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IMPACT OF WOODY PLANTS SPECIES ON SOIL PHYSICO-CHEMICAL PROPERTIES ALONG GRAZING GRADIENTS IN RANGELANDS OF EASTERN ETHIOPIA[1]

[IMPACTO DE LAS PLANTAS LEÑOSAS EN LAS CARACTERÍSTICAS FÍSICO-QUÍMICAS EN UN GRADIENTE DE PASTOREO EN LOS PASTIZALES ORIENTALES DE ETIOPIA]

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SUMMARY

In the lowlands of arid and semiarid rangelands woody plants plays an important role in soil fertility maintenance, providing food, medicine, cosmetics, fodder, fuel wood and pesticides. A better understanding of the interaction of woody plants on their immediate environment is needed to guide optimum management of native vegetation in the production landscapes. However, the impact of woody plant species on soil properties remains poorly understood. This study evaluates the impact of two dominant woody plant species (*A. senegal and B. aegyptica*) on soil physico-chemical properties along grazing gradients in rangelands of eastern Ethiopia. Six trees of each species were selected from light, moderate and heavy grazing sites. Soil sample data at two depths (0-15 and 16-30 cm) were collected from under and open areas of *A. senegal* and *B. aegyptica* from each grazing sites, and analysed for nutrient contents. The nutrient status of soil under both woody species was significantly higher especially with regard to soil organic matter (4.37%), total nitrogen (0.313%), and available phosphorus (11.62) than the open grassland with soil organic matter (3.82%), total nitrogen (0.246%), and available phosphorus (10.94 mg/Kg soil) for *A. Senegal*. The soil organic matter (3.93%), total nitrogen (0.285%), available phosphorus (11.66 mg/Kg soil) were significantly higher than open grassland with soil organic matter (3.52%), total nitrogen (0.218%), available phosphorus (10.73 mg/Kg soil) for *B. aegyptica*. This was more pronounced in the top 15 cm of soil under *A. senegal* woody plant species and on the light and moderate grazing site. 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 *A. senegal* and *B. aegyptica* plants in the lowlands of eastern Ethiopia.

Key words: Bordade rangeland; eastern Ethiopia; soil properties; woody plant species.

RESUMEN

En las tierras bajas de los pastizales áridos y semiáridos, las plantas leñosas desempeñan un papel importante en el mantenimiento de la fertilidad del suelo, proporcionando alimentos, medicinas, cosméticos, forraje, leña y pesticidas. Se necesita una mejor comprensión de la interacción de las plantas leñosas en su entorno inmediato para guiar el manejo óptimo de la vegetación nativa en los paisajes de producción. Sin embargo, el impacto de las especies de plantas leñosas en las propiedades del suelo sigue siendo poco conocido. Este estudio evalúa el impacto de dos especies de plantas leñosas dominantes (*A. senegal* y *B. aegyptica*) en las propiedades fisicoquímicas del suelo a lo largo de los gradientes de pastoreo en los pastizales del este de Etiopía. Seis árboles de cada especie se seleccionaron de pastos ligeros, moderados y pesados. Se recogieron datos de la muestra de suelo a dos profundidades (0-15 y 16-30 cm) de áreas abiertas y abiertas de *A. senegal* y *B. aegyptica* de cada sitio de pastoreo y se analizaron los contenidos de nutrientes. El estado nutricional de los suelos bajo ambas especies leñosas fue significativamente mayor, especialmente con respecto a la materia orgánica del suelo (4.37%), nitrógeno total (0.313%) y fósforo disponible (11.62) Nitrógeno total (0.246%) y fósforo disponible (10.94 mg / Kg de suelo) para *A. senegal*. La materia orgánica del suelo (3.93%), el nitrógeno total (0.285%), el fósforo disponible (11.66 mg / Kg de suelo) fueron significativamente más altos que los pastizales abiertos con materia orgánica del suelo (3.52%), nitrógeno

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total (0.218%) y fósforo disponible 10.73 mg / Kg de suelo) para *B. aegyptica*. Esto fue más pronunciado en la porción de 15 cm superiores del suelo de especies de plantas leñosas bajo *A. senegal* y en el sitio de pastoreo ligero y moderado. Por lo tanto, este árbol tiene un efecto significativo en la mejora de la fertilidad del suelo en los pastizales de recursos pobres y, como resultado, es importante retener las plantas dispersas de *A. senegal* y *B. aegyptica* en las tierras bajas del este de Etiopía.

Palabras clave: pastizales de Bordade; Etiopía oriental; propiedades del suelo; especies de plantas leñosas.

