SMC at different slope positions may be explained through the difference in soil erosion rates. The mean values of soil moisture content of the US, MS and FS slope positions on land with Jatropha were 18.83, 20.34 and 23.03 % and on adjacent land without Jatropha were 14.26, 16.27 and 16.8 % respectively. The difference was statistically significant at 0.05 levels of significance (Table 2). The mean values of moisture content of the both land use for the slope positions shown a decreasing trend from US to FS positions (Table 2). However, comparing the land with Jatropha and adjacent land without Jatropha at each slope positions, the mean value recorded under land with Jatropha was greater than the value recorded under adjacent land without Jatropha of the same slope category. The land covered with Jatropha may reduce the evaporation chance to occur by increasing surface cover, and also the dawn movements of soil nutrients along the slope positions resulted for high deposition of soil materials in foot slope area which contribute the greatest amount of SMC recorded under land with *J.*curcas of foot slope area. In line with this finding, Ahmed (2002) reported that variation in topography, land use and soil attributes all affect the distribution of soil moisture content.

4.2. Effect of Jatropha (*Jatropha curcas L.)* on Soil Chemical Properties

4.2.1. Soil pH and Electrical Conductivity (EC)

The analysis results presented in Table 3 shown that the highest (6.58) and lowest (5.67) mean value of pH was recorded under the land with Jatropha and adjacent land without Jatropha respectively. The value was statistically significance difference at 0.05 levels of significance. The lowest values of soil pH at the adjacent land without Jatropha could be because of loss of basic cations through leaching and drain by runoff generated on degraded land whereas highest value of soil pH on land with Jatropha might be due to addition of organic matter from plant residues, litters and, recycling basic cations from deeper soil layers to the top surface by its fine root structure. Organic matter acts as a significant buffer for pH, helping the soil to maintain a fairly constant and neutral pH and high CEC. The relative change also showed that the pH value increased by 16.05 % under land with J.curcas as compared to the adjacent land without *J.curcas*. This implies that *J.curcas* has the possibility to improve the value of soil pH. The improvement of soil pH can bring the improvement on selected soil chemical properties because pH controls all chemical reactions in soil. The sampled soils under land with Jatropha rated as slightly acid while adjacent land without Jatropha rated as medium acidic according to rating given by Bruce (1997).

Considering the US, MS and FS slope positions, the highest mean values 6.31 of soil pH was observed on foot slope positions and the lowest mean values 5.95 was observed on upper slope positions respectively. The difference was statistically significance at 0.05 (Table 3). This is because erosion can significantly accumulate these soluble ions such as $Ca^{2+,}$ Mg^{2+} and K^{+} from the upper slope and deposit on the foot slope positions where leaching is weaker and soil enrichment is stronger. As previous study carried by Belay (1996); Abayneh (2001) and Mohammed *et al.* (2005) showed that the soil in high altitude and those higher slopes had low pH values because of washing out of solutes and basic cations from these parts. The correlation matrix (Table 7) indicated that a positive and highly significance relationships between soil pH value and Ca (r = 0.92**), Mg (r = 0.92**) and K (r = 0.74**). This finding is also in agreement with Chun-Chih *et al.* (2004) who reported that the highest mean value of soil pH on the foot slope positions compared to upper slope positions.

Table 3: Main effects of land use and slope positions on selected chemical properties of the soils and the value of their relative change

