ISSN: 0976-3376

Available Online at http://www.journalajst.com

ASIAN JOURNAL OF SCIENCE AND TECHNOLOGY

*Asian Journal of Science and Technology*
*Vol. 09, Issue, 01, pp.7338-7346, January, 2018*

# RESEARCH ARTICLE

# IMPACT OF TREE SPECIES IN DIFFERENT SUB-HABITATS ON SOIL PHYSICO-CHEMICAL PROPERTIES OF ALLAIDEGE RANGELAND, SOUTHERN AFAR, ETHIOPIA

**Brehanu Megersa and *Ashenafi Worku**

Werer Research Centre, Ethiopian Institute of Agricultural Research, P.O. Box 2003, Addis Ababa, Ethiopia

## ARTICLE INFO

***Article History:***
Received 18th October, 2017
Received in revised form
24th November, 2017
Accepted 16th December, 2017
Published online 31st January, 2018

***Key words:***

Tree species; Soil properties; Canopy; Sub-habitat and Allaidege rangeland.

## ABSTRACT

Rangelands tree species plays a significant role in soil fertility maintenance, providing food, fodder, fuel wood and other uses. However, the impact of tree species on soil properties remains poorly understood. This study evaluates the effect of three dominant indigenous tree species (Acacia melifera, Acacia senegal and Acacia nubica) and one exotic tree species (Prosopis juliflora) with their different sub-habitats on soil physico-chemical properties of Allaidege rangeland, Southern Afar Region of Ethiopia. The results of the study revealed that soil texture (silt and clay), BD, TP, pHe, SOM, TN, CEC and exchangeable bases contents studied were significantly affected ($P \leq 0.05$) by tree species of both sub-habitats. Furthermore, the soils textural classes were ranged from silt clay loam to sandy loam in both sub-habitats of tree species. The SOM CEC and TN content were significantly higher soils at indigenous Acacia tree species under canopied sub-habitat than that of Prosopis juliflora under canopied sub-habitat and also higher than uncanopied of all studied tree species. This was more pronounced in the top 20 cm of soil under canopied of Acacia melifera followed by Acacia nubica and senegal tree species, due to better under growth herbaceous layer and also relatively good nitrogen fixing capacity. Therefore, this tree has a significant effect on soil fertility improvement in resource poor rangelands and as a result, it is important to retain scattered indigenous Acacia tree species in Allaidege rangeland.



## INTRODUCTION

In many part rangeland areas, different tree species may have negative and positive effects on their immediate environment especially on soil and water. Because of established trees create sub-habitats, which differ from the open grassland and exert different influences on the herbaceous layer (Frost and Mc Dougald 1989; Smit and Swart 1994; Asferachew *et al*. 1998). Depending on their physiological and morphological nature, different tree species can also reduce soil erosion and reverse desertification (Young 1989). Tree species are also known to improve the nutrient status of soil under their canopies (Gedda 2003). Compared to the adjacent uncanopied areas, soil under tree canopies often have higher concentrations of organic matter, available nitrogen and exchangeable cations, with a better physical structure and improved water infiltration (Young 1989; Vetaas 1992; Smit and Swart 1994). In general, higher soil enrichment under tree canopies and also many theories reason are presented, such as leaf litter from leaf fall (Belsky *et al*. 1989), stem flow and through fall (Williams *et al*. 1987), droppings from birds and mammals (Belsky *et al*. 1989) and the accumulation of nutrients from areas beyond the crowns by means of lateral tree roots (Tiedemann and Klemmedson 1973). Previous studies have demonstrated that different tree species influence the soil environment in different ways, which relates to tree species traits. Certainly, studies of the rangeland plant biodiversity on soil properties frequently observed stronger effects of plant community composition than species richness, indicative of the importance of plant species traits for soil and ecosystem properties (Tilman *et al*. 1997; Hector *et al*. 1999). Similarly, soil moisture, pH, microbial biomass, respiration rate, and N availability differed among tree species grown in pots, and the difference could in part be attributed to differences in tree species growth rates (Priha *et al*. 1999; Ayres *et al*. 2004; Heath *et al*. 2005). These plant species effects on soils can have positive, neutral, or negative feedbacks to the plant species, which depends in part on whether the plant is an early- or late-succession species (De-Deyn *et al*. 2003; Kardol *et al*. 2006). Most studies in this rangeland related to the impact of grazing around a watering point on the rangeland soil status mainly focus on land degradation and soil nutrient loss for the productivities (Gedda 2003; Kidane and Pieterse 2006). However, there is lack of scientific information on soil physico-chemical properties under both sub-habitats of different tree species in the rangeland; where the influence of soil productivity is also an important determinant of biomass yield. In addition to this, they are few studies that can be cited along this line in United States of America and Australia. On the other hand wide

****Corresponding author:*** **Ashenafi Worku**
Werer Research Centre, Ethiopian Institute of Agricultural Research, P.O. Box 2003, Addis Ababa, Ethiopia.

variability exists between sites and countries. Therefore, the objective of this study is to evaluate the effect of tree species and their canopy effect on soil physico-chemical properties of Allaidege rangeland, Southern Afar, Ethiopia

## METHODS AND MATERIALS

### Description of Study Area

The Allaidege rangeland is situated in the southern part of the Afar regional state of Ethiopia 270 km north-east of Addis Ababa. Geographically the rangeland is located between the coordinates of 9°35’17.170” N; 40°11’4.161” E, 9°35’12.996” N; 40°29’6.947” E, 9°3’16.271” N; 40°10’58.144” E and 9°3’12.33” N; 40°28’58.83” E, east of the main highway that leads to the neighboring countries of Eritrea and Djibouti. The mean annual rainfall recorded is 571.3 mm and bimodal rainfall pattern. More than 85% of the rain occurs from February to May and June to September. The rangeland has a semi-arid climate where the monthly temperatures vary from a mean minimum of 14.8 and 23.7° C to a mean maximum of 30.5 and 37.9° C (Ashenafi and Bobe 2016). The mean annual free water evaporation by the Class A pan, relative humidity and mean daily sunshine recorded are 2803.7 mm, 50 % and 8.5 hrs/day, respectively.