INTRODUCTION

Savanna trees may have negative and positive influence on their immediate environment depending on woody plants density. Dense woody plants may have negative effects on herbaceous vegetation due to competition for available soil nutrients, water (Teshome *et al.*, 2012) and decreased light intensity for under canopy vegetation (Kahi *et al.*, 2009). Scattered woody plants have positive effect on the herbaceous layer by altering resource availability and microclimatic condition. These may occur through improved soil water availability related to hydraulic lift, or through a reduction in the incoming solar irradiation, thus decreasing sub-canopy evapotranspiration, soil temperatures and reducing water stress for herbaceous community. Increased animal deposits under canopied areas may further increase nutrient availability, contributing to an 'island of fertility' effect (Abdallah *et al.*, 2008). Thus, a grass patch of high nutrient content created beneath tree canopy compared to open grassland (Treydte *et al.*, 2007) and, grasses growing under woody canopies had a higher biomass, greener leaf material and stayed green for longer into the dry season than grasses growing further away from woody plants (Treydte *et al.*, 2008).

It is found in the lowlands of Ethiopia, as multipurpose woody plants, *A. senegal* and *B. aegyptica* plays an important role in soil fertility maintenance, providing food, medicine, cosmetics, fodder, fuel wood and pesticides (Mansor *et al*., 2004; Abule *et al*., 2005; Belay and Kebede, 2010), although these patterns can be modified by livestock grazing management. Their presence through grazing, trampling or dung fertilization may also modify the influence of woody plants on soil nutrients (Abdallah *et al.*, 2012). Therefore, a better understanding of these patterns is needed to guide optimum management of native vegetation in the production landscapes.

Despite the importance assigned to woody plants, they are being cleared from rangelands in eastern Africa for charcoal, firewood and timber production and expansion of cultivation (Treydte *et al*., 2007; Zelalem, 2010). In arid and semi-arid ecosystems, where variations in spatial and temporal moisture and nutrients are extreme, clearing of woody plants may result in loss of soil nutrients from already nutrient poor ecosystem which in turn leads to loss of palatable nutritious grasses (Ludwig *et al.*, 2004). Such loses in species composition has the possibility of affecting negatively the populations of grazing livestock and wildlife that select these sites and livelihood of the people (Treydte *et al.*, 2007). Hence, local communities are facing with the decision of either removing woody plants for immediate charcoal use or preserving them to take the advantage of their potential positive effects on other plants and animals.

In the lowlands of eastern Ethiopia, in spite of the presence of multipurpose woody plants (Zelalem, 2010), there is only a limited understanding of the relationships between individual woody plants with soil nutrients especially how grazing affects the relationship between them. Therefore, this study come up with clear findings that could help to understand the role of *A. senegal* and *B. aegyptica* in soil nutrients management, which at the same time enhances the local communities awareness in retaining the existing scattered trees on the rangelands. The objective of this study was influences of woody plants on soil nutrients along grazing gradients in lowlands of eastern Ethiopia.

MATERIALS AND METHODS

Study area

The study was carried out in the Bordade Rangelands of the Oromia Regional State, eastern Ethiopia (40° 12ˈ31.37ˈˈto 40°32ˈ12.32ˈˈ E and 8° 56ˈ38.75ˈˈN to 9°13ˈ58.35ˈˈ N), ~ 268 km east of Addis Ababa. The rainfall in the study areas is bimodal with a short rainy season from March to April, and the main rainy season from July to September. The mean minimum rainfall is ~400 mm and means maximum rainfall ~900 mm. The mean annual temperature is 21°C. The natural vegetation of the study area is characterized as Acacia-wooded grasslands (Le Houérou and Corra, 1980). This study was carried out from September to December 2014, immediately after the main rainy season.

Experimental Procedures

Site selection

Three sites that were subjected to different intensities of grazing (light, moderate and heavy) were systematically identified, based on the history and intensity of livestock grazing and discussion with local pastoralists and district pastoral development offices staff, who have extensive knowledge of study areas and visual field observations prior to this study (Abule *et al*., 2005)

The site representing light grazing was located in Bordade peasant association. This site falls in a portion of rangelands, protected by the private in order to secure feed for certain categories of animals such as milking, suckling, sick and pregnant (breeding) animals that do not migrate during the dry season. Hence the site is underutilized due to under stocking. The vegetation cover and the composition were therefore in good condition.

The site representing moderate grazing was located in Buri Arba. The site falls within an area which serves as private grazing lands, protected and fenced with thorny bushes for dry season grazing. This site is located adjacent to the neighbouring pastoral grazing lands and because of the nearness of the area, illegal grazing is common throughout the year.

The site representing heavy grazing is located in pastoralists grazing land which are owned communally and on which continuous heavy grazing is practiced throughout the year. The site is characterized by low basal cover, high proportion of bare ground, increase in the encroachment of harmful plants, dominance by dwarf woody plants and disappearing of trees.

The sites for replication of each species were collected from sandy loam soil types, at altitude 960-1,112 m.a.s.l. This was done to minimize the variability within replications.

