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Jatropha Curcas L. for Rehabilitation of Degraded Land of Gilgel Gibe Watershed, South Western Ethiopia

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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. 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. The overall objective of this study was to assess the role of *Jatropha curcas* to rehabilitate soil fertility. To achieve the objective**,** Melka Leku sub watershed was selected from Oromia regional state**.** 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 revealed that, all selected soil physico-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 that of 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. The land use interaction by slope positions were significance ($p< 0.05$) difference for measured soil parameters except for mean value of bulk density, silt and sand at three slope under land with Jatropha and upper and middle slope of adjacent land. Therefore, 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.*

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 (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). Land degradation has been recognized to be one of the chronic and continuous problems that have been deteriorated natural resource at alarming rate however; many efforts have been made against it (Yohannes, 1999; Genene, 2006).

The problem is primarily caused by soil erosion; that cause by cultivation of steep slope and inadequate investments in soil conservation, erosive rainfall patterns, declining use of fallow, limited recycling of crop residues to the soil, deforestation and overgrazing (Belay, 2003). 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 and reducing water infiltration Therefore, soil erosion has been a major threat to the reduction of productive capacity of the soil (Nsabimana *et al*., 2008). Approximately 90 % of the population lives in reduced agricultural productivity due to low soil fertilities (Simon, 2012). The study site is not an exceptional from the problem that mentioned above.

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. *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). *J.curcas* used 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 (Adem, 2011). It also 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). Jatropha 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 (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. Therefore, objective of this study were to understand the role of *Jatropha curcas on rehabilitation of degraded soil fertility of Gilgel Gibe Watershed. This systematic* and focused research on *Jatropha curcas* L. for rehabilitation of degraded land was essential and may play a significant role for policy maker, academic purpose, research institution, rural communities and for Gilgel Gibe watershed development.

MATERIALS AND METHODS

Description of the Study Area

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 site is 222km far from Addis Ababa, capital city of Ethiopia. Geographically the site 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 mean annual rainfall of the study site varies between 900-1300 mm. About 86% of the annual rainfall is during the months of March to September.

The total population of the study area is 1443. Out of this, 548 were male and 895 were female. The people of the study area concerned with mixed agriculture where they integrated crops production with livestock husbandry. The land use types was categorized as 59 % is arable, 8 % covered by shrubs and forest ruminants, 28 % occupied by villages / homesteads, 1 % is grazing land and 4 % of the site was degraded land. The land form belongs in the study site 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 site is deep red and gray, classified as Nitisols.

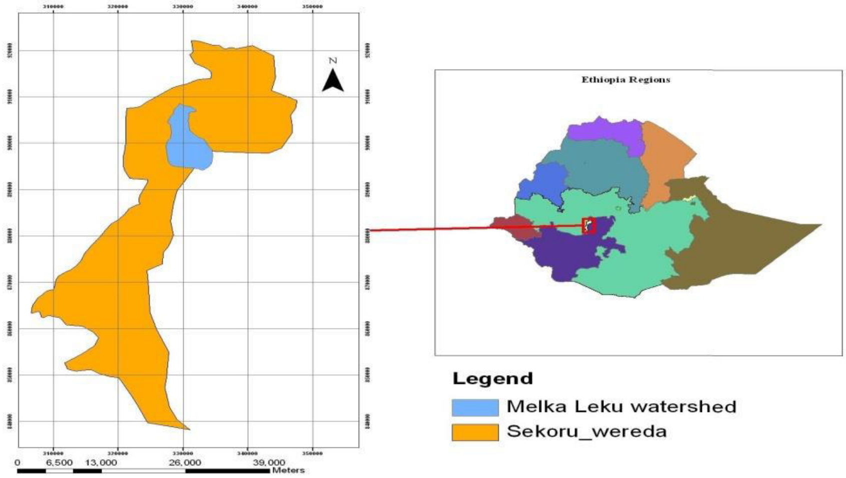

Figure1: Maps of the study area

Methods of Data Collection and Analysis

Soil sampling and Laboratory analysis

Two representative land use types namely, land with Jatropha (*Jatropha curcas.* L) and adjacent land without Jatropha were selected from (lower, middle and upper) topographic position. Disturbed and undisturbed soil samples were collected from each land use type in three replicates from the three slope positions, lower (0-5%), middle (6-15%), and upper (15-22%) slope gradients. At each slope position the two land use types were selected from a more or less similar altitude, slope and soil types. For soil chemical property analysis, 18 disturbed soil sample from 2 land use x 3 slope position x 3 replication were considered. Ten soil samples were collected from 0-30cm soil depth to make one composite sample for each replication. Undisturbed soil samples were also taken by using core ring to investigate soil bulk density and soil moisture content. For soil physical property analysis, eighteen (18) undisturbed soil samples were taken from top layers of 0-30 cm soil depth. The disturbed soil samples collected were air dried, mixed well and pass through a 2 mm sieve for chemical analysis. The analysis was carried out at the soil laboratory of the Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) following standard laboratory procedures.

Soil particle size distribution was determined by the Boycouos hydrometric method (Bouyoucos, 1962;Van Reeuwijk, 1992).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. 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= weight fresh soil (g) + weight of empty core (g), B=weight of oven dry soil (g) +weight of empty core (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 and calculated by the following formula indicated by (FAO, 2007):-

$BD = \frac{\text{Wt of oven dry soil (g)}}{\text{Volume of the core(cm3)}} x100$ Weights of oven dry soils (g) and V is the volume of the cylindrical core (cm^3).