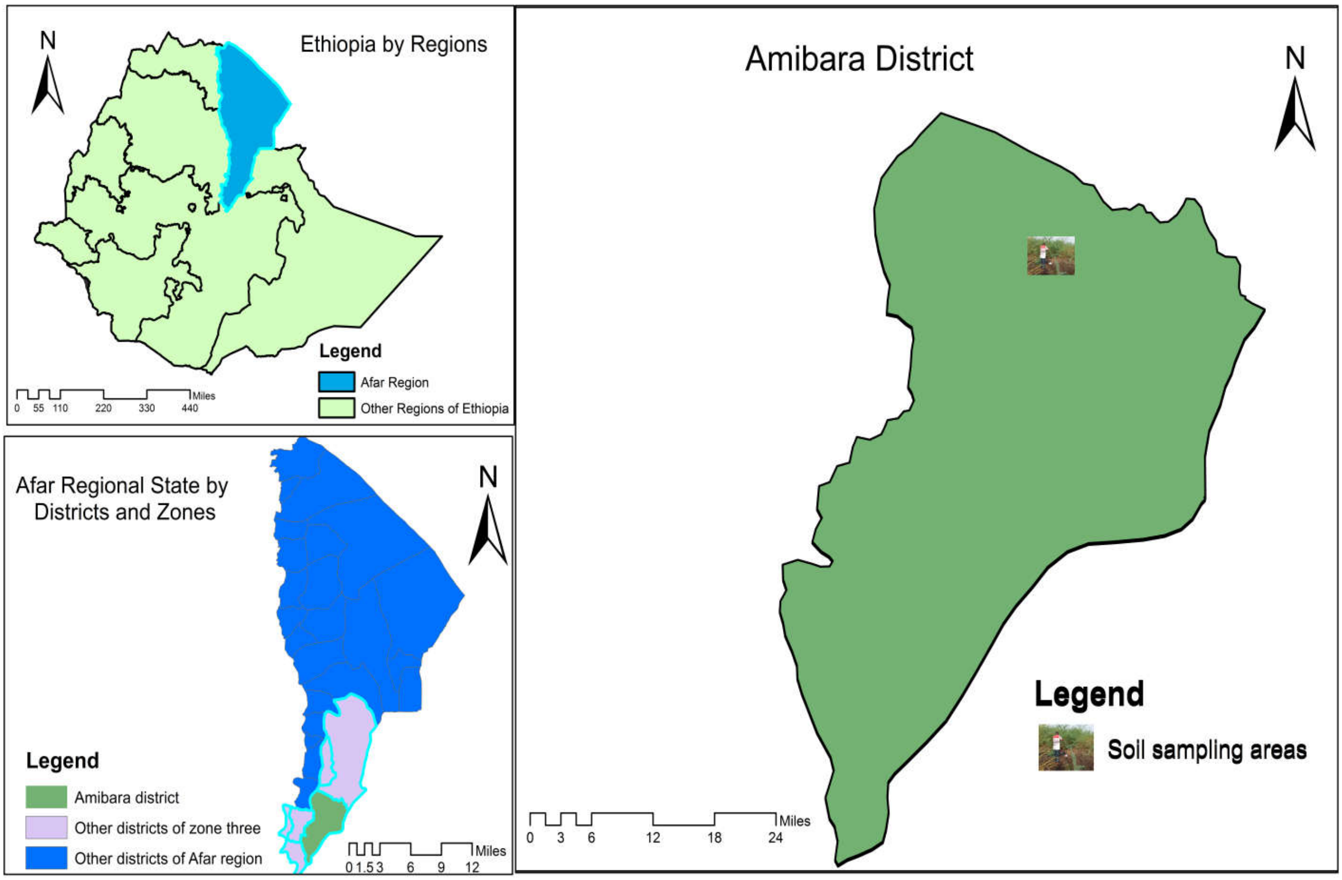


**Figure 1. Location map of the study area**

### Site selection and field layout

A reconnaissance survey was conducted with multi-disciplinary teams, involving pastoralist, soil experts and rangeland researchers to select the study site. Further assistance was obtained from the indigenous rangeland knowledge of the pastoralists, scientific publications, physical observations and field group discussions for selection of representative sites of each vegetation type of rangelands in which the study was conducted. Founded on reconnaissance survey and information collected, similar in vegetation type, slope, and ecological niche were selected and demarcated to conduct the experiment. These experimental sites have three dominant indigenous tree species (*Acacia melifera, Acacia senegal and Acacia nubica*) and one exotic tree species (*Prosopis juliflora*) with their different sub-habitats. A soil samples collected from 4 tree species areas with 2 sub-habitats (canopied and uncanopied sub-habitat areas). Triplicate soil samples from 4 tree species with 2 sub-habitats, a total of 32 soil samples were used for assessment of soil fertility status in this rangeland. All soil samples were collected at a depth of 20 cm. During sample collection any foreign material such as plant residues and gravels were discarded. Areas near trees and those with specific features such as old manures, wet spots, and compost pits were excluded from sampling. Finally, about 1 kg of each composite soil sample was bagged, properly labeled, and transported to the laboratory for analysis.

### Soil sample preparation and analysis

The collected soils were air-dried on plastic trays, gently crushed using pestle and mortar and passed through a 2 mm sieve.

Particle size distribution was determined by the hydrometer method (Bouyoucos 1962). Once the sand, silt and clay separates were calculated in percent, the soil was assigned to a textural class based on the soil textural triangle using International Soil Science Society system. The soil bulk density, particle density and total porosity (%) were determined according to the methods described by (Black

1965). Soil reaction (pHe) and electrical conductivity (ECe) were determined from saturated paste extract following the methods described by FAO (1999). Soil pHe was measured potentiometrically using a digital pH-meter and EC by digital conductivity meter according to the method outlined by the FAO (1999) and USSLS (1954), respectively. Organic carbon was analyzed by wet oxidation with potassium dichromate ($K_2Cr_2O_7$) in a sulfuric acid medium (Walkley and Black 1934). Percent organic matter content of the soils was estimated by multiplying the value of percent organic carbon by the conversion factor of 1.724. Total N was analyzed using the Kjeldahl digestion, distillation and titration method as described by Blake (1965) by oxidizing the OM in concentrated sulfuric acid solution (0.1N $H_2SO_4$). Available phosphorus was determined calorimetrically using spectrophotometer after the extraction of the soil samples with 0.5M sodium bicarbonate ($NaHCO_3$) adjusted at pH 8.5 following the Olsen extraction method as described by Olsen et al. (1954). Available potassium was measured by flame photometer from neutral normal ammonium acetate extraction (Kundsen *et al*. 1982). The exchangeable bases (Ca, Mg Na and K) were determined from extraction of neutral normal ammonium acetate extraction. Ca and Mg were EDTA titration method, while exchangeable K and Na were determined by flame photometer. All exchangeable bases were expressed as cmol $_{(+)}$ kg$^{-1}$ soil. The cation exchange capacity (CEC) of the soils was determined by the neutral normal ammonium acetate method according to the percolation tube procedure (Van Reeuwijk 1992).

## Data Analysis

Analyses of variance were used to test differences in soil fertility status across the tree species under both sub-habitats. For statistically different parameter ($P < 0.05$), means were separated using the Least Significant Difference (LSD) comparison test. Correlation analyses were also carried out to detect functional relationships among key soil variables.

# RESULTS AND DISCUSSIONS

## Effects of Tree Species under Different Sub-habitats on Soil Physico-chemical Properties

The information of soil physico-chemical properties is crucial for tree species rangeland management under different sub-habitats, because soil is the primary factor determining the potential for rangeland plant production of an area within a particular climate (Holecheck *et al*. 1989). Generally, the analysis of variance for major soil physico-chemical properties under tree species and their canopies affects both sub-habitats (under and outside canopy sub-habitat) are presented (Table 1 and 2).