Woody Species selection, Sub-Habitat Identification and Field Layouts

Woody species selection

Widely spaced (isolated), matured tree species with extended canopy cover of *A.senegal* and *B. aegyptica* were selected. These woody plants were chosen based on the fact that previous studies indicated that they are abundant and important in the study area (Zelalem, 2010). At each of the grazing intensity site, six trees of each species were randomly selected. The heights and canopy diameters of the selected trees were measured. A measuring pole of 10 m, graduated at every 100 cm, and measuring tape was used to take the measurements of tree heights and canopy diameters.

Sub-habitat identification

Having identified the sites and the woody plants under investigation, the next step was sub-habitat characterization or identification. Accordingly, two sub-habitats, viz., under-canopy and the corresponding open grassland were considered. This method is considered because trees in Bordade rangeland circumstances are sparse in distribution (Zelalem, 2010). Under tree canopy means it is area located directly beneath the tree crown. On the other hand, open grassland is located beyond the influence of the roots of the woody plants. Absence of tree roots in the open grassland zone was confirmed by digging 1 m deep trenches at various locations around each tree.

Table 1 Heights and canopy diameters (means and SE) of replicated woody species

Woody species	N	Height (m)	Canopy diameter (m)
Acacia senegal	18	5.8±0.25	10.8± 0.465
Balanite aegyptica	18	4.6±0.23	6.7±0.224

Field layouts

At each selected site, 6 individual woody plants for each tree species were considered for the study. The grass and soil samples were collected from two sub-habitats, viz., under-canopy and open areas. As a result, measurements of grass and soil parameters were taken on four directions (east, west, South and north) by quadrants from the under canopy outward into the open area. In due course of open area sampling, care was taken so that neighbouring trees, their shade and other influences are avoided.

Soil Sampling and Analysis

Data on soil properties were taken at (0-15) and (15-30) cm depths using auger from each tree species per sub-habitat, at four directions as sampling of herbaceous vegetation. These procedures were followed to compensate for short-range spatial variability between individual soils samples. The 30 cm depth for soil were considered during sampling in order to accommodate mobile nutrients such as nitrogen, where large volumes of soil might be disturbed. The grounds for taking the soil samples at the two soil depths is to examine if there is any variation in the distributions of soil physico-chemical properties within and among woody sub-habitat. Soil samples were taken from five points (at four directions and at center) of each quadrant and bulked as one sample. Hence a total of 576 (3 sites x 2 tree species x 6 tree x 2 sub- habitats x 2 soil depth x 4 soil sample) soil samples were taken for this study. The soil samples from each woody at same soil depth in each sub-habitat were pooled and mixed to form one composite sample of soil sample. Soil samples were mixed thoroughly to form composite sample for each grazing, tree species, sub-habitat, soil depth and quadrant basis; and representative samples were taken for laboratory analysis. Finally, a total of 144 composite soil samples were made (3 sites x 2 woody plants x 6 individual woody plants x 2 sub- habitats x 2 soil depth).

The collected soil samples were properly labelled and packed in plastic bags and transported to HU soil laboratory. Before laboratory analysis, samples were air-dried, ground and passed through 2 mm size sieve. Required soil parameters were analysed including soil pH, organic matter (OM), total nitrogen (TN), available phosphorus (P), Cation Exchange Capacity (CEC), soil texture (% Silt, Clay and Sand) and electrical conductivity (EC) following standard procedures at HU soil laboratory.

Soil pH was determined using 1:2.5 soils: water ratio suspensions using the Bouyoucos hydrometer method (Carter, 1993). Electrical conductivity was measured by conductivity meter on saturated soil paste extracts obtained by applying suction (Van Reevwijk, 1992). The total nitrogen contents in soils were determined using the Kjeldahl procedure by oxidizing the organic matter with sulphuric acid and converting the nitrogen into $NH4+$ as ammonium sulphate (Jackson, 1958). Organic Carbon (OC) was determined according to the Walkley and Black (1934) method. The per cent soil organic matter was calculated by multiplying the per cent organic carbon by a factor of 1.724 (Brady, 1990), following the standard practice that organic matter is composed of 58% carbon. Available P was determined using the standard Olsen extraction method (Olsen *et al*., 1954), Soil cation exchange capacity (CEC) was measured after leaching the ammonium acetate extracted (ammonium ion standard) soil samples with 10% sodium chloride solution. The amount of ammonium ion in the percolate was determined by the Kjeldahl procedure and reported as CEC (Hesse, 1972) and finally, texture determination was carried out by the hydrometer method (Okalebo *et al*., 2002).

Experimental Design and Data Analysis

Variables included for analyses were soil pH, organic matter; total nitrogen, available phosphorus, cat ion exchange capacity, soil texture and electric conductivity were included as explanatory variables. A split plot ANOVA using SAS (9.1), with grazing, woody species, sub-habitat and soil depth as categorical predictors or factors and soil properties as dependent variables was performed to test the factors' main and interactive effects on all variables. The model included the effect of grazing, tree species, sub-habitat, soil depth and their interactions. The values of the probability lower than 0.05 ($P < 0.05$) were regarded as statistically significant. Significant differences among mean values were done using least significant difference (LSD) method.