Treatments	PH-H_2O	EC(ms/cm)*	OC (%)	OM (%)	TN (%)	AvP(ppm)
			Land use types			
LWJ	6.58±0.16[a**]	0.07±0.01[a]	4.01±0.44[a]	6.91±0.77[a]	0.41±0.05[a]	18.93±3.6[a]
LWOJ	5.67±021[b]	0.05±0.004[b]	1.84±0.88[b]	3.17±1.52[b]	0.27±0.04[b]	14.2±2.02[b]
RC (%)	16	40	117.9	117.9	51.85	33.3
LSD(0.05)	0.11	0.01	0.35	0.61	0.02	0.09
P-value	0.0001	0.001	0.0001	0.0001	0.001	0.0001
			Slope positions			
US	5.95±0.49 [c]	0.05±0.006[b]	2.24±1.48[c]	3.87±2.6[c]	0.29±0.06[c]	13.82±1.7[c]
MS	6.11±0.54[b]	0.06±0.005[b]	2.85±1.25[b]	4.91±2.2[b]	0.35±0.08[b]	16.62±2.8[b]
FS	6.31±0.47[a]	0.07±0.01[a]	3.66±0.87[a]	6.32±1.5[a]	0.39±0.08[a]	19.23±4.4[a]
LSD(0.05)	0.13	0.01	0.43	0.75	0.02	2.28
P-value	0.0001	0.001	0.0001	0.0001	0.0001	0.0007
CV (%)	1.85	10.5	12.01	12.03	5.54	9.41

*EC = electric conductivity; OC = organic carbon; OM = organic matter; TN = total nitrogen: AvP = available phosphorus LWJ = land with Jatropha; LWOJ = land without Jatropha; US (16-22%) = upper slope; MS (6-15%) = middle slope; FS (0-5%) = foot slope

**Interaction effects means within a column followed by the same letter are not significantly different at 5% level of significance

The interaction effect of land use with topographic position was statistically significance at 0.05 (Table 4).The highest mean value of pH (6.73) was recorded on the land with *J. curcas* on the foot slope positions whereas the lowest mean value of pH 5.44 was observed on adjacent land without *J. curcas* on upper slope positions. This result agrees with Kumar *et al*. (2009) finding who explained the mean value of the soil pH under land with *J.curcas* and under adjacent land without *J.curcas* at different slope positions was significantly different.

The values of electrical conductivity (EC) were non saline across the land use system due to the fact that the study area received high amount of rainfall (900-1300mm). However, electrical conductivity was significantly ($P < 0.05$) affected by land use systems, slope of land, and interaction of land use and slope (Table 4). The highest mean value of EC (0.07ms/cm) was recorded under the land with *J.curcas* whereas the lowest mean value 0.05ms/cm was recorded under the adjacent land without *J.curcas* respectively. The relative change was increased by 40 % on land with Jatropha site. The credible reason for this could be accumulation of exchangeable bases from decomposition of organic matter results high EC at land with Jatropha plantation. In harmony with this result, Habtamu (2011) findings showed that the mean value EC under the *J. curcas* is higher than the mean value of EC away from the plant *J. curcas*.

The mean value of EC (0.07ms/cm) obtained from the foot slope positions was significantly greater than the value of EC (0.05 ms/cm) observed in the upper slope position area. When we compared topographic positions of the land with Jatropha and adjacent land without Jatropha with each other, the mean values of EC of at upper, middle and foot slope of the land with *J.curcas* was increased by 20.83, 11.11 and 60.71 % respectively.

Table 4: The mean (±MSD) interaction effects of land use types and slope positions on selected soil chemical properties

