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# Soil property variations in relation to exclosure and open grazing land use types in the Central Rift Valley area of Ethiopia

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## Abstract

**Background:** Land degradation and unsustainable management practices have resulted in soil organic carbon and nutrient depletion, hydrological instability, reduced primary productivity, and low biological diversity. In response to these problems, communities in the Central Rift Valley area of Ethiopia have started to establish exclosures about three decades ago. This study has investigated the variations in selected soil properties (soil textural fractions, bulk density, soil moisture content, pH ($H_2O$) and soil organic carbon content) under two land use types: open grazing land and exclosures in the Central Rift Valley of Ethiopia.

**Results:** Results showed that soil organic carbon varied significantly with land use types ($p = 0.040$), soil depths ($p = 0.010$) and the interaction effect ($p = 0.039$). The soil moisture content showed significant variation ($p < 0.0001$) only with soil depth.

**Conclusion:** Exclosure land use type has shown an improvement in soil organic carbon against the findings by Mekuria et al. [International Conferenceon Advances in Agricultural, Biological & Environmental Sciences(AABES-2014), Dubai (UAE) 2014]. Thus, highly degraded open grazing should be designated as exclosure land management zone to restore and rehabilitate severely degraded landscape in the fragile environment of the rift valley area of Ethiopia.

**Keywords:** Land use, Exclosure, Grazing land, Soil physical properties, Soil chemical properties, Ethiopia

## Background

Soil is a vital natural resource that is not capable of being renewed on the human time scale (Liu et al. 2006). It is a living and dynamic natural body that plays many key roles in terrestrial ecosystems, for instance, as sources of available nutrients to plants, maintenances in hydrological stability and biological diversity. Sustaining soil and environmental features are the most effective methods for ensuring sufficient food supply to support life, reduce soil degradation and improve soil health (Soares et al. 2005). They also play a role in the global carbon cycle and will have a positive impact if soils are managed. However, land use changes, mainly conversion of natural forest to agricultural and grazing lands are known to result in changes in soil chemical, physical and biological properties (Houghton et al. 2000), yet the sign and magnitude of these changes vary with land cover and land management (Celik 2005). Conversion of a natural ecosystem (for instance, natural forests) to an agricultural and unmanaged land use systems may cause some changes in the soil properties (Amusan et al. 2001). Conversion of natural landscapes into cultivated and grazing systems cause an abrupt decline in soil organic matter and reduces the nutrient content of soil through reduced litter production, increase erosion rates and decomposition of organic matter by oxidation (Chen and Xu 2010). Similarly, various reports (e.g. Solomon et al. 2002; Lal 2005; Yimer et al. 2007) indicate that conversion of natural forest into agricultural ecosystems negatively affects SOC concentration and stock by 20–50 %. Thus, mitigation strategies to reduce the impact of climate change (FAO 2006) by augmenting carbon sequestration and reducing CO2 emissions from soils include proper forest management

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and afforestation or reforestation programs and restoration of degraded landscapes through exclosure and integration of physical soil and water conservations with agronomic measures become crucial.

Livestock overgrazing is one of the most important factor that results in grassland degradation, soil erosion and nutrient losses (Wei et al. 2011). Due to overgrazing, the natural vegetation in the northern highlands of Ethiopia has virtually disappeared, leaving degraded communal grazing lands with irregularly spaced trees and shrubs and vast areas of bare lands devoid of vegetation (Nedessa et al. 2005). The effects of grazing on soil properties have shown to be dependent on the type of grazing management practices. For instance, communal grazing lands in northern Ethiopia have shown lower total soil nitrogen (N), available phosphorus (P), and cation exchange capacity compared to exclosures (Mekuria et al. 2011).

In the current study area, mixed farming system, in which livestock production is as important as crop production, forces farmers to allocate land for grazing (Dereje 2006). Recently, the problem in the study area is clearly observed as much of the extensively grazing lands on the sloping landscapes and flat bare lands were abandoned and are highly degraded. Hence, the area is exposed to serious land degradation, including soil erosion and heavy sediment deposition on the foot slope of the cultivated lands.