## Effects of Tree Species on Soil Physical Properties

### Soil Texture

Soil texture have key role in determine water and solute/nutrient movement within soil profile for plant growth (Gupta 2004). Analysis of variance for soil texture revealed that it was significantly affected by tree species ($P \leq 0.05$) under both sub-habitats; whereas the soil sand content was not affected by tree species ($P > 0.05$) at out-side canopy sub-habitats of tree species (Table 1). Accordingly, trees species in the study areas had textural classes ranging from silt clay loam to sandy loam under both study sub-habitats; the highest sand texture soil were recorded at *Acacia senegal* tree species (54.35 %) under canopy sub-habitat and (54.79 %) out-side canopy sub-habitats. The result further indicated that, the highest clay fraction was recorded *Acacia nubica* tree species at under canopy sub-habitat (29.27 %) and out-side canopy sub-habitat (30.03 %). The result probably indicates that different tree species have adaptations to their preferences for specific soil texture.

**Table 1. Main effects of tree species and their canopy effect on some soil physical properties of Allaidege rangeland, Southern Afar Region of Ethiopia**

| Different tree species | Clay (%) | Silt (%) | Sand (%) | STC | BD (g cm$^{-3}$) | PD (g cm$^{-3}$) | TP (%) |
|---|---|---|---|---|---|---|---|
| | Outside canopy sub-habitat | | | | | | |
| *Prosopis juliflora* | 27.45$^{a}$ | 23.11$^{b}$ | 49.44$^{ba}$ | SiCL | 1.39$^{a}$ | 2.52 | 44.84$^{b}$ |
| *Acacia senegal* | 17.65$^{b}$ | 27.56$^{ba}$ | 54.79$^{a}$ | SL | 1.32$^{b}$ | 2.56 | 48.44$^{ba}$ |
| *Acacia melifera* | 20.25$^{b}$ | 29.42$^{a}$ | 50.33$^{ba}$ | L | 1.35$^{ba}$ | 2.54 | 46.85$^{ba}$ |
| *Acacia nubica* | 30.03$^{a}$ | 23.94$^{b}$ | 46.03$^{b}$ | SiCL | 1.31$^{b}$ | 2.57 | 49.03$^{a}$ |
| LSD(0.05) | 7.24 | 4.31 | 8.46 | | 0.059 | NS | 2.51 |
| | Under canopy sub-habitat | | | | | | |
| *Prosopis juliflora* | 27.58$^{ba}$ | 23.59$^{b}$ | 48.83 | SiCL | 1.35$^{a}$ | 2.53 | 46.64$^{b}$ |
| *Acacia senegal* | 17.42$^{b}$ | 28.23$^{ba}$ | 54.35 | SL | 1.29$^{ba}$ | 2.55 | 49.41$^{ba}$ |
| *Acacia melifera* | 19.24$^{b}$ | 30.52$^{a}$ | 50.24 | L | 1.23$^{b}$ | 2.52 | 51.19$^{a}$ |
| *Acacia nubica* | 29.27$^{a}$ | 24.19$^{b}$ | 46.54 | SiCL | 1.27$^{b}$ | 2.53 | 49.80$^{ba}$ |
| LSD(0.05) | 7.02 | 5.67 | NS | | 0.065 | NS | 2.69 |

*Means within a column and the same factor followed by same letter are not significantly different from each other at P > 0.05. NS = Not significant; LSD = Least significant difference; STC = Soil texture class; SiCL = Silt Clay Loam, SL = Sandy Loam, L = Loam, BD = Bulk density; PD = Particle density; TP = Total porosity

This investigation was supported by those reports (Githae *et al*. 2011; Mohammed *et al*. 2016). In addition to this, *Acacia senegal* and *Acacia melifera* tree species needs well drain and sandy type of soils in relative to *Acacia nubica* tree species, whereas, *Prosopis juliflora* tree species has been wide range of adaptation and can grow to soil texture. Generally this study agreed with those reported by (Aggarwal 1998 and Geesing *et al*. 2000).

### Bulk Density, Particle Density and Total Porosity

Variation in mean values of soil bulk density and total porosity of tree species under both sub-habitats were statistically significant ($p < 0.05$), except particle density which appeared non-significant under both sub-habitat (Table 1). Moreover, the highest soil bulk density was recorded *Prosopis juliflora* tree species at under canopy sub-habitat (1.35 g $cm^{-3}$) and out-side canopy sub-habitat (1.39 g $cm^{-3}$), whereas lowest soil bulk density of tree species at under canopy (1.23 g $cm^{-3}$) and out-side canopy sub-habitat (1.31 g $cm^{-3}$) were recorded for *Acacia melifera* and *Acacia nubica* tree species, respectively. The lower soil bulk density values recorded under canopy sub-habitat of *Acacia melifera* tree species as compared to the other three tree species under both sub-habitats observed. Such differences could probably be due to the influences tree species have different on leaf litter, root decked, better under growth of herbaceous layer and other inputs that improves soil organic matters. Soil bulk density was significantly and negatively correlated with SOM (r = -0.87**), and TP (r = -0.98**) whereas it was positively associated with ECe (r = 0.75*) and exchangeable Na (r = 0.73*) (Table 5). Similarly, the differences in tree species on soil bulk density were probably related to SOM and TP of soil (Mahmood *et al*. 2001; Mishra, 2002). Contrary to the case of soil particle density was lowest and highest recorded under canopy sub-habitat of *Acacia melifera* and *Acacia senegal* tree species, respectively, whereas in outside canopy sub-habitat of tree species, it was highest and the lowest soil particle density values were recorded under *Prosopis juliflora* and *Acacia nubica* tree species, respectively. The probably reason indicates that the tree species have different niches/areas to be adapted and this makes for variation in soil parent materials with the chemical composition and crystal structure of the mineral particles. Differently to the case of porosity it was highest in *Acacia melifera* tree species (51.19 %) and lowest in *Prosopis juliflora* tree species (46.64 %) under canopy sub-habitat (Table 1). The same trend was observed for porosity under out-side canopy sub-habitat of tree species. The same holds true for lower bulk density with concomitant higher porosity under acacia species tree could be attributed, due to acacia species have relatively higher soil organic matter than *Prosopis juliflora* tree species because of better under growth other plants, leaf litter, root decked and others input to soil system. Factor that affects bulk density also affects total porosity. Association of soil porosity with soil bulk density and SOM was negatively and positively correlated (r) value of -0.98** and 0.74** respectively (Table 5). In general, the results obtained from this study are in agreement with the findings reported by various authors (Joffre and Rambal 1988; Gomes and De-Muñiz 1990).