Land use types	Slope	PH-H_2O	EC(ms/cm)*	OC (%)	OM (%)	TN (%)	AvP(ppm)
LWJ	US	$6.39 \pm 0.11^{b**}$	0.058 ± 0.01^{bc}	3.6 ± 0.15^{b}	6.2 ± 0.26^{b}	0.35 ± 0.01^{c}	15.68 ± 1.5^{c}
	MS	6.61 ± 0.06^{a}	0.06 ± 0.04^{b}	3.98 ± 0.31^{ab}	6.86 ± 0.54^{ab}	0.42 ± 0.04^{b}	18.98 ± 1.1^{b}
	FS	6.73 ± 0.04^{a}	0.09 ± 0.01^{a}	4.44 ± 0.39^{a}	7.65 ± 0.68^{a}	0.46 ± 0.02^{a}	22.81 ± 1.3^{a}
LWOJ	US	5.44 ± 0.08^{e}	0.048 ± 0.01^{d}	0.89 ± 0.1^{e}	1.5 ± 0.18^{e}	0.24 ± 0.01^{e}	12.64 ± 1.3^{d}
	MS	5.62 ± 0.04^{cd}	0.054 ± 0.02^{cd}	1.72 ± 0.2^{d}	3 ± 0.35^{d}	0.27 ± 0.01^{d}	14.26 ± 0.9^{cd}
	FS	5.9 ± 0.22^{c}	0.056 ± 0.01^{bc}	1.8 ± 0.06^{c}	5 ± 0.1^{c}	0.31 ± 0.01^{c}	15 ± 1.5^{cd}
P-value		0.0001	0.0001	0.0001	0.0001	0.0001	0.0002
LSD(0.05)		0.16	0.01	0.16	0.01	0.04	2.05
CV (%)		1.43	5.63	1.43	5.63	5.95	9.13

*EC = electric conductivity; OC = organic carbon; OM = organic matter; TN = total nitrogen: AvP = available phosphorus LWJ = land with Jatropha; LWOJ = land without Jatropha; US (16-22%) = upper slope; MS (6-15%) = middle slope; FS (0-5%) = foot slope

**Interaction effects means within a column followed by the same letter are not significantly different at 5% level of significance

4.2.2. Organic Carbon and Organic Matter

The study results indicated that the highest mean value of soil OC (4.01 %) and OM (6.91 %) were recorded under land with *J. curcas* and the lowest mean value OC (1.74 %) and OM (3.17%) were measured under adjacent land without *J. curcas*. This difference between land use types was significantly variable at P value of 0.05 (Table 3). The reason for considerably higher OC and OM under land with *J.curcas* was due to accumulation of plant roots exudates, decomposed of plant litter and leaves shade and limited soil disturbance that enhance accumulation of OC and OM. The relative change of OC and OM was also increased by 130.5 and 117.98 % under Jatropha land respectively. Other study similar to this finding have been reported by Soulama (2008) who observed highest OC under Jatropha hedgerows compared to neighboring soils. Furthermore, Singh and Ghoshal (2011) observed that the highest OC in land with Jatropha compare to other in agro-ecosystems. According to rating given by Charman and Roper (2000), the value of soil OC was ranges from high to moderate for land with Jatropha and adjacent land without Jatropha correspondingly. Similarly, as rating given by Hazelton and

Murphy (2007) the soil OM content under land with Jatropha and adjacent land without Jatropha was very high to medium accordingly. This implies that soil of land with Jatropha has good physical (structural condition and high structural stability) and chemical conditions.

The result indicated in table 3 shown that the effect of slope positions and its interaction with land use types were affect OC and OM significantly ($P < 0.05$) .The highest mean value of OC and OM were observed on the foot slope positions and followed by MS and US slope positions. This result is in agreements with Sariyildiz *et al*. (2005) finding who reported that concentrations of OC and OM were higher in the middle and lower slope positions than in the upper slope positions. The highest mean interaction value of land use with slope positions were recorded under land with *J. curcas* on the foot slope positions while the lowest value was recorded under adjacent land without *J. curcas* on the upper slope positions. The mean value of OM of the land with *J.curcas* at upper, middle and foot slope positions were increased by 313, 128.67 and 53 % compare to land without Jatropha of the same topographic positions respectively. This is mainly due to the steepness of the US positions compared to MS and FS positions together with low vegetation cover of this land use type.