To control the land and soil degradation problems in the semi-arid and dry land areas of Ethiopia attention has been given to manage the degraded landscapes through conversion to exclosures. Exclosures are rehabilitation techniques (Mekuria et al. 2007) where areas are closed off from the interference of human and domestic animals with the goal of promoting natural regeneration of plants and reducing land degradation of formerly degraded communal grazing lands (Mekuria and Ayenekulu 2011) and to maintain economically productive and biologically diverse vegetation (Mengistu et al. 2005).

Exclosure reduce nutrient loss from a site by controlling runoff (vegetation acting as a physical barrier to soil erosion), this eventually improves the capability of the land to support diverse plant species, including exotic plantations (Mengistu et al. 2005). In Ethiopia, this has improved soil fertility by augmenting soil nutrients from decomposed plant remains and increase soil organic matter by 1.1 %, total nitrogen by 0.1 %, and available phosphorous by 1.8 mg $kg^{-1}$ compared with communal grazing lands after exclosure establishment (Mekuria et al. 2007; Mengistu et al. 2005). Few case studies conducted in the highlands of Ethiopia have also shown that exclosures can be effective in restoring degraded lands and increase soil organic carbon (Mekuria et al. 2011; Mekuria 2013). For example, Mekuria (2013) reported an increase in soil carbon following the establishment of exclosures on grazing lands in the semi-arid lowlands of Northern Ethiopia, while Young-Zhong et al. (2005) demonstrated a decrease in soil carbon in Mongolia. Fusun et al. (2010) in Tibetan plateau livestock exclusion showed a significantly increased soil organic carbon and total N concentrations. On the contrary, Mekuria et al. (2014) concluded that in the "*Woina Dega*" agroecological zone of Ethiopia (ACZ) exclosures of 1–7 years had no effect on soil nutrients and soil carbon. All these examples suggest that studies on the impact of exclosures on soil properties and soil carbon are not consistent. These, together with the inconclusiveness of the evidence indicate that there is a need to study the changes in soil physical and chemical properties following the establishment of exclosures. Such understanding would help: (1) inform land managers working on the restoration of degraded ecosystem to improve ecosystem services, and (2) maximize carbon sequestration and other ecosystem services from existing exclosures established in degraded ecosystems (Mekuria et al. 2014).

Since exclosure is a new management option and a rapidly evolving complex ecosystem, it demands more investigations in the areas of its potential in maintaining vegetation diversity and thereby improves soil conditions. Thus, the study area was designated as "closed area" in 1967 with the aim of rehabilitation of highly degraded lands, and totally closed from interference of livestock and human being since 1998. Since then, gullies have become stabilized and their expansions have been blocked due to the improvements in vegetation cover through natural regenerations and enrichment plantations.

The rift valley area is the driest and most fragile part of Ethiopia where even limited disturbance of the land will have a profound effect on the soil, water resources and over all environment of the area. Though the problem is not unique to Ethiopia especially in the northern part of the country, but assessing the impacts of restoration practices in the rift valley would generate additional information representing the most environmental fragile part of the country where no detailed impact assessment studies have been conducted. Such information has a paramount importance in evaluating the impacts of restoration practices in improving soil properties and soil carbon sequestration potentials of degraded landscapes. Quantification and assessment of changes in C pool sizes and fluxes are fundamental to understanding the effects of changes in land use/land cover on ecosystem functioning and limiting greenhouse gas emissions (Jaramillo et al. 2003; Lemma et al. 2006; Tesfaye et al. 2016).

Based on these premises, however, this study has examined the long-term potential contribution of exclosure as alternative strategy for rehabilitation of degraded land

and as a means to maintain soil property improvement. Thus, the objective of this study was to evaluate the possible effects of exclosure compared to adjacent open grazing land (hereafter referred to as "land use types") on selected soil physical (particle fractions, bulk density and moisture) and chemical properties (pH and soil carbon) in the Central Rift Valley area of Ethiopia.