## Effects of Tree species on Soil Chemical Properties

### Soil Reaction (pHe) and Electrical Conductivity (ECe)

The analytical results (Table 2) indicated that the soil reaction (pHe) and electrical conductivity (ECe) of the saturated paste extract of soil taken from trees species under both sub-habitats. The mean values of pHe showed significant ($P \leq 0.05$) differences among trees species under both sub-habitats. Moreover under canopy sub-habitat, the highest (7.71) and lowest (7.34) soil pHe values were recorded for *Acacia senegal* trees species and *Prosopis juliflora* tree species, respectively (Table 2), whereas outside canopy sub-habitat, the highest (7.88) and the lowest (7.70) soil pHe values were recorded in *Acacia melifera* trees species and *Prosopis juliflora* tree species, respectively. The probably reason in *Prosopis juliflora* tree species relatively lower in soil reaction (pHe) due to maximum reduction of basic cations that comes through capillarity rise form ground water was reflected, which had deep and larger root area than Acacia tree species. They also concluded that pattern of root growth synchronized with the depth of improvement in alkaline wastelands and helped in accumulation, retranslocation and retardation of soil nutrients for developing soil-vegetation system on such soils. The results of this study were in agreement with those reported by different authors (Hagos and Smit 2005; Grellier *et al*. 2013). In addition to the above reason, the mechanisms by which tree species influence exchangeable cations include specific differences in the uptake of exchangeable bases especially exchangeable sodium; this resulted for the variation of soil pHe under different tree species. Pearson's correlation matrix shows that, soil pHe was significantly and positively correlated with exchangeable Na with r values of 0.68*. Similar result was reported by (Finzi *et al*. 1998). Electrical conductivity (ECe) of soil was non-significant difference among trees species under both sub-habitats. The result further indicates that the lower values of ECe recorded were under canopy sub-habitat of *Acacia nubica* trees species (0.57 dS $m^{-1}$) and out-side canopy sub-habitat (0.62 dS $m^{-1}$), whereas higher values was recorded under *Prosopis juliflora* trees species canopy sub-habitat (0.86 dS $m^{-1}$) and out-side canopy sub-habitat (1.06 dS $m^{-1}$). On the other hand, different trees species have been successfully used in the reclamation of saline/sodic soils (Elkins 1985; Basavaraja *et al*. 2011). The reduction in ECe might be have been hastened by root action that increased water intake rate in the soil. This was due to root penetration of tree plantation in the soil that provided channels for the percolating water. Soils are classed saline if the conductivity of the saturation extract exceeds 2 dS $m^{-1}$ (Brady 1990). Generally, Allaidege rangeland areas lower salt content which less than 1dS $m^{-1}$ that means non-saline and non-sodic soil.

### Soil organic matter and Total nitrogen

Soil organic matter is considered to improve water-holding capacity, nutrient release and soil structure and also an important for the productivity of rangelands tree species (Jeddi and Chaieb 2009; Abdallah *et al*. 2012). The mean values for soil organic matter were significantly ($p \leq 0.05$) affected by trees species under both sub-habitats (Table 2). Besides, SOM higher values recorded were under canopied sub-habitat of *Acacia melifera* trees species (3.04 %) and under out-side canopied sub-habitat of *Acacia nubica* trees species (2.59 %), whereas lower SOM values recorded were in *Prosopis juliflora* tree species under canopy sub-habitat (2.24 %) and out-side canopy (1.64 %). *Prosopis juliflora* tree species lower soil organic matter values than that of tested indigenous Acacia tree species and also out-side canopy. This is an indication of different tree species' have diverse potential to enhancing herbage productivity in the rangelands as they improve soil fertility under and out-side their canopies in the rangeland. In addition to this, *Prosopis juliflora* tree species have allilophytic effect plant to other under growth of herbaceous layers. This observation is in agreement with the reports of other authors relating to soil (Williams *et al*. 1987; Dachung *et al*. 2014). According to the rating of Tekalign (1991), soil organic matter content of the studied areas was ranges from low to medium status in trees species under both sub-habitats. The medium SOM values were recorded under canopy sub-habitat of indigenous Acacia tree species. The total nitrogen contents of soil generally followed similar trends with the soil organic matter contents.

**Table 2. Influence of trees species and their canopy effects on soil reaction (pHe), Electrical conductivity (ECe), Soil organic matter (SOM), Total nitrogen (TN), Available phosphorus (Av. P) and Available potassium (Av. K)**

| Different vegetation species | Outside Canopy Sub-habitat | | | | | |
|---|---|---|---|---|---|---|
| | pHe | ECe (dS $m^{-1}$) | SOM (%) | TN (%) | Av.P (mg $kg^{-1}$) | Av.K (mg $kg^{-1}$) |
| *Prosopis juliflora* | 7.70$^{b}$ | 1.06 | 2.14$^{b}$ | 0.080$^{b}$ | 12.04 | 455.0 |
| *Acacia senegal* | 7.82$^{ba}$ | 0.84 | 2.58$^{a}$ | 0.131$^{a}$ | 11.47 | 474.6 |
| *Acacia melifera* | 7.88$^{a}$ | 0.77 | 2.51$^{a}$ | 0.128$^{a}$ | 11.86 | 492.6 |
| *Acacia nubica* | 7.72$^{b}$ | 0.62 | 2.59$^{a}$ | 0.132$^{a}$ | 11.41 | 503.6 |
| LSD(0.05) | 0.06 | NS | 0.16 | 0.008 | NS | NS |
| | Under Canopy Sub-habitat | | | | | |
| *Prosopis juliflora* | 7.34$^{c}$ | 0.86 | 2.24$^{b}$ | 0.112$^{b}$ | 12.41$^{a}$ | 467.2 |
| *Acacia senegal* | 7.71$^{a}$ | 0.74 | 2.88$^{a}$ | 0.144$^{a}$ | 11.64$^{b}$ | 469.4 |
| *Acacia melifera* | 7.67$^{ba}$ | 0.71 | 3.04$^{a}$ | 0.152$^{a}$ | 11.91$^{ba}$ | 573.2 |
| *Acacia nubica* | 7.53$^{b}$ | 0.57 | 2.96$^{a}$ | 0.148$^{a}$ | 11.52$^{b}$ | 526.2 |
| LSD(0.05) | 0.05 | NS | 0.17 | 0.0084 | 0.70 | NS |

*Means within a column and the same factor followed by same letter are not significantly different from each other at P > 0.05. NS = Not significant; LSD = Least significant difference; Av.P = Available phosphorus; Av.K =Available potassium; SOM = Soil organic matter TN = Total nitrogen.