RESULTS AND DISCUSSION

Effect of Grazing on Soil Physico-chemical Properties

The analysis of variance for major soil physical and chemical properties along grazing gradients is presented in Table 2.

Table 2. Influence of grazing on major soil physical and chemical properties in Bordade rangeland of Ethiopia.

Parameters	Light	Moderate	Heavy	$LSD_{(0.05)}$
Sand (%)	60.8^{c}	64.5^{b}	68.2^{a}	0.38
Silt (%)	21^{a}	20.6^{a}	18.8^{b}	0.15
Clay (%)	18.33^{a}	14.91^{b}	13.1^{c}	0.17
pH (%)	8.61^{a}	8.28^{b}	7.98^{c}	0.04
EC (dSm^{-1})	0.26^{a}	0.221^{b}	0.212^{c}	0.006
CEC (Meq/100 g Soil)	21.3^{a}	14.3^{b}	9.8^{c}	0.79
Total N (%)	0.3^{a}	0.201^{b}	0.18^{c}	0.0067
OM (%)	4.5^{a}	3.9^{b}	3.32^{c}	0.041
P (mg/Kg soil)	12.12^{a}	11.5^{b}	10^{c}	0.15

Means with the same letter within row are not significantly different ($p<0.05$); Key words: CEC = cation exchange capacity; EC = electrical conductance; N = nitrogen; OM= organic matter; P = phosphorus

Organic matter, total nitrogen and available phosphorus

There was a significant (P < 0.001) difference in soil OM, TN and AP along grazing gradients. Highest mean values were displayed for the light grazing sites followed by moderate grazing and least at heavy grazing sites (Table 2). This result agreed with reports by He *et al*. (2011); Kioko *et al*. (2012) and Habtamicael *et al*. (2013), who reported higher organic matter and total nitrogen at light grazing sites compared to heavy grazing sites. The difference in soil OM and TN contents along grazing sites can be explained by the difference in soil erosion, biomass return (Kioko *et al*., 2012) and species composition (Klumpp *et al*., 2009). Light grazing sites may have gained nutrients from plant decomposition, as there was minimal removal through herbivore defoliation and minimal soil loss through erosion due to high cover of herbaceous species that shields soil from erosion (Kioko *et al*., 2012). Overgrazing caused by livestock grazing reduces plant biomass accumulation and cause a shift in plant species composition (Klumpp *et al*., 2009), which in turn affect soil fertility (Savadogo *et al*., 2007) because of changes in root biomass (Klumpp *et al.*, 2009) and quality of organic matter, and decrease soil capacity to sequester carbon (Savadogo *et al*., 2007; Klumpp *et al*., 2009).

According to Tessema *et al*. (2011), lower soil nutrients at heavy grazing could be related to higher sand content and lower clay contents as well as lack of animal excreta due to continuous removal by communities for fuel and other purpose. In the present study higher OM at light and moderate grazing sites than corresponding heavy grazing sites could be explained by nutrients gained from high biomass production and cover of herbaceous species. Ayana *et al*. (2012) reported high basal cover of grasses correlated with high soil organic carbon in southern Ethiopia.

Although urine and faeces depositions increase soil nitrogen and phosphorus in many grazed systems (Sedighe *et al*., 2012), this was not observed in our study where livestock were included on either seasonal or year-round basis. The plausible explanation for the increased nitrogen at light grazing site could be an increase in soil organic matter accumulation (Habtamicael *et al*., 2013). Dung is immediately collected by pastoral for fuel and verified in the rangelands in Ethiopia (Tessema *et al*., 2011). In current study, higher values of total nitrogen at light grazing is probably related to higher soil OM content which in turn related to high biomass being returned to soil under this site (Hunde *et al*., 2011).

The results of this study also showed that AP show increasing trends along grazing gradients from heavy grazing to light grazing sites, which support the reports by Tessema *et al*. (2011) and Teague *et al*. (2011). In this regard, El-Dewiny *et al*. (2006) reported the release of higher phosphorus during degradation of organic matter. Subsequently, the availability of phosphorus at light grazing site is greater than that of site with high grazing intensity.
The positive impact of light grazing pressure on the amount and availability of soil nutrients has many influences on the biodiversity and livelihood of the local people near the study sites. The controlled grazing reducing the extinction of indigenous vegetation and increase the amount of grass produced in a given areas, which in turn helps the local people to get enough feed for their livestock. Therefore, reducing livestock pressure within the landscape has an important role in restructuring vegetation management through nutrient concentration (Muchiru *et al*., 2003).