## Methods

### Description of the study area

The study was conducted in Dehra *Kebele*[1], Dodota Sire District, Arsi Zone, which is about 125 km southeast of Addis Ababa and 50 km North of Assela, the Zonal capital (Fig. 1). Geographically, it is located between $8^0$ 16′N–8° 20′ 31″N latitude and 39° 19′E–39° 20′ 47″E longitude, lying between 1635 and 1795 m a.s.l. altitudes, and covering a total area of about 2436 hectares (OPEDB 2000) with a gently sloping and hilly landscapes.

The study area is characterized as dry tropical climate. The rainfall is bi-modal, with short rain season between April and June while the long rain season is between July and September. It receives a mean annual rainfall ranging from 500 to 700 mm. The mean monthly temperature is 25 °C with mean monthly maximum and minimum temperatures of 27 and 23 °C, respectively. Based on the data obtained from the District Agricultural Office (OPEDB 2000), the major land use types in the district include agricultural lands (17,744 ha), grazing land (5331 ha), forest coverage (6300 ha), water body (2020 ha), sugarcane plantation (2718 ha), park lands (2500 ha), irrigation (560 ha), investment lands (215 ha) and built up areas cover (7172 ha).

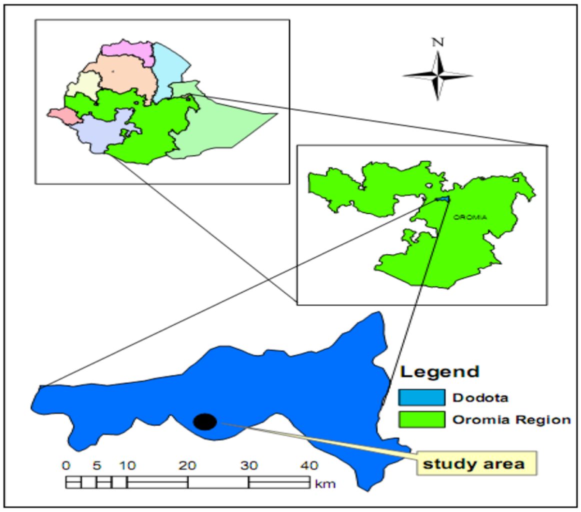

**Fig. 1** Location map of the study area

The major vegetation types of the study area are characterized by acacia woodland which includes species such as *Acacia tortilis, Acacia oerfota, Acacia etbaica, Acacia Senegal* and *Acacia nilotica.* Moreover, other tree species like *Solanium Incanum, Solanium Somalensis, Calpurnia Aurea, Schinus Molle, Dichrostachys Cinera, Vernonia Natalensis* and *Croton Dichogamous* (Dereje 2006) are common.

The study area falls within the Central Rift Valley area of Ethiopia. According to the OPEDB (2000), the major soil types in the district include Cambisols (45 %), Leptosols (35 %) and Andosol (20 %) with Leptosols as the dominant soil type in the study area mantling the sloping topography. These soils are characterized by whitish color and shallowness in their depth (less than 25 cm depth) overlying hard bed rocks.

### Soil sampling

The elevation range (1635–1795 m a.s.l.) was divided into four blocks with 40 meters contour vertical intervals to control the variability in soil properties due to micro-topographic differences. Then the presence of the two land use types (open grazing land and exclosure) were checked followed by locating sample plots in each land use types. In each elevation range (block) and land use types three sample plots (20 m × 20 m) were established randomly and five small soil pits (from four corners and at the center) were opened in an 'X' design. From each small and shallow pit, soil samples from two fixed depths (0–10 and 10–20 cm) were collected and samples from the same depth were thoroughly mixed in a large bucket to form composite soil samples for the plot (Fig. 2).

A total of 48 composite soil samples were collected (4 blocks × 2 land use types × 3 replication of sample plots × 2 soil depths) forming a Randomized Complete Block Design (RCBD) for data analysis. The soil samples were air-dried at room temperature and sieved (<2 mm) prior to any laboratory analysis except for soil moisture content and bulk density determinations. Undisturbed soil samples were collected separately with a core sampler (10 cm height and 7.2 cm diameter) from each soil depth to determine the soil bulk density and thereby the soil moisture content (SMC, %). All samples were analyzed at Kulumsa Agricultural Research Center (KARC), Arsi Zone, Ethiopia.