**Table 3. Influence of trees species and their canopy effects on Exchangeable Bases (Ca+Mg, Na and K) and Cation Exchange Capacity (CEC)**

| Different vegetation species | Outside canopy sub-habitat | | | |
|---|---|---|---|---|
| | Exchangeable bases (meq/100g of soil) | | | CEC |
| | Ca+Mg | Na | K | (cmol (+) $Kg^{-1}$) |
| *Prosopis juliflora* | 19.36$^{ab}$ | 3.30$^{a}$ | 0.97$^{a}$ | 23.46$^{ab}$ |
| *Acacia senegal* | 16.52$^{b}$ | 1.34$^{b}$ | 0.75$^{b}$ | 24.25$^{a}$ |
| *Acacia melifera* | 21.36$^{a}$ | 1.52$^{b}$ | 0.52$^{c}$ | 26.52$^{a}$ |
| *Acacia nubica* | 17.36$^{b}$ | 1.81$^{b}$ | 0.58$^{c}$ | 20.02$^{b}$ |
| LSD(0.05) | 3.61 | 0.89 | 0.08 | 3.95 |
| | Under canopy sub-habitat | | | |
| *Prosopis juliflora* | 17.86$^{ab}$ | 2.78$^{a}$ | 0.94$^{a}$ | 24.01$^{b}$ |
| *Acacia senegal* | 15.36$^{b}$ | 1.17$^{b}$ | 0.67$^{b}$ | 26.28$^{b}$ |
| *Acacia melifera* | 19.03$^{a}$ | 1.36$^{b}$ | 0. 51$^{c}$ | 30.97$^{a}$ |
| *Acacia nubica* | 18.97$^{a}$ | 1.51$^{b}$ | 0. 47$^{c}$ | 26.20$^{b}$ |
| LSD(0.05) | 2.98 | 0.87 | 0.08 | 3.81 |

*Means within a column and the same factor followed by same letter are not significantly different from each other at P > 0.05. NS = Not significant; LSD = Least significant difference; CEC = Cation Exchange Capacity

The mean values of soil total nitrogen contents showed significant ($P \leq 0.05$) differences among tree species of both sub-habitats (Table 2). The highest (0.152 %) and lowest (0.112 %) soil total nitrogen values were recorded under canopy sub-habitat of *Acacia melifera* tree species and *Prosopis juliflora* tree species, respectively (Table 2), whereas uncanopied sub-habitat, the highest (0.132 %) and the lowest (0.08 %) soil total nitrogen values were recorded *Acacia nubica* tree species and *Prosopis juliflora* tree species, respectively. The high nitrogen and organic carbon of soils indigenous Acacia trees canopies sub-habitat was attributed to the semi-deciduous nature of the species and the strong symbiotic relationship with the native soil microbes. The results of this study indicate that *Prosopis juliflora* is not more efficient in improving soil fertility than indigenous Acacia trees. Thus, *Prosopis juliflora* should not be encouraged to grow in arid and semi arid areas at the expense of native tree species like indigenous Acacia trees. Therefore, the findings of this study are in agreement with the results of similar recent studies reported by Kinyua (1996), Wasonga (2001) and Hagos and Smit, (2005).

## Available phosphorus and Available potassium

Available phosphorus possibly has the most complicated chemistry in the soil and because of it occurs in soils in both organic and inorganic forms.

Available phosphorus value was significantly ($P \leq 0.05$) affected by among canopied sub-habitats of trees species, but it was non-significant variations among uncanopied sub-habitats of tree species (Table 2). The highest (12.41 mg $kg^{-1}$) and lowest (11.52 mg $kg^{-1}$) available phosphorus content of the soil were recorded under canopied sub-habitat of *Prosopis juliflora* tree species and *Acacia nubica* tree species, respectively. The same trend was observed for available phosphorus content of the soil uncanopied tree species. The mechanisms by which tree species influence available phosphorus include specific differences in the uptake of available phosphorus and production of litter high in organic acid content and the stimulation of mineral weathering (Finzi *et al.* 1998). These results were supported those reported by (Jeddi and Chaieb 2009; Abdallah *et al*. 2012; Agena *et al.* 2014). Total K present in the soil, the largest portion (90-98%) is found in a relatively unavailable form to plants whereas only 1 to 2% of the soil K is readily available to plants (Tahir 2009). Available potassium was non-significant variations among trees species of both sub-habitats (Table 2). The highest available potassium content of the soil was recorded under canopied sub-habitat of *Acacia melifera* followed by *Acacia nubica* tree species, whereas the lowest available potassium content of the soil was recorded under canopied sub-habitat of *Prosopis juliflora* tree species. It was the highest and lowest was recorded at uncanopied sub-habitat of *Acacia nubica* tree species and *Prosopis juliflora* tree species, respectively. This could be due to the mechanisms by which tree species influence available potassium include specific differences in the uptake of available potassium and production of litter high in organic acid content and the stimulation of mineral weathering (Finzi *et al*. 1998).

high in organic acid content and the stimulation of mineral weathering (Finzi *et al*. 1998).

**Table 4. Pearson's correlation matrix for various soil physicochemical parameters**

| | Clay | Silt | Sand | BD | TP | pHe | ECe | SOM | TN | Ca+Mg | Na | CEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clay | 1 | | | | | | | | | | | |
| Silt | -0.87** | 1 | | | | | | | | | | |
| Sand | -0.89** | 0.58$^{NS}$ | 1 | | | | | | | | | |
| BD | 0.27$^{NS}$ | -0.49$^{NS}$ | 0.00$^{NS}$ | 1 | | | | | | | | |
| TP | -0.28$^{NS}$ | 0.49$^{NS}$ | 0.03$^{NS}$ | -0.98** | 1 | | | | | | | |
| pHe | -0.73* | 0.82* | 0.49$^{NS}$ | -0.34$^{NS}$ | 0.37$^{NS}$ | 1 | | | | | | |
| ECe | -0.10$^{NS}$ | -0.19$^{NS}$ | 0.35$^{NS}$ | 0.75* | -0.80* | -0.17$^{NS}$ | 1 | | | | | |
| SOM | -0.37$^{NS}$ | 0.59$^{NS}$ | 0.10$^{NS}$ | -0.87** | 0.74* | 0.44$^{NS}$ | -0.86** | 1 | | | | |
| TN | -0.37$^{NS}$ | 0.58$^{NS}$ | 0.09$^{NS}$ | -0.84** | 0.72* | 0.43$^{NS}$ | -0.87** | 0.99** | 1 | | | |
| Ca+Mg | 0.21$^{NS}$ | 0.09$^{NS}$ | -0.45$^{NS}$ | 0.22$^{NS}$ | -0.31$^{NS}$ | 0.41$^{NS}$ | 0.09$^{NS}$ | -0.22$^{NS}$ | 0.22$^{NS}$ | 1 | | |
| Na | -0.59$^{NS}$ | -0.72* | -0.35$^{NS}$ | 0.73* | -0.80* | 0.68* | 0.86** | -0.92** | -0.91** | 0.25$^{NS}$ | 1 | |
| CEC | 0.68* | 0.74* | -0.30$^{NS}$ | -0.59$^{NS}$ | 0.47$^{NS}$ | 0.46$^{NS}$ | 0.14$^{NS}$ | 0.69* | 0.67* | 0.27$^{NS}$ | - 0.42$^{NS}$ | 1 |

* = Significant at $P < 0.05$; ** = Significant at $P < 0.01$; BD = Bulk density; TP= Total porosity; pHe = Soil reaction; ECe = Electrical conductivity; SOM = Soil organic matter; TN = total nitrogen; CEC = Cation exchange capacity