Cat ion exchange capacity, electric conductance and pH

There was a significant (P<0.001) difference in CEC, EC and pH along grazing gradients. The highest soil CEC, EC and pH were recorded at light grazing sites followed by moderate and least at heavy grazing sites (Table 2).These results are in agreement with studies by Teague *et al*. (2011); Ajorlo *et al*. (2011) and Kioko *et al*. (2012), that reported highest values of these parameters at light grazing site.

According to Kioko *et al*. (2012), high soil CEC at light grazing could be explained by high soil organic matter at light grazing site. Organic matter plays a role of retaining cations and protecting them from leaching and removal by runoff. In current study higher CEC at light grazing site could be explained by higher OM in the soil at light grazing site. The soil pH was higher in the site with low grazing pressure than corresponding heavy grazing pressure sites, which was likely due to higher level of EC at light grazing sites. Similarly, based on the positive association between exchangeable cat ions and soil pH (Hagos and Smit, 2005), a higher pH at light grazing in current study could be explained by higher EC in the soil at light grazing site than corresponding moderate and heavy grazing sites.

Sand, silt and clay

In terms of grazing intensity, there was significant (P<0.001) difference for the soil content in sand, silt and clay in three grazing site was observed. The heavy grazing sites had a highest percentage of sand followed by the moderate and least at light grazing site. The clay and silt contents were highest at light grazing followed by the moderate grazing and least at heavy grazing sites (Table 2). The results of this study showed that sand was the dominant fraction in soils in all rangeland vegetation types, which have shown the decline with increases in soil degradation. Itanna (2005) classified soil types with >18% silt as susceptible to crust formation and such soils increase bareness of the ground and enhance runoff under heavy grazing by livestock and as a result reduce forage production. Moreover, such soil types have been observed to enhance gully formation in the rangelands favoring more loss of nutrients from the soils. This necessitates appropriate soil management.

The finding of this study concurred with study by Tessema *et al*. (2011), who reported higher percentage of clay and low percentage of sand at light grazing site than corresponding heavy grazing sites. According to Tessema *et al*. (2011), the higher sand content is probably caused by increasing run off and soil erosion, triggered by the higher percentage of bare ground and low basal cover, as well as low standing biomass production. Similarly, higher percentage of clay and silt contents at light grazing site than corresponding heavy grazing related to reduced loss of silt and clay fraction through the process of soil erosion due to presence of high vegetation cover (Hunde *et al*., 2011). In present study the higher sand percentage at heavy grazing could be explained by low biomass production and cover of herbaceous species.

Effect of woody plant Species on Soil Physico-chemical Properties

The analysis of variance for major soil physical and chemical properties under *A. Senegal* and *B. aegyptica* tree species is presented in Table 3.

There are indications that soil enrichment can differ between tree species that grow in the same environment. Legume tree species form one of the most evident functional groups by its potential for the symbiotic fixation of atmospheric N and, even independent of this capacity, by the high levels of N in their tissues (Jeddi and Chaeib, 2009). Hence, both above and below ground litter inputs from legume trees are thought to enhance soil's biological activity and nutrient release from organic matter.

In current study, there were significant ($P < 0.001$) difference in soil OM and TN accumulation among the two varieties. Higher soil organic matter and total nitrogen input under leguminous trees (*A. senegal* tree species) than that of corresponding under non-leguminous trees species (*B. aegyptica* tree species) (Table 3). Dachung *et al*. (2014) studied the effect of tree species on soil nutrients in Nigeria and reported higher organic matter and total nitrogen content under *A. Senegal* tree species than other tree species. Githae *et al*., (2011) also found a significant difference between the carbon and nitrogen content under *A. senegal* and that of open areas in Kenya. This is an indication of the species' potential of enhancing herbage productivity in the rangelands as they improve soil fertility under their canopies in the dry land areas of Ethiopia. According to Dachung *et al*. (2014) higher organic matter and total nitrogen recorded under *A. senegal* compared to under *B. aegytica* tree species could be related to the ability of leguminous tree species to increase N availability. Higher OM and TN under *A. Senegal* tree species in current study could be explained by higher biomass accumulation under *A. senegal* tree species than corresponding under *B.aegyptica* tree species and nitrogen fixing ability of the species.

Table 3. Influence of woody plant species on major soil physical and chemical properties in Bordade rangeland of Ethiopia.

Parameters	*A.senegal*	*B. aegyptica*	LSD $_{(0.05)}$
Sand (%)	64.26^b	64.65^a	0.309
Silt (%)	20.12^a	20.11^a	0.342
Clay (%)	15.64^a	15.23^b	0.142
pH (%)	8.32^a	8.31^a	0.031
EC (dSm^{-1})	0.23^a	0.23^a	0.005
CEC (Meq/100 g Soil)	14.49^b	15.79^a	0.644
Total N (%)	0.24^a	0.21^b	0.005
P (mg/Kg Soil	11.28^a	11.19^a	0.121
OM (%)	4.09^a	3.73^b	0.05