4.2.3. Total Nitrogen and Available Phosphorus

The analysis result revealed that the mean values of both total nitrogen and available phosphorus were significantly higher ($P<0.05$) under land with *J. curcas* than adjacent land without *J. curcas*. The total nitrogen content under land with *J. curcas* and adjacent land without *J.curcas* was 0.41 and 0.23 %, and available phosphorus was 18.93 and 14.18 ppm respectively (Table 3). The nutrient availability improved through recycling of the biomass back into the soil and decomposition of OM from *J. curcas* maybe the reason for the significant enhancement of the amount of TN and AvP in the land planted with *J. curcas*. Moreover, the correlation matrix (Table 7) also indicated that there was a positive and significantly relationship between TN and OM content ($p<0.01$, $r=0.95^{**}$), AvP and OM ($p<0.01$, r=0.79**). The TN rated as very high according to Bruce and Rayment (1982) and the AvP rated as high based on Holford and Cullis (1985) rating for the land treated with *J. curcas*. Relative change of the TN and AvP under land with Jatropha and adjacent land without Jatropha was increased by 51.85 and 33.49 % respectively. These results are consistent with many authors (Shehu, 2013; Kumar *et al*., 2009;

Habtamu, 2011) who described that the averaged value of TN and AvP of the land with *J.curcas* was higher than that of land without Jatropha plantation.

Regarding the impacts of slope positions, the result indicated that the mean value of TN and AvP were higher on the foot slope positions than on the upper slope positions. This was statistically significance differences at 0.05 levels of significance (Table 3). The highest mean value of TN and AvP were observed under the land treated with Jatropha at the foot slope positions. On the contrary, the lowest values of TN and AvP were observed in the adjacent land not planted by Jatropha of the upper slope positions. This statistically ($P< 0.05$) different levels of both TN and AvP found with relation of land use type and topographic positions were due to slopes control the movement of soil material in a hill slope and contribute to the spatial differences of soil properties. The result is in harmony with Buyinza and Nabalegw (2011) reported that areas protected with plants had an increasing trend in total nitrogen and available phosphorus from upper slope to foot slope position.

4.2.4. Cation Exchange Capacities (CEC) and Exchangeable Bases and PBS

The study results indicated that the mean value of cation exchange capacities (CEC) of the soil of land with *J. curcas* and adjacent land without *J.curcas* were 40.94 cmol (+)/kg and 27.24 cmol (+)/kg respectively. Hence, the highest value of CEC was observed under land with Jatropha and its relative change was increased by 50.3 % in contrast to the land without Jatropha .The difference between the two soils was also statistically significance difference ($P < 0.05$) (Table 5). This is most likely attributed to increment in exchangeable cations ($Ca^{2+,}$ Mg^{2+} and K^{+}), OM and clay contents under land with Jatropha. It is a general truth that both clay and colloidal OM have the ability to absorb and hold positively charged ions. Thus, soils containing high clay and OM contents have high CEC. In line with this Kibret (2008) reported that soil CEC is associated with clay and OM colloids, and especially OM renders soils have a better CEC. Furthermore, the relationships between CEC and $Ca^{2+}{}_{,}$ (r=0.99**), Mg^{2+}(r=0.89**), K^{+}(r=0.89**), OM (r=0.97**) and clay (r=0. 86**) revealed that the high significant and positively associated. Similar to this study, Habtamu (2011) showed that the average CEC of the soil under Jatropha was considerably greater than the soils away from Jatropha plantation.

Table 5: Main effects of land use and slope positions on CEC, Exchangeable Bases and PBS of the soils and the value of their relative change

Treatments	cmol(+)/kg					PBS*(%)
	CEC*	Ca	Mg	K	Na	
			Land use types			
LWJ	40.94±[a**]	26.57±4.54[a]	3.12±0.6[a]	1.75±0.7[a]	0.08±0.15[a]	76.48±3.4[a]
LWOJ	27.24[±b]	16.35±2.41[b]	1.8±0.3[b]	0.79±0.4[b]	0.045±0.2[b]	70.75±4.8[b]
RC (%)	50.3	62.5	73.3	121	77.8	8
LSD(0.05)	6.37	1.65	0.22	0.37	0.056	2.96
P-Value	0.0001	0.0001	0.0001	0.0001	0.0013	0.0009
			Slope positions			
US	29.25±5.48[c]	17.71±4.04[c]	1.94±0.53[c]	0.72±0.34[c]	0.55±0.11[c]	69.31±4.75[b]
MS	33.6±8.46[b]	21.76±5.64[b]	2.48±0.75[b]	1.28±0.55[b]	0.79±0.04[b]	75.75±2.61[a]
FS	39.41±8.83[a]	25.37±6.88[a]	2.96±0.91[a]	1.81±0.87[a]	0.93±0.05[a]	75.79±4.87[a]
LSD(0.05)	2.44	2.02	0.26	0.45	0.068	3.63
P-value	0.0001	0.0001	0.0001	0.0001	0.001	0.0021
CV (%)	5.78	7.53	8.79	14.32	14.31	3.77