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[1] *Kebele* is the lowest government administration structure in the country.

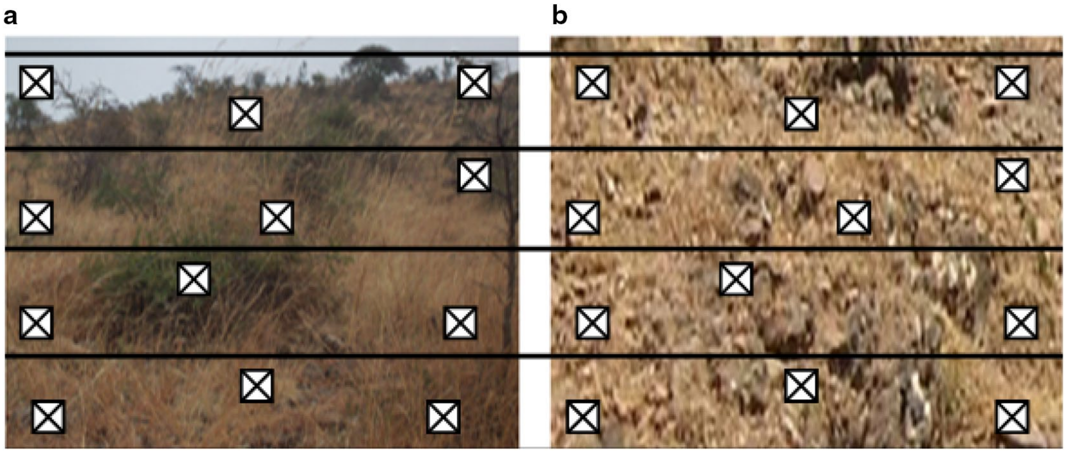

**Fig. 2** Soil sampling layout/sketch at exclosure (**a**) and grazing (**b**) land use types

### Soil analysis

Soil particle sizes for the <2 mm fractions were determined following the Boycouos hydrometric method (Bouyoucos 1962) after destroying organic matter using hydrogen peroxide ($H_2O_2$) and dispersing the soils with sodium hexameta phosphate ($NaPO_3$). The soil bulk density (Bd) was determined using the core method and calculated as the mass of oven-dried soil (105 °C) divided by its volume (Chen et al. 2010).

$$\rho s\left(\frac{g}{cm3}\right) = \frac{Ms}{Vb}$$

where $\rho s$ = soil bulk density (g $cm^{-3}$), Ms = mass of soil after oven dry (g), Vb = bulk volume of the soil ($cm^{-3}$)

The gravimetric soil moisture content (SMC, %) was determined following the method described by (Cuenca 1989). Before the soil was oven dried, the initial weights were measured followed by oven drying for 24 h at 105 °C, and weighing the oven dried soil. Gravimetric soil moisture content was determined using the following formula.

$$MC(\%) = \frac{Wwet - Wdry}{Wdry} \times 100$$

where MC = soil water content on mass basis (%), Wwet = the weight of the wet soil sample (g), and Wdry = the weight of the dried soil sample (g)

The soil pH was measured potentiometrically with a digital pH meter in the supernatant suspension of 1: 2.5, soil: water suspension (Carter 1993). Soil organic carbon (SOC, %) content was determined following the Walkley and Black method (Walkley and Black 1934). The Kjeldahl digestion procedure was followed for the determination of total nitrogen (Bremner and Mulvancy 1982).

### Statistical data analysis

The soil particle size class, bulk density, moisture content, soil pH, organic carbon, total nitrogen and carbon to nitrogen ratio obtained from the soil analyses were subject to two-way Analysis of Variance (ANOVA) to find out the variation with land use types and soil depths as well as their interaction effects using the General Linear Model (GLM) procedure of SPSS version 16.0 for windows (SPSSS Inc., Chicago, USA). Mean comparisons were made using the Tukey Honest Significant Difference (THSD) test ($\rho < 0.05$).