**Table 5. Influence of sub-habitat on major soil physical and chemical properties in Allaidege rangeland of Ethiopia**

| Parameters | Under canopy | Out-side canopy | LSD |
|---|---|---|---|
| Sand (%) | 49.99 | 50.15 | NS |
| Silt (%) | 26.63$^{a}$ | 26.00$^{b}$ | 0.21 |
| Clay (%) | 23.38$^{b}$ | 23.85$^{a}$ | 0.14 |
| Bulk density (g $cm^{-3}$) | 1.29$^{b}$ | 1.34$^{a}$ | 0.041 |
| Particle density (g $cm^{-3}$) | 2.53 | 2.55 | NS |
| Total Porosity (%) | 49.29$^{a}$ | 47.29$^{b}$ | 1.21 |
| pHe | 8.11 | 8.18 | NS |
| ECe (dS $m^{-1}$) | 0.72 | 0.82 | NS |
| Organic Matter (%) | 2.78$^{a}$ | 2.36$^{b}$ | 0.36 |
| Total Nitrogen (%) | 0.139$^{a}$ | 0.118$^{b}$ | 0.016 |
| Available phosphorus (mg $kg^{-1}$) | 11.87 | 11.69 | NS |
| Available potassium (mg $kg^{-1}$) | 509.01$^{a}$ | 481.40$^{b}$ | 15.35 |
| Exchangeable Ca+Mg (meq/100g of soil) | 17.81$^{b}$ | 18.65$^{a}$ | 0.81 |
| Exchangeable N (meq/100g of soil) | 1.71 | 1.99 | NS |
| Exchangeable K (meq/100g of soil) | 0.65 | 0.71 | NS |
| CEC (meq/100g of soil) | 26.87$^{a}$ | 23.56$^{b}$ | 2.31 |

Means with the same letter within row are not significantly different ($p < 0.05$)

### Basic exchangeable cations (Ca+Mg, Na and K)

The values of all exchangeable cations were significantly ($P \leq 0.05$) affected by trees species under both sub-habitats (Tables 3). The highest (19.03 meq/100 of soils) and lowest (15.36 meq/100 of soils) exchangeable calcium plus magnesium content of the soil were recorded under canopied sub-habitat of *Acacia melifera* tree species and *Acacia senegal* tree species, respectively. The same trend was observed for exchangeable calcium plus magnesium content of the soil of uncanopied tree species. The result farther indicated, the highest exchangeable sodium content of the soil was recorded under canopied sub-habitat (2.78 meq/100gm of soils) and uncanopied sub-habitat (3.30 meq/100 gm of soils) of *Prosopis juliflora* tree species, respectively. While the lowest values exchangeable sodium content of the soil were recorded at uncanopied sub-habitat (1.81 % meq/100 gm of soils) and under canopied sub-habitat (1.51 meq/100gm of soils) of *Acacia Nubica* tree species (Table 3). Besides, the same trend was observed for exchangeable potassium in both sub-habitats. The analysis of variance showed that the exchangeable bases (Ca+Mg, Na and K) had been influenced by tree species. This could be due to the mechanisms by which tree species influence exchangeable cations include specific differences in the uptake of exchangeable bases, nitrogen fixation, and production of litter

In addition to this, the difference in tree species could have varies canopy densities this influence soil evaporation that fervors net accumulation rather than leaching of cations. The result presented in this study agreed with the results reported by many authors Abebe (1994); Githae *et al*. (2011) and Mohammed *et al*. (2016).

### Cation exchange capacity (CEC)

Cation exchange capacity (CEC) describes the potential fertility of soils and related to the soil texture, organic matter content, and the dominant types of the clay minerals in the soil (Brady and Weil 2002). This concurrently implicates the important aspect of cation exchange capacity as potential component of soil fertility (Thompson and Troeh 1978). However, in this study, the cation exchange capacity (CEC) of the soils in the study area were significantly ($P \leq 0.05$) affected by trees species under both sub-habitats (Tables 3). As the result shows, the highest cation exchange capacity of the soil was recorded under canopied sub-habitat (30.97 cmol $_{(+)}$ $Kg^{-1}$) and uncanopied sub-habitat (26.52 cmol $_{(+)}$ $Kg^{-1}$) of *Acacia melifera* tree species. On other hand, the lowest values were recorded under canopied sub-habitat of *Prosopis juliflora* tree species (24.01 cmol $_{(+)}$ $Kg^{-1}$) and uncanopied sub-habitat of *Acacia nubica* tree species (20.02 cmol $_{(+)}$ $Kg^{-1}$). The highest CEC was observed in soils under canopied sub-habitat of *Acacia melifera* tree species and decreased in order: *Acacia melifera* > *Acacia senegal* > *Acacia nubica* > *Prosopis juliflora* due to the variations in the rate of humification of organic matter added through the litter fall of these species. Similarly, the difference in tree species on soil CEC were probably related to soil clay content and soil organic matter (Githae *et al*. 2011; Mohammed *et al*. 2016). The CEC measurements indicate soil with a CEC of < 16 cmol $_{(+)}$ $Kg^{-1}$ are considered not to be fertile and such soils are highly weathered while fertile soils have a CEC of > 24 cmol $_{(+)}$ $Kg^{-1}$ (Gachene and Kimaru, 2003). The mean values of CEC under all tree species are < 24 cmol $_{(+)}$ $Kg^{-1}$. This means that all tree species can perform well on soil good in nutrients.

**Effect of Sub-habitat on Soil Physico-chemical Properties**

The analysis of variance for major soil physical and chemical properties under tree canopy and out-side canopy is presented in Table 5. In a present study higher organic matter, total nitrogen and available phosphorus under tree canopies compared to out-side canopy sub-habitat could be explained by the contribution of high biomass production of herbaceous species to nutrient input of the soil and minimal soil loss through erosion due to high herbaceous cover. The result presented in this study agreed with the report of (Mohammed *et al*. 2016). The current study showed that the areas under tree canopy had higher cation exchange capacity, available potassium and total porosity compared to areas away from the tree canopy (Table 5). Pearson's correlation matrix shows that, CEC was significantly and negatively correlated with OM (r = 0.54*) and clay contents (r = 0.56*) (Table 4). The higher CEC and nutrient status were due to increase in organic matter under canopy sub-habitat of trees species (Abdullah *et al*. 2012 and Grellier *et al*. 2013).

The result further showed significant variations among different sub-habitats of tree species the mean values of soil clay and silt content, but soil sand content was non-significant differences observed (Table 5). Relatively lower soil clay and sand content were recorded under canopied sub-habitat than corresponding outside the tree canopies. This difference might be due to the soil outside the tree canopies dries out faster as a result of being more exposed to direct solar radiation. In similar to the result of this study, Abule *et al*. (2005); Apko *et al*. (2005) and Agena *et al*. (2014) reported unavailability of any significant effect of tree canopy on clay of percentage. According to Agena *et al*. (2014), soil texture is mainly dependent on parent material of soil. The current finding showed that the highest soil porosity recorded under canopies sub-habitat as compared to uncanopied sub-habitat of tree species (Table 5), due to high soil organic matter from under growth herbaceous layer, leaf litter, root decked and others input to soil system and the reverse true for soil bulk density. Factor that affects bulk density also affects total porosity. Association of bulk density with exchangeable sodium and OM was positively and negatively correlated (r) value of 0.73* and -0.87**, respectively (Table 4). In general, this results for reduction number large pores and increases number of relatively small sized pores and as a result total porosity decreases implies for increasing bulk density. Similar results were reported by (Muhammad *et al*., 2002; Srivastava *et al*., 2014).