*CEC = cation exchange capacity; PBS = percent base saturation; LWJ = land with Jatropha; LWOJ = land without Jatropha; US (16-22%) = upper slope; MS (6-15%) = middle slope; FS (0-5%) = foot slope
**Interaction effects means within a column followed by the same letter are not significantly different at 5% level of significance

The mean value of CEC of at US, MS and FS positions were 29.25, 33.61 and 39.41cmol (+)/kg respectively. There was significance difference ($P < 0.05$) among these slope ranges (Table 5). The highest mean value of CEC was recorded at foot slope whereas the lowest mean value was recorded at the upper slope. This result is in agreement with Huggett (1975) who reported that the value of CEC on upper topographic position was less than that of lower topographic position. The highest and the lowest value of CEC were recorded under land with *J.curcas* on the foot slope positions and adjacent land without *J.curcas* on the upper slope positions respectively. The probable reason for substantially higher CEC in the lower slope managed with *J.curcas* was because of basic cation on the upper slope positions that moved to the lower slope positions and accumulated on foot slope positions due to erosions and also the contribution of organic matter from this plant. Bahilu *et al*. (2014) also reported in agreement with this study, high mean value of CEC was obtained at the lower slope position of land covered by plants and low mean value was obtained at grazing land on upper slope position.

The results of exchangeable bases were significantly different (P< 0.05 (Table 5) due to land use effect. The higher and the lowest mean value of Ca^{+2}, Mg^{+2}, K^{+} and Na^{+} were recorded under land with Jatropha and adjacent land without Jatropha accordingly. As compared to adjacent land without Jatropha, exchangeable Ca^{+2}, Mg^{2+}, K^{+} and Na^{+} were increased under land with Jatropha by 59.38, 73.33, 121.51 and 39.47 %, respectively. The highest relative change was observed in K^{+} while the least relative change was observed in Na^{+}. The increasing in basic cations on land with *J.curcas* was might be due to plant's root system facilitates the nutrient cycling from subsurface. In line with this study Munyinda *et al.* (2009) reported that *J.curcas* is able to pump minerals from the depth of the soil to the surface because of its deep reaching tap root. Besides, this finding is in agreement with Velayutham (2000) who reported that the lowest and the highest mean value of Ca^{+2}, Mg^{+2} and K^{+} were observed before and after Jatropha plantations at different soil depth. The effect of slope positions (Table 5), and also combined effect of topographic positions and land use type (table 6) on exchangeable bases ($Ca^{+2,}$ Mg^{+2}, K^{+} and Na^{+}) were statistically significant ($P < 0.05$). The highest mean value of the all exchangeable bases (Ca^{+2}, Mg^{+2}, K^{+} and $Na^{+)}$ were observed under land with *J.curcas* on the foot slope positions whereas the lowest values were measured under adjacent land without *J.curcas* on the upper slope positions. Besides, almost all types of exchangeable bases at upper area of the watershed where Jatropha was planted had greater amount than land without this plant. Kellman (2002) also stated that the nutrient loss across the slope positions can be dramatically decreased through the presence of Jatropha plants on a site.