## Results and discussions

### Soil physical property variations

#### *Soil particle size fractions (%)*

The soil particle size fraction (%) of sand, silt and clay did not significantly varied with land use types and soil depths (Table 1). The overall mean sand fraction was found to be high (over 70 %) in both land use types and depths (Table 2). The silt and clay particle size fractions were found to be slightly higher in the exclosure ($20.0 \pm 0.52$, $8.2 \pm 0.35$, respectively), than in the grazing land ($19.4 \pm 0.52$, $7.50 \pm 0.33$, respectively) (Table 2).

The particle size class of the soil in the two land uses and soil depth is sandy loam, indicating no variations in the parent material the soil is derived from. The dominancy in the sand size fraction might have resulted from the selective transportation of the fine fractions down the slopes leaving behind sand size fractions. According to Sandor et al. (1986), soil erosion and selective removal of soil particles do affect the particle sizes. Although particle size fractions are inherent soil properties, their variation sometimes could be associated with the management practices, mainly through mismanagement of

**Table 1 Summary of two-way ANOVA results for sand, silt and clay fractions, soil moisture content and bulk density in relation to land use types and soil depths**

| Source of variation | df | Sand (%) | | Silt (%) | | Clay (%) | | Bd (g/cm$^3$) | | SMC (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MS | ρ | MS | ρ | MS | ρ | MS | ρ | MS | ρ |
| LU | 1 | 15.00 | 0.068 | 52.08 | 0.31 | 6.38 | 0.140 | 0.001 | 0.901 | 1.24 | 0.169 |
| D | 1 | 29.63 | 0.180 | 33.33 | 0.16 | 0.13 | 0.831 | 0.008 | 0.327 | 39.24 | <0.0001 |
| LU × D | 1 | 3.25 | 0.320 | 25.52 | 0.34 | 6.38 | 0.140 | 0.008 | 0.924 | 0.61 | 0.330 |
| Error | 44 | 6.309 | | 5.32 | | 2.82 | | 0.009 | | 0.637 | |

*df* Degree of freedom, *LU* land use, *D* soil depth, *MS* mean square, *Bd* bulk density, *SMC* soil moisture content

**Table 2 Soil textural fractions (%) in relation to the land use types and soil depths (mean ± SE)**

| Variables | Depth(cm) | Land use | | |
|---|---|---|---|---|
| | | Exclosure | Grazing land | Overall |
| Sand | 0–10 | 72.3 (±0.71) | 74.4 (±1.02) | 73.3 (±0.65)$^{a}$ |
| | 10–20 | 71.3 (±0.48) | 71.9 (±0.54) | 71.6 (±0.36)$^{a}$ |
| | Overall | 71.8 (±0.43)$^{a}$ | 73.1 (±0.62)$^{a}$ | |
| Silt | 0–10 | 19.6 (±0.60) | 18.7 (±0.92) | 19.2 (±0.65)$^{a}$ |
| | 10–20 | 20.3 (±0.57) | 20.1 (±0.47) | 20.2 (±0.36)$^{a}$ |
| | Overall | 20.0 (±0.52)$^{a}$ | 19.4 (±0.50)$^{a}$ | |
| Clay | 0–10 | 7.9 (±0.51) | 7.1 (±0.41) | 7.5 (±0.34)$^{a}$ |
| | 10–20 | 8.5 (±0.48) | 7.9 (±0.51) | 8.2 (±0.35)$^{a}$ |
| | Overall | 8.2 (±0.35)$^{a}$ | 7.5 (±0.33)$^{a}$ | |
| Textural class | 0–10 | SL | SL | SL |
| | 10–20 | SL | SL | SL |
| | Overall | SL | SL | |

Overall means followed by the same letter (s) across columns and rows are not significantly different ($p = 0.05$) with respect to land uses and soil depth

*SL* sandy loam, *SE* standard error of the mean

soil resources without appropriate conservation measures, resulting directly to the changes in particle size distribution through removals by sheet and rill erosions (Toy et al. 2002).