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

The analysis variance indicated that the soil OM, TN and AP were significantly (P< 0.001) influenced by sub-habitat. The higher soil organic matter, total nitrogen and available phosphorus under tree canopy as well as lower values for organic matter, total nitrogen and available phosphorus were recorded at open grassland sites (Table 4). This result also complements previous findings that higher soil organic matter, total nitrogen and available phosphorus under tree canopy (Abdallah *et al*., 2012; Jeddi and Chaieb, 2012; Agena *et al.*, 2014). Similar finding by Belay and Kebede, (2010) state the concentration of OM and TN under tree canopy to be higher than open grassland in Borana rangelands. This is an indication of the woody plant potential of increasing soil OM and TN; hence soil fertility in the dry land areas of Ethiopia. Therefore, the current study indicates that *A. Senegal* and *B. aegyptica* tree species has the potential of enhancing herbage productivity in the rangelands as they improve soil fertility.

Several factors contributed for the formation of difference in OM and total N under tree canopies and open grassland sites. One of the most important factors is the nutrient inputs by tree litter (Hudak *et al.*, 2003; Agena *et al.*, 2014). Litter fall inputs are relatively low in dry lands owing to constraints in plant productivity (Berg *et al*. 1999) in arid and semiarid rangelands but, they may be substantially higher immediately beneath the canopy (Wang et al., 2010). In addition trees can accumulate nutrients in top-soil layers through their root system and they also attract birds and browsing animals, which deposit their feces beneath the canopies leading to higher soil N, P and OM contents (Belsky *et al*., 1989). Furthermore, Abdallah *et al*. (2008) suggested that the droppings from birds under tree canopies were one of the major inputs of nutrients to the soil. Differences in cover and dry matter production of herbaceous plants between tree canopies and the open grassland sites may also exacerbate these differences (Whitford, 2002).

The analysis of variance showed that the CEC and EC had been influenced by tree species. Higher soil cat ion exchange capacity and electric conductivity under *A.senegal* than that of *B.aegytica* tree species (Table 3). The mechanisms by which tree species influence exchangeable cat ions include specific differences in the uptake of exchangeable bases, nitrogen fixation, and production of litter high in organic acid content and the stimulation of mineral weathering (Finzi *et al*., 1998). Similarly, the difference in tree species on soil CEC were probably related to soil clay content and soil organic matter (Githae *et al*., 2011)

The CEC measurements indicate soil with a CEC of <16 meq/100 g are considered not to be fertile and such soils are highly weathered while fertile soils have a CEC of >24 meq/100 g (Gachene and Kimaru, 2003). The mean values of CEC under both tree species are <16 meq/100 g. This means that *A. Senegal* and *B. aegyptica* can perform well on soil poor in nutrients.

Analysis of variance for soil sand and clay content revealed that it was significantly affected by tree species ($P < 0.05$). Whereas the soil clay content was not affected by tree species ($P = 0.05$). The mean values for clay content were higher under *A. senegal* compared to *B. aegytica* tree species. The mean values for sand content were lower under *A. senegal* compared to *B. aegyptica* tree species (Table 3).

Effect of Sub-habitat on Soil Physico-chemical Properties

The analysis of variance for major soil physical and chemical properties under tree canopy and open grassland is presented in Table 4.

Table 4. Influence of sub-habitat on major soil physical and chemical properties in Bordade rangeland of Ethiopia.

Parameters	Under canopy	Open grassland	LSD (0.05)
Sand (%)	64.38[a]	64.52[a]	0.309
Silt (%)	20.03[a]	20.2[a]	0.342
Clay (%)	15.59[a]	15.28[b]	0.142
pH (%)	8.37[a]	8.21[b]	0.031
EC (dSm^{-1})	0.25[a]	0.21[b]	0.005
CEC (Meq/100 g Soil)	15.67[a]	14.71[b]	0.644
Total N (%)	0.243[a]	0.21[b]	0.0054
P (mg/Kg Soil	11.64[a]	10.83[b]	0.121
OM (%)	4.15[a]	3.67[b]	0.046

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

In a present study higher organic matter, total nitrogen and available phosphorus under tree canopies compared to open grassland sites 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 current study showed that the areas under tree canopy had higher cat ion exchange capacity, electrical conductance and pH compared to areas away from the tree canopy ($P < 0.001$). The soil cat ion exchange capacity, electrical conductivity and pH contents were higher under tree canopy than corresponding open grassland sites (Table 4).

The cat ion exchange capacity was higher under tree canopies compared to open grassland sites, as studies elsewhere (Abdallah *et al*., 2012 and Grellier *et al*., 2013). This can possibly be explained by the base pump function of trees and shrubs that reallocates nutrients from deeper soil layers to the surface by litter input to the top soil (Vanlauwe *et al*., 2005). In this study higher CEC under tree canopies could be explained by high biomass production of herbaceous species and higher pH under tree canopies relative to open grassland sites.