Table 6: The mean (±MSD) interaction effects of land use types and slope positions on selected soil chemical properties

Land use type	Slope	Cmol(+)/kg					PBS *%
		CEC	Ca	Mg	K	Na	
	US	$34.13±1.14^{c**}$	$21.26±1.5^{c}$	$2.42±0.15^{c}$	$1.09±0.26^{c}$	$0.05±0.01^{b}$	$74.6±1.1^{bc}$
	MS	$41.29±.8^{b}$	$26.84±1.1^{b}$	$3.15±0.11^{b}$	$1.75±0.28^{b}$	$0.05±0.01^{b}$	$77±0.95^{ab}$
LWJ	FS	$47.38±1.1^{a}$	$31.59±1.4^{a}$	$3.79±0.14^{a}$	$2.52±.26^{a}$	$0.07±0.01^{a}$	$80.1±0.59^{a}$
	US	$24.37±1.34^{e}$	$14.16±1.3^{f}$	$1.47±0.18^{f}$	$0.48±0.22^{d}$	$0.03±0.01^{c}$	$66.3±5.3^{d}$
	MS	$25.93±1.24^{e}$	$26.84±1.1^{b}$	$1.8±0.16^{e}$	$0.81±0.15^{cd}$	$0.04±0.0^{bc}$	$71.4±3.44^{c}$
LWOJ	FS	$31.42±1.14^{d}$	$19.15±1.5^{d}$	$2.13±0.15^{d}$	$0.96±0.55^{cd}$	$0.04±0.0^{bc}$	$72.3±1.1^{bc}$
P-value		0.0001	0.0001	0.0001	0.0001	0.0001	0.001
LSD(0.05)		3.3	1.84	0.25	0.55	0.01	4.81
CV (%)		3.74	4.67	5.49	12.23	9.42	3.59

*CEC = cation exchange capacity; PBS = percent base saturation; LWJ = land with Jatropha; LWOJ = land without Jatropha; US (16-22%) = upper slope; MS (6-15%) = middle slope; FS (0-5%) = foot slope

**Interaction effects means within a column followed by the same letter are not significantly different at 5% level of significance

PBS is the percentage of the CEC occupied by the basic cations Na^+, Ca^{2+}, Mg^{2+} and K^+. The PBS under land with *J.curcas* and adjacent land without *J.curcas* was 76.48 and 70.75 % respectively. The relative change of PBS under land with Jatropha was enhanced by 8.1% and this change also significantly (P<.0.05) increased. The mean values of PBS were 69.31, 75.75 and 75.79 % at upper, middle, and foot slope positions respectively. Across the slope positions from upper to lower topographic position the PBS was indicated that significant increment (P < 0.05). The mean value of PBS under land with Jatropha of foot slope area was significantly higher than all interaction effect of land use types and slope positions except middle slope area of land covered by Jatropha (table 6). The result agreement with earlier findings of Buyinza and Nabalegw (2011) who reported that area protected by plant was shown significantly increasingin percentage base saturation from upper slope to lower slope position.

Table 7: Pearson's correlation matrix for selected soil physico-chemical parameters