**Conclusion and Recommendation**

From this finding, it can be concluded that the retaining indigenous and exotic tree species resource poor rangelands have been effective in improving of soil nutrient enrichment and the areas under indigenous and exotic tree species were in a better condition than uncanopied sub-habitat of tree species. This is especially true with regards to total porosity, soil organic matter, Total Nitrogen, CEC available phosphorus and potassium which are significantly higher under tree canopied sub-habitat. It can be also concluded that the enrichment of the soil is mainly restricted to the top 20 cm of soil, which is commonly more sensitive to changes in plant cover. Similarly, this study confirmed that indigenous acacia tree species especially *Acacia melifera* followed by *Acacia nubica* and *Acacia senegal* had a higher positive effect on soil nutrient enrichment than corresponding *Prosopis juliflora* tree species. This is especially true with regard to soil OM, TN, and CEC. Therefore, the improvements of soil nutrients due presence of indigenous and exotic tree species were depends on the species of trees and also their under growth of herbaceous layers. The relative importance of facilitation that trees may have in terms of soil enrichments diminished or totally removed with heavy and continuous grazing. This emphasizes the importance of conservative stocking rates as proper range management. Supplementary research should be carried out involving larger and more replicated areas with these indigenous and exotic tree species at different season and years to obtain more definitive results on regional or national scales. This study recommends that caution be exercised in extrapolating the results to other arid rangelands as this work was conducted at only one site.

**Conflict of Interests:** The authors have not declared any conflict of interests.

## REFERENCE

Abdallah, F., Noumi, Z., Ouled-Belgacem, A., Michalet, R., Touzard, B., Chaieb, M., 2012. The influence of Acacia tortilis on grazing, and water availability along the growing season, on the understory herbaceous vegetation in southern Tunisia. *Journal of Arid Environments*, 76: 105-114.

Abebe, T. 1994. Growth-performance of some multi-purpose trees and shrubs in the semiarid areas of southern Ethiopia. Agroforestry Systems, 26:237-248.

Abule, E., Smit, G.N., Snyman, H.A., 2005. The influence of woody plants and Livestock grazing on grass species composition, yield and soil nutrients in the Middle Awash valley of Ethiopia. *Journal of Arid Environments,* 60: 343-358.

Agena, A.T., Tilahun, F.E., Bekele, L. 2014. Effects of tree species on microclimate and soil amelioration in the central rift valley of Ethiopia. *Journal of soil science and Environmental Management,* 5:62-71.

Aggarwal, R.K. 1998. Effect of Prosopis species on properties of arid zone soils. InJ. C. Tewari, NM. Pasiecznik, LN. Harsh and P.J.C. Harris, eds. Prosopis species in the arid and semi-arid zones of India. Proceedings of a conference held at the Central Arid Zone Research Institute. Jodhpur, Rajasthan. India, November 21 - 22, 1993. pp. 27-29, the Prosopis Society of India and the Henry Doubleday Research Association.

Asferachew, A., Masresha, F., Zerihun, W. 1998. Investigations on canopy feature of three indigenous woodland tree species of Ethiopia. SINET: *Ethiopian Journal of Science,* 21 (1), 113–132.

Ashenafi, W. and Bobe B, 2016. Studies on Soil Physical Properties of Salt Affected Soil in Amibara Area, Central Rift Valley of Ethiopia. *International Journal of Agricultural Sciences and Natural Resources,* 3(2); 8-17.

Ayres, E., Heath, J., Possell, M., Black, H.I.J., Kerstiens, G., 2004. Tree physiological responses to above-ground herbivory directly modify below-ground processes of soil carbon and nitrogen cycling. Ecology Letters 7:469–479.

Basavaraja, P.K., Sharma, S.D., Dhananjaya, B.N., Badrinath, M.S., 2011. Acacia nilotica: A Tree Species for Amelioration of Sodic Soils in Central Dry Zone of Karnataka, *India, Research Journal of Agricultural Sciences,* 2(2): 311-316.

Belsky, A.J., Amundson, R.G., Duxburg, J.M., Riha, S.J., Ali, A.R., Mwonga, S.M., 1989. The effect of trees on their physical, chemical and biological environments in a semi-arid savanna in Kenya. *Journal of Applied Ecology,* (26): 1005–1024.

Black, C.A. 1965. Method of Soil Analysis. Part 2. Chemical and Microbiological Properties. American Society of Agronomy, Inc, Madison.

Blake, C.A., 1965. Methods of soil analysis. Part 1, American Society of Agronomy. Madison, Wisconsin, USA.

Bouyoucos, G.J., 1962. Hydrometer method improved for making particle size analysis of soil. Agronomy Journal, 54:464-465.

Brady, N.C. and Weil, R.R. 2002. The Nature and Properties of Soils. 13$^{th}$ ed. Macmillan Publishing Company, Inc. USA.

Brady, N.C., 1990. The nature and properties of soils. 10$^{th}$ edition. New York. 621p.

Dachung, G., Verinumbe, I., Ayuba, S.A. 2014. Effect of agroforestry trees on chemical properties of vertisols of the Sahel region of borno state, Nigeria. *Journal of research in forestry, wildlife and environmental,* 6(1): 1-7.

De-Deyn, G.B. Raaijmakers, C.E., Zoomer, H.R., Berg, M.P., De-Ruiter, P.C., 2003. Soil invertebrate fauna enhances grassland succession and diversity. Nature 422: 711–713.

Elkins, C.B., 1985. Plant roots as tillage tools. In Tillage Machinery Systems as Related to Cropping Systems. Proceedings of International Conference on Soil Dynamics Auburn Alabama 3: 519-523.

FAO, 1999. Soil Salinity Assessment: Methods and Interpretation of Electrical Conductivity Measurements. FAO Irrigation and Drainage Paper 57, Rome, Italy.

Finzi, A.C., Canham, C.D., Breemen, N.V. 1998. Canopy tree-soil interactions within temperate forests: species effects on pH and cations. Ecological Applications, 8: 447-454.

Frost, W.E., and McDougald, N.K., 1989. Tree canopy effects on herbaceous production of annual rangeland during drought. *Journal of Range Management* 42, 281–283

Gachene, C.K., and Kimaru, G. 2003. Soil fertility and land productivity. A guide for extensive workers in the Eastern Africa region. Nairobi, Kenya.

Gedda, A.E., 2003. Rangeland evaluation in relation to pastoralist's perceptions in the Middle Awash Valley of Ethiopia. Ph.D. Thesis, University of the Free State, Bloemfontein, South Africa, 297pp.

Geesing, D., Felker, P., Bingham, R.L. 2000. Influence of mesquite (Prosopis glandulosa) on soil nitrogen and carbon development: implications for agroforestry and global carbon sequestration. *Journal of Arid Environment*, 46: 157-180.