#### *Soil bulk density (g cm$^{-3}$) and Soil moisture content (%)*

Both soil bulk density and SMC did not vary with land use types. However, variation in soil moisture content was significant with soil depth ($p < 0.0001$, Table 1): higher (4.77 ± 0.19) in the subsurface soil layer (10–20) than in the top surface soil (Table 3).

The higher soil bulk density under grazing land use is attributed to the lower SOC and the effect of soil compaction due to livestock trampling. The correlation also showed a strong association with SOC contents (Fig. 3). Bewket and Stroosnijder (2003) also indicated higher soil bulk density under open grazing land than exclosure.

Although variation was not significant, soil moisture content was found to be higher under exclosure than in open grazing land use due to higher soil organic carbon and decreased soil bulk density (Fig. 4). This is consistent with the study by Kevin et al. (2011) that higher organic carbon increases the soil moisture content through improvements in soil structure. The soil moisture content also showed significant difference with soil depths; higher in subsurface soil under due to the relatively higher fine particle fractions (silt + clay) in the subsurface soil giving a better moisture holding capacity. In addition, the presence of less evaporation from the sub-soil coupled with increased downward water movement through gravity could have contributed to the increased amounts of soil moisture with depth. Fua (2004) also indicated that the sub-surface soil had higher soil moisture content as compared with the layer above.

### Soil chemical property variations

#### *Soil pH ($H_2O$)*

No significant variation was observed in soil pH with land use types ($p = 0.400$) and soil depth ($p = 0.305$, Table 4). Though not significant, soil pH was slightly higher in the exclosure (7.16) than in the grazing land (7.08, Table 5). The absence of significant variation in soil pH with land use types might be due to less leaching of base cations. According to Mekuria et al. (2007),

**Table 3 Soil bulk density and soil moisture content in relation to the land use types and soil depths (mean ± SE)**

| Variables | Depth (cm) | Land use | | Overall |
|---|---|---|---|---|
| | | Exclosure | Grazing land | |
| Bd (g/cm$^3$) | 0–10 | 1.23 (±0.03) | 1.25 (±0.02) | 1.24 (±0.01)$^{a}$ |
| | 10–20 | 1.25 (±0.03) | 1.28 (±0.02) | 1.26 (±0.01)$^{a}$ |
| | Overall | 1.24 (±0.02)$^{a}$ | 1.27 (±0.01)$^{a}$ | |
| SMC (%) | 0–10 | 3.01 (±0.09) | 2.91 (±0.24) | 2.96 (±0.13)$^{a}$ |
| | 10–20 | 5.04 (±0.19) | 4.49 (±0.31) | 4.77 (±0.19)$^{b}$ |
| | Overall | 4.03 (±0.23)$^{a}$ | 3.70 (±0.25)$^{a}$ | |

Overall means followed by the same letter(s) across columns and rows were not significantly different ($p = 0.05$) with respect to land uses at each soil depths

*Bd* bulk density, *SMC* soil moisture content

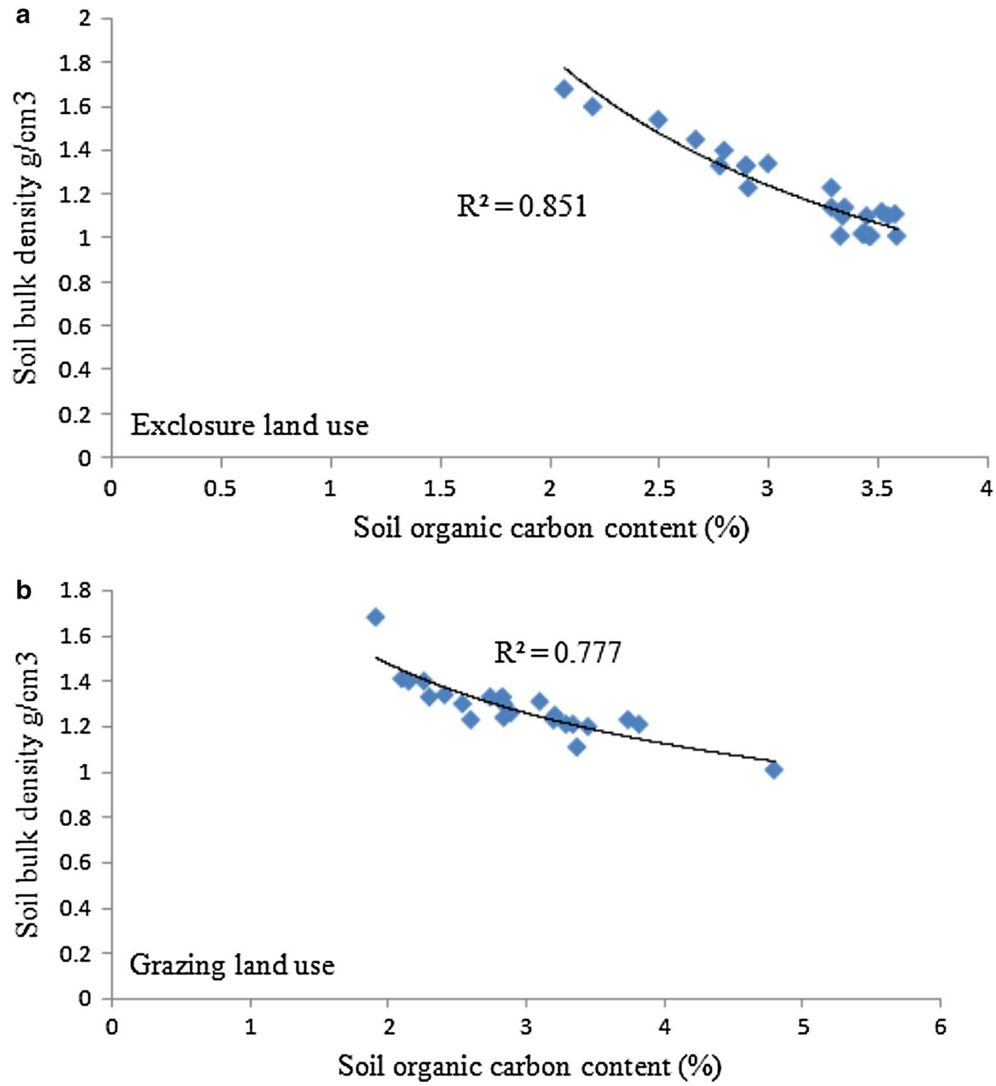

**Fig. 3** Relationships between mean SOC and Bd at exclosure (**a**) and grazing land (**b**) land use

exclosures and grazing lands showed no significant variation in soil pH. However, the overall mean soil pH was slightly higher in the exclosure due to the effects of organic matter that trap base cations as compared to the grazing land. Therefore, organic matter accumulation might reduce soil erosion resulting in higher soluble base cations ($Ca^{2+}$ and $Mg^{2+}$) that reduce $H^+$ responsible for acidity, which in turn increases soil pH in the soil. In the study, the overall mean pH value (7.07–7.17) is within the preferred range (6.6–7.3) (Landon 1991), indicating that there are more base cations rather than aluminum, manganese and hydrogen. In addition, the neutral nature of soil of the study area could be attributed to the low rainfall which is inadequate to remove basic cations out of the surface horizons of the soils.

#### *Soil organic carbon (SOC, %)*

Soil organic carbon (SOC, %) showed significant variations with land use types ($p = 0.040$), soil depths ($p = 0.010$) and the interaction effect ($p = 0.039$, Table 4). SOC was higher in soil under the exclosure (3.29 ± 0.20), in the upper surface soil (3.25 ± 0.19) than, respectively, in grazing land use type and lower sub surface soil layer (Table 5).