	SMC	BD	Sand	Silt	Clay	PH	EC	OC	OM	TN	AvP	CEC	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	PBS
SMC	1																
BD	-.49*	1															
Sand	-.62**	.59**	1														
Silt	-.37ns	.38ns	.43	1													
Clay	.63**	-.59*	-.91**	-75**	1												
pH	.82**	-.51*	-.79**	-.57*	.83**	1											
EC	.82**	-.42*	-.63**	-.53*	.70**	.75**	1										
OC	.79**	-.48*	-.77**	-.63**	.83**	.93**	.75**	1									
OM	.79**	-.48*	-.77**	-.63**	.83**	.93**	.75**	1.0**	1								
TN	.82**	-.45*	-.72**	-.62**	.80**	.94**	.85**	.95**	.95**	1							
AvP	.75**	-.38ns	-.66**	-.62**	.77**	.74**	.89**	.79**	.79**	.87**	1						
CEC	.83**	-.55*	-.78**	-65**	.86**	.93**	.88**	.92**	.92**	.97**	.88**	1					
Ca^{2+}	.84**	-.57**	-.77**	-.65**	.85**	.92**	.9**	.9**	.9**	.97**	.89**	.99**	1				
Mg^{2+}	.84**	-.58*	-.77**	-.65**	.85**	.92**	.9**	.9**	.9**	.97**	.89**	.99**	1**	1			
K^{+}	.75**	.38ns	-.66**	-.62**	.77**	.74**	.89**	.79**	.79**	.87**	1**	.89**	.89**	.89**	1		
Na^{+}	.79**	-.41ns	-.57*	-.57*	.68**	.72**	.96**	.73**	.73**	.79**	.84**	.85**	.86**	.86**	.84**	1	
PBS	.69**	-.54*	-57*	-.53*	.66**	.65**	.8**	.71**	.71**	.78**	.8**	.76**	.82**	.82**	.8**	.72**	1

**=highly significant;*= significant, ns =non significant; BD=bulk density; SMC=soil moisture content; pH=potential for hydrogen; EC=electrical conductivity; OC=Organic carbon; OM= organic matter; TN=total nitrogen; AvP=available phosphorous; CEC=cation exchange capacity; Ca^{2+}= Calcium; Mg^{2+}=Magnesium, k^{+}=Potassium; Na^{+}=sodium and PBS=percentage base saturation

5. CONCLUSIONS AND RECOMMENDATIONS

The obtained result in this study revealed that Jatropha plantations have the potential of improving physico-chemical properties of soil of the study area. Bulk density, soil moisture content, sand, silt ,clay, pH, EC, OC, OM, TN, AvP, CEC, exchangeable cations ($Ca^{2+,}$ $Mg^{2+,}$ K^{+} and Na^{+}) and PBS showed statistically significant difference at ($P < 0.05$) for the soil under land with Jatropha and adjacent land without Jatropha. The attributes of the soils under lands with Jatropha showed overall change towards the direction of increasing their fertility compared to the soils attributes of the adjacent land without Jatropha plantations. Their mean interaction effects of land by slope position also were significantly higher under land with Jatropha except bulk density sand and silt. Analysis results also indicated that significant ($P < 0.05$) soil nutrient improvement along the slope gradient under land with Jatropha compare to adjacent land without Jatropha except soil bulk density and silt fractions. Hence, based on obtained results of this study, *J.curcas* plantations is pumping soil nutrient rather than mining it.

Generally *J.curcas* plantation was enhanced fertility of the soil which brings back the life to the "dead" soil. Therefore, Jatropha plantation has promising potential to play a decisive role on soil fertility improvement of degraded land. For this reason, Jatropha plantations could be not only as an alternative but also a compulsory to improve the soil physico-chemical properties of the soil in the study area. Despite more research is needed to be done on longer years stand than the ones considered in this research. Taken the contribution of Jatropha for soil fertility improvement that enhance rehabilitation of degraded land, this study recommended that appropriate site selection should be carried out for Jatropha plantation based on detailed land use planning. To increase the benefit obtained from the Jatropha plantation, management and conservation activities should be strengthened in the future. In this study only selected physico-chemical properties of the soil were tested, therefore, further study should be considered the effect of *J. curcas* on soil biological properties and micro nutrients, the socio-economic and other environment effects.