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 according to Van Reeuwijk, (1992). The soil organic carbon was determined by the Walkley-Black oxidation method 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). 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+}) measured by AAS method and Exchangeable potassium (K^+) and sodium (Na^+) 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^+) to 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

Statically 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.

RESULTS AND DISCUSSION

Soil physical properties

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 and erosion resistivity nature of clay particles which reduces the clay fractions likely to be lost by selective erosion processes and slow clay movement down into soil profile. 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. 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 lower slope positions. On the contrary, the highest mean value of the clay fractions 52 % was recorded on the lower 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}
LS	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

* LWJ = land with Jatropha; LWOJ = land without Jatropha; US (16-22%) = upper slope; MS (6-15%) = middle slope; LS (0-5%) = Lower 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 lower 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 lower 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 lower 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 lower 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 (%)
	US	18.83±1.95[bc**]	1.14±0.08	31.33±8.1[bc]	19.33±7	48.66±13[abc]
LWJ	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]
	US	14.26±1.31[d]	1.23±0.05	42.67±3.1[a]	24.66±5.8	32.63±3[d]
LWOJ	MS	16.27±1.52[cd]	1.20±0.03	39.33±1.2[ab]	23.67±2.1	36.57±1.5[cd]
	LS	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

* LWJ = land with Jatropha; LWOJ = land without Jatropha; US (16-22%) = upper slope; MS (6-15%) = middle slope; LS (0-5%) = lower slope
**Interaction effects means within a column followed by the same letter are not significantly different at 5% level of significance

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 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 density 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 owing 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 lower 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 LS) 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 LS 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 an increasing trend from US to LS 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 lower slope area which contribute the greatest amount of SMC recorded under land with *J.*curcas of lower 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.

Soil Chemical Properties

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. 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*. The improvement of soil pH can bring the improvement on selected soil chemical properties because pH controls all chemical reactions in soil.

Considering the US, MS and LS slope positions, the highest mean values 6.31 of soil pH was observed on lower 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 lower slope positions where leaching is weaker and soil enrichment is stronger. As previous study carried by 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 lower 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}
LS	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

* LWJ = land with Jatropha; LWOJ = land without Jatropha; US (16-22%) = upper slope; MS (6-15%) = middle slope; LS (0-5%) = foot slope

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

The mean interaction effect of land use by 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 lower 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 in mean pH . 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 lower 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 lower 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	$6.39{\pm}0.11^{b**}$	$0.058{\pm}0.01^{bc}$	$3.6{\pm}0.15^{b}$	$6.2{\pm}0.26^{b}$	$0.35{\pm}0.01^{c}$	$15.68{\pm}1.5^{c}$
	MS	$6.61{\pm}0.06^{a}$	$0.06{\pm}0.04^{b}$	$3.98{\pm}0.31^{ab}$	$6.86{\pm}0.54^{ab}$	$0.42{\pm}0.04^{b}$	$18.98{\pm}1.1^{b}$
	FS	$6.73{\pm}0.04^{a}$	$0.09{\pm}0.01^{a}$	$4.44{\pm}0.39^{a}$	$7.65{\pm}0.68^{a}$	$0.46{\pm}0.02^{a}$	$22.81{\pm}1.3^{a}$
LWOJ	US	$5.44{\pm}0.08^{e}$	$0.048{\pm}0.01^{d}$	$0.89{\pm}0.1^{e}$	$1.5{\pm}0.18^{e}$	$0.24{\pm}0.01^{e}$	$12.64{\pm}1.3^{d}$
	MS	$5.62{\pm}0.04^{cd}$	$0.054{\pm}0.02^{cd}$	$1.72{\pm}0.2^{d}$	$3{\pm}0.35^{d}$	$0.27{\pm}0.01^{d}$	$14.26{\pm}0.9^{cd}$
	LS	$5.9{\pm}0.22^{c}$	$0.056{\pm}0.01^{bc}$	$1.8{\pm}0.06^{c}$	$5{\pm}0.1^{c}$	$0.31{\pm}0.01^{c}$	$15{\pm}1.5^{cd}$
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

LWJ = land with Jatropha; LWOJ = land without Jatropha; US (16-22%) = upper slope; MS (6-15%) = middle slope; LS (0-5%) = lower slope

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

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. 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 lower 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 lower 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 lower 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.

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 lower 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 lower 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.

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}
LS	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

* LWJ = land with Jatropha; LWOJ = land without Jatropha; US (16-22%) = upper slope; MS (6-15%) = middle slope; LS (0-5%) = lower slope

**Main effect 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 LS 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 lower slope whereas the lowest mean value was recorded at the upper slope. The highest and the lowest value of CEC were recorded under land with *J.curcas* on the lower 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 lower 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]
LWJ	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]
	LS	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]
LWOJ	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]
	LS	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

* LWJ = land with Jatropha; LWOJ = land without Jatropha; US (16-22%) = upper slope; MS (6-15%) = middle slope; LS (0-5%) = lowe slope

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

CONCLUSIONS

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.

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