The soil under exclosure has a significantly higher soil organic carbon than open grazing land, which is a result of organic matter accumulation through liter fall from the trees/shrubs. The result is in agreement with Mekuria and Veldkamp (2005) in that grazing land and exclosure differ considerably in their soil organic carbon content reflecting the higher amount in exclosures than in open grazing land. The current exclosure site is dominated by

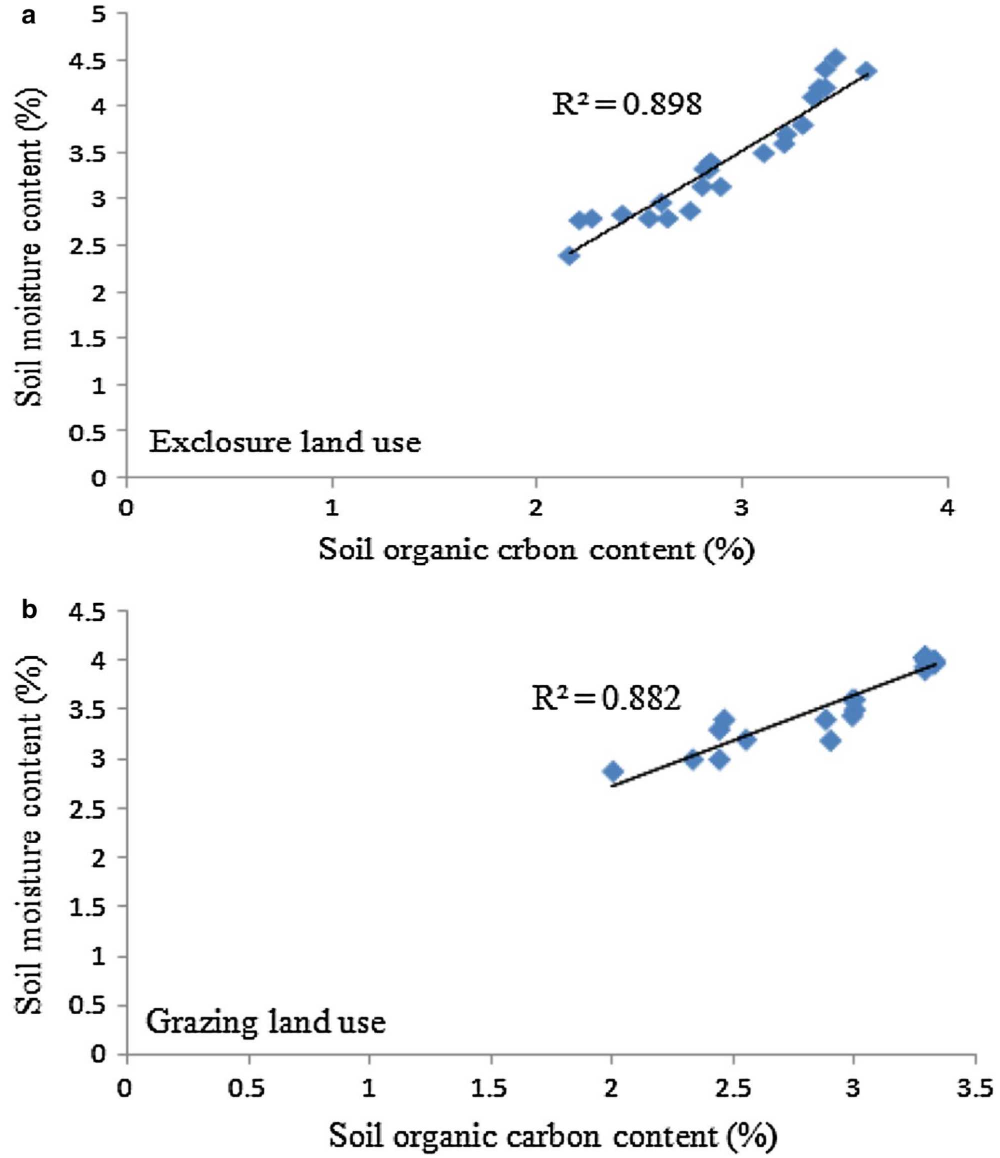

**Fig. 4