Githae, E.W., Charles, K.K. and Jesse, T.N. 2011. Soil physicochemical properties under Acacia Senegal varieties in the dry land areas of Kenya. *African Journal of Plant Science,* 5(8): 475-482.

Gomes, A.V., Andg, I., Demuñiz, B., 1990. Wood structure and ultra structure of Prosopis caldenia, P. chilensis and P. juliflora and influence of ecological factors. pp. 195-216. In: The Current State of Knowledge on Prosopis juliflora. (Eds.) MA Habit and JC Saavedra. FAO, Rome, Italy.

Grellier, S., Ward, D., Janeau, J.L., Podwojewski, P., Lorentz, S., Abbadie, L., Valentin, C., Barot, S.B. 2013. Positive versus negative environmental impacts of tree encroachment in South Africa. *Acta Oecologica*, 53:1– 10.

Gupta, P.K., 2004. Soil, Plant, Water and Fertilizer Analysis. Shyam Printing Press, Agrobios, India.

Hagos, M.G., and Smit, G.N. 2005. Soil enrichment by Acacia mellifera subsp. Detinens on nutrient poor sandy soil in a semi-arid southern African savannah. *Journal of Arid Environments,* 61: 47 – 59.

Heath, J., Ayres, E., Possell, M., Bardgett, R.D., Black, H.I.J., 2005. Rising atmospheric CO2 reduces sequestration of root-derived soil carbon. *Science*, 309: 1711–1713.

Hector, A., Schmid, B., Beierkuhnlein, C., Caldeira, M.C., Diemer, M, 1999. Plant diversity and productivity experiments in European grasslands. *Science,* 286: 1123–1127

Holecheck, J.L., Pieper, R.D., Herbel, C.H., 1989. Range management principles and parcties 1$^{st}$ Ed. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Jeddi, K. and Chaieb, M. 2009. Using trees as a restoration tool in Tunisian arid areas: effects on under storey vegetation and soil nutrients. *Rangeland Journal,* 31: 377–384

Joffre, R., and Rambal, S. 1988. Soil water improvement by trees in the rangelands of south Spain. *Acta ecologica*. 9: 405-472.

Kardol, P., Bezemer, T.M., Putten, W.H., 2006. Temporal variation in plant-soil feedback controls succession. Ecology Letters 9: 1080–1088.

Kidane, G., and Pieterse, P.J. 2006. Impact of grazing around a watering point on soil status of a semi-arid rangeland in Ethiopia, *African Journal of Ecology*, 1-8.

Kinyua, D.M. 1996. Micro-environmental influence of Acacia etbaica and Acacia tortilis on herbaceous layer production in Mukcgodo rangeland, Laikipia District. MSc. Thesis, University of Nairobi. Unpublished

Knudsen, D., Peterson, G.A., Pratt, P.F., 1982. Potassium. In: A.L. Page (Ed.) Methods of soil analysis. Chemical and microbiological properties. America Society of Agronomy, and Soil Science of America, Inc. Madison, Wisconsin, USA. 229-230

Mahmood, K., Morris, J., Collopy, J., Slavich, P. 2001. Groundwater uptake and sustainability of farm plantations on saline sites in Punjab province, Pakistan. *Agric. Water Manage,* 48: 1-20.

Mishra, A. 2002. Ameliorative effect of tree species on physical and chemical properties of sodic soils in Uttar Pradesh. PhD. Thesis, ICFRE, Dehradun.

Mohammed, M., Abule, E., Lisanework, N. 2016. Impact of woody plants species on soil physico-chemical properties along grazing gradients in rangelands of eastern Ethiopia. Tropical *and Subtropical Agroecosystems*, 19: 343 – 355.

Muhammad, S.S., Anwar, H., Abdul, R., 2002. Effect of salt on bulk density, particle density and porosity of different soil series, *Asia Journal of plant sciences*, 5(1): 5-6.

Muthana, K.D. 1985. Prosopis species development in India. pp. 181-191. In: The Current State of Knowledge on Prosopis tamarugo. (Ed.) M. A. Habit. FAO, Rome, Italy.

Olsen, S.R., Cole, C.V., Watanable, F.S., Dean, L.A., 1954. Estimation of variable phosphorus in soil by extraction with sodium bicarbonate. USDA Circular. 939: 1-19.

Priha, O., Hallantie, T., Smolander, A. 1999. Comparing microbial biomass, denitrification enzyme activity, and numbers of nitrifiers in the rhizospheres of Pinus sylvestris, Picea abies and Betula pendula seedlings by microscale methods. *Biology and Fertility of Soils*, 30:14–19.

Smit, G.N. and Swart, J.S. 1994. The influence of leguminous and non-leguminous woody plants on the herbaceous layer and soil under varying competition regimes in Mixed Bushveld. *African Journal of Range and Forage Science,* 11, 27–33.

Srivastava, P.K., Gupta, M., Pandey, A., Pandey, V., Singh, N., Tewari, S.K., 2014. Effects of sodicity induced changes in soil physical properties on paddy root growth. *Journal of Plant Soil Environmental,* 60(4): 165–169.

Tahir, M. 2009. Response of Maize (zea maysl.) to salinity and potassium supply. Doctoral Dissertation, Institute of soil and environmental sciences university of Agriculture, Faisalabad, Pakistan.

Tekalign, T., 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa.

Thompson, L.M. and Troeh, F.R. 1978. Soil and soil fertility.4$^{th}$ edition. Mcgraw-Hill, Inc. USA.

Tiedemann, A.R. and Klemmedson, J.O. 1973. Effect of Mesquite on physical and chemical properties of the soil. *Journal of Range Management,* 26, 27–29.

Tilman, D., Knops, J., Wedin, D., Reich, P., Ritchie, M., 1997. The influence of functional diversity and composition on ecosystem processes. *Science*, 277:1300–1302.

USSLS, 1954. Diagnosis and improvement of saline and alkali soils. USDA Agriculture Handbook 60, USDA, Washington, D.C.

Van-Reeuwijk, L.P., 1992. Procedures for soil analysis (3rd Ed.). International Soil Reference Center, Wageningen, Netherlands.

Vetaas, O.R. 1992. Micro-site effects of trees and shrubs in dry season savanna. *Journal of Vegetation Science* 3, 337–344.

Walkley, A., and Black, I.A, 1934. An examination of the Digestion method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Journal Soil Science,* 37: 29-38.

Wasonga, V.O, 2001. Effect of Balanites glabra canopy cover on soil organic matter, soil moisture and selected grass species production in Isinya, Kajiado, Kenya. MSc. Thesis, University of Nairobi. Unpublished

Williams, A.G., Kent, M., Ternan, J.L., 1987. Quantity and quality of bracken through fall, stem flow and litter flow in a Dartmoor catchment. Journal of Applied Ecology 24, 217–230.

Young, A., 1989. Agroforestry for Soil Conservation. International Council for Research in Agro-forestry, Nairobi.

*******