In line with Jeddi and Chaib, (2009) and Abule *et al*. (2005), the result of this study showed higher values for electric conductivity under tree canopies compared to the open grasslands.

Higher exchangeable cat ions under tree canopies are associated with high tree litter biomass (Agena *et al*., 2014) and biomass production of herbaceous species (Abdallah *et al*., 2012), which upon decomposition release soluble nutrients to the soil (Agena *et al*., 2014). In this study the higher EC under tree canopies could be explained by high biomass production of herbaceous species and higher pH under tree canopies relative to open grassland sites.

Contrary to the reports of lower pH under tree canopies (Hagos and Smit, 2005; Grellier *et al*., 2013), higher soil pH values were recorded under tree canopies in this study. Comparable results were reported by Abule *et al*. (2005) and Abdallah *et al*. (2008), who recorded a higher pH in canopied sub habitats compared to open grassland sites. The exact reasons for these differences regarding the influence of tree canopies on soil pH are not known. However, based on the positive association between exchangeable cat ions and soil pH (Hagos and Smit, 2005), a higher pH under the tree canopy were often correlated with a higher content of exchangeable cat ions (Jeddi and Chaib, 2009).

The result of current study showed significant ($P < 0.001$) effect of tree canopy on the clay content, but we did not find any significant ($P > 0.05$) difference in content of sand and silt under tree canopy and open grassland sites. Higher soil clay content was recorded under tree canopy than corresponding open grassland (Table 4).

In contrast 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.

Effect of Soil Depth on Soil Physico-chemical Properties

The analysis of variance for major soil physical and chemical properties at two depths is presented in Table 5.

Table 5. Vertical distribution of major soil physical and chemical properties at Bordade rangelands of Ethiopia.

Parameters	0-15cm	16-30cm	LSD $_{(0.05)}$
Sand (%)	64.39^a	64.51^a	0.309
Silt (%)	20.03^a	20.20^a	0.342
Clay (%)	15.58^a	15.29^b	0.142
pH (%)	8.30^a	8.33^a	0.031
EC (dSm^{-1})	0.241^a	0.218^b	0.005
CEC (Meq/100 g Soil)	15.59^a	14.69^b	0.644
Total N (%)	0.235^a	0.215^b	0.0054
P (mg/Kg Soil)	11.31^a	11.16^b	0.121
OM (%)	3.95^a	3.87^b	0.046

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

There were highly significant influence of soil depth on OM, TN and AP ($P < 0.05$). Higher soil OM, TN and AP content at the 0-15cm soil layer than that of corresponding sub-surface soils (Tab 4). In line with the studies by Jeddi and Chaib. (2009), Lemma and Fassil. (2010) and Ajorlo *et al*. (2011), this study reported higher soil OM, TN and AP at surface soil than that of sub-surface soil. According to Ajorlo *et al*. (2011), the higher concentrations of the soil OM, TN and AP in the upper soil layer could be explained by the continuous accumulation of un-decayed and partially decomposed plants and animal residues on the surface soils. Higher OM, TN and AP at the surface soil in current study could be explained by high biomass accumulation and plant cover in surface soil.

There was highly significant difference of electric conductance and cat ion exchange capacity due to soil depth ($P< 0.05$). Whereas pH were not significantly affected by soil depth ($P=0.05$). The effect of soil depth in this study was observed as a decrease EC and CEC with an increase in soil depth. This is in agreement with other reports for EC (Jeddi and Chaib, 2009; Samuel *et al.,* 2013) and CEC (Oseni *et al*., 2007). In general, the results are also consistent with a decline in soil nutrients with depth for a large number of studies of tree effects on soil nutrients (Eldridge and Wong, 2005) though some studies did not detect changes in soil nutrients with depth under tree canopies.

There was a highly significant ($P< 0.0001$) difference in content of clay particle due to soil depth. Whereas the content of sand and silt particle were not significantly affected by soil depth ($P=0.05$). The soil clay content in the 0-15cm soil layer was much higher than that of corresponding sub-surface soils (Table 5). This implies that the content of clay were higher at the top of soil compared to the sub soil.

Interactive Effect of Grazing, Tree Species Sub-Habitat and Soil Depth on Soil Physico-chemical Properties

The soil OM, TN and AP were significantly ($P < 0.05$) higher under tree canopy than that of open area, but the effect was significantly greater at light grazing site compared to moderate and heavy grazing intensity (Tables 6). In agreement with Abdalla *et al*. (2012), Abdallah and Chaeib (2012), the main results of this study show the decreasing importance of woody plants with increasing grazing pressures, which could be related to dramatic decline in litter (Carrera *et al*., 2008) and biomass production at heavy grazing site (Abule *et al*., 2005). The decline in tree litter plays an important role of decreasing organic matter and consequently soil nutrients and moisture (Carrera *et al*. 2008).

Table 6. Interactive effects of grazing and tree species on mean values organic matter, total nitrogen and available phosphorus.