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APPENDICES

Appendix 1: ANOVA result for selected physico-chemical properties the soil under two land uses in the Melka Laku watershed

Soil parameters	R^2	MSE	F- value	P-value	CV (%)
SMC (%)	0.74	2.07	30.64	0.0001	10.4
BD(g/cm3)	0.70	0.08	5.78	0.031	6.36
Sand (%)	0.76	5.43	17.42	0.0009	17.26
Silt (%)	0.70	3.98	9.15	0.0091	18.03
Clay (%)	0.75	7.25	31.89	0.007	13.68
pH	0.95.5	0.1	89.82	0.0001	1.83
EC(ms/cm)	0.75	0.003	26.83	0.0001	10.5
OC (%)	0.94	0.25	96.67	0.0001	12.02
OM (%)	0.94	0.44	96.67	0.0001	12.02
TN (%)	0.96	0.02	88.76	0.0001	5.52
AvP(ppm)	0.80	1.65	29.92	0.0001	11
CEC(mol(+)/kg)	0.96	1.12	99.33	0.0001	5.78
Ca(mol(+)/kg)	0.94	1.01	78.39	0.0001	7.52
Mg(mol(+)/kg)	0.98	0.13	74.11	0.0001	8.79
K(mol(+)/kg)	0.80	0.3	30.07	0.0001	20.12
Na(mol(+)/kg)	0.92	0.004	16.17	0.0013	7.21
PBS (%)	072	2.64	17.63	0.0009	3.93

Appendix 2: Mean value for soil physico-chemical properties under two land use system in the

Soil parameters	LWJ	Rating	LWOJ	Rating	Sources
SMC (%)	20.73	-	15.18	-	-
BD(g/cm3)	1.12	low	1.21	low	Holford and Cullis(1985)
Sand (%)	26.88	Moderate	37.89	moderate	Pan and Brian(2007)
Silt (%)	18.44	low	23.97	moderate	
Clay (%)	54.44	high	37.67	moderate	
pH-H20	6.58	slightly acid	5.67	Medium acidic	Bruce (1997)
EC(ms/cm)	0.07	Non saline	0.05	Non saline	Frank (1990)
OC (%)	4.01	high	1.84	moderate	Charman and Roper (2000)
OM (%)	6.91	V.high	3.17	moderate	Hazelton and Murphy (2007)
TN (%)	0.41	V.high	0.27	high	Bruce and Rayment (1982)
avail P(ppm)	18.93	high	14.18	medium	Holford and Cullis(1985)
CEC(mol(+)/kg)	40.94	high	27.24	high	Hazelton and Murphy (2007)
Ca(mol(+)/kg)	26.57	V.high	16.35	high	Frank (1990)
Mg(mol(+)/kg)	3.12	V.high	1.8	high	
K(mol(+)/kg)	1.75	high	0.79	low	
Na(mol(+)/kg)	0.82	high	0.71	medium	
BS (%)	76.48	high	70.75	high	

Appendix 3: Fertilizer value of *J. curcas* oil cake, root and other manures

Fertilizer properties	*J.curcas* Oil cake (%)	*J. curcas* Root (%)	Cow dung (%)	Neem oil Cake (%)	Chicken manure (%)
Nitrogen	3.2 - 4.44	2.16	0.97	5.00	3.04
Phosphorus	1.4 - 2.09	0.08	0.69	1.00	6.27
Potassium	1.2 - 1.68	2.18	1.66	1.50	2.08
Moisture	4.58	-	9.70	-	10.19

Source: (Delgado and Parado, 1989)

Appendix 4: The mean value of soils chemical properties collected before and after the plantation of Jatropha

Soil depth	(BR)S1	(AR)S1	(BR)S2	(BR)S2	(BR)S3	(AR)S3
Chemical Properties						
pH	11.9	9.9	11.2	10.1	11.2	9.1
EC	1.1	0.9	0.9	1.0	1.1	1.0
OC	0.43	0.53	0.45	0.51	0.24	0.45
Na +	7.45	7.43	7.42	7.40	6.45	6.41
K+	0.59	0.60	0.52	0.56	0.49	0.55
Ca2+	11.0	11.34	10.0	11	10.0	10.9
Mg2+	2.09	2.09	2.09	2.08	2.08	2.08
CEC	16.71	16.77	16.43	16.72	16.51	16.62
ESP	47.80	51.46	45.58	50.05	44.33	50.33

Source: (Velayutham, 200)