Grazing*Habitat	OM	N	P
G_1H_1	4.89[a]	0.324[a]	12.73[a]
G_1H_2	4.11[b]	0.271[b]	11.69[b]
G_2H_1	4.18[b]	0.213[c]	11.92[b]
G_2H_2	3.63[c]	0.191[c]	11.06[c]
G_3H_1	3.39[d]	0.194[c]	10.26[d]
G_3H_2	3.26[e]	0.158[d]	9.75[e]
Grazing(G)	***	***	***
Grazing*Habitat	OM	N	P
SE_{GxH}	0.0284	0.0034	0.747
Habitat (H)	***	***	***
GxH	***	***	**

***= Extremely significant (P<0.0001 or <0.001); **=highly significant (p<0.01); G_1=light grazing; G_2=moderate grazing; G_2=heavy grazing; H_1=under canopy; H_2=open grassland

The soil OM, TN and AP were significantly higher under the canopy for both tree species, but the effect was significantly greater under the canopy of *A. senegal* relative to *B. aegyptica* tree species ($P < 0.05$; Table 7). The result of this study showed that *A. senegal* had greater positive effect in OM, TN and AP improvement than that of *B. aegyptica* tree species, which could be explained by N-fixing ability and higher biomass production under *A. senegal* compared to *B. aegyptica* tree species. Additionally, N concentrations of *A. senegal* leaves are substantially higher than those in other non N_2-fixing woody species, such as *B. aegyptica* (Deans *et al*., 2003), and their decomposition can increase the soil concentration of this element.

The result of this study showed highly significant ($P<0.001$) interactive effects of tree species with grazing intensities on soil CEC, EC and pH, which suggests that the effect of tree species on electric conductivity, cat ion exchange capacity and pH did not constant along grazing gradients (Table 8). Mean values of pH were significantly higher under the canopy of *A. senegal* compared to *B. aegytica* tree species at light and moderate grazing sites, but the effect of *A. senegal* were lower than that of *B. aegytica* tree species at heavy grazing sites.

Table 7. Interactive effects of sub-habitat with tree species on organic carbon and available phosphorus

Tree*Habitat interaction	OM	P	N
T_1H_1	4.37[a]	11.62[a]	0.313[a]
T_1H_2	3.82[c]	10.94[c]	0.246[c]
T_2H_1	3.93[b]	11.66[b]	0.285[b]
T_2H_2	3.52[d]	10.73[d]	0.218[d]
Tree (T)	***	Ns	***
Habitat (H)	***	***	***
GxT	**	*	**
CV	13.56	14.26	17.31
SE_{GxT}	0.023	0.061	0.003

***= Extremely significant ($P<0.0001$ or <0.001); **=highly significant ($p<0.01$); ns=non-significant ($p>0.05$); Means with the same letter are not significantly different ($p<0.05$); T_1=A.senegal; T_2=B.aegytica

Table 8. Interactive effects of grazing and tree species on cat ion exchange capacity, electric conductivity and pH

Grazing*Tree interaction	CEC	EC	pH
G_1T_1	23.13[a]	0.262[a]	8.64[a]
G_1T_2	19.48[b]	0.249[b]	8.59[a]
G_2T_1	14.50[c]	0.216[d]	8.32[b]
G_2T_2	14.19[c]	0.226[c]	8.23[c]
G_3T_1	9.733[e]	0.221[c]	7.93[d]
G_3T_2	9.796[f]	0.203[d]	8.03[e]
Grazing(G)	***	***	***
Tree(T)	***	*	ns
GxT	***	***	***
CV	12.9	6.5	1.14
SE_{GxT}	0.397	0.003	0.0192

***= Extremely significant ($P<0.0001$ or <0.001); **=highly significant ($p<0.01$); ns=non-significant ($p>0.05$); Means with the same letter are not significantly different ($p<0.05$); T_1=A.senegal; T_2=B.aegytica

CONCLUSIONS

From this finding, it can be concluded that the retaining scattered woody plants in resource poor lowlands of Ethiopia have been effective in improving of soil nutrient enrichment and the areas under scattered woody plants were in a better condition than the open grassland areas. This is especially true with regards to soil OM, TN, AP, CEC, EC and pH, which are significantly higher under tree canopies. It can be also concluded that the enrichment of the soil is mainly restricted to the top 15 cm of soil, which is commonly more sensitive to changes in plant cover. Similarly, this study confirmed that *A. senegal* had a higher positive effect on soil nutrient enrichment than corresponding *B. aegyptica* tree species. This is especially true with regard to soil OM, TN, AP, CEC and EC.

Heavy grazing proved to be a strong overriding effect on the positive influences of woody plants in in the lowlands of Ethiopia. Therefore, the improvements of soil nutrients due presence of woody plants depends on grazing and the species of woody plants. 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.

Further research should be carried out involving larger and more replicated areas with these woody plants 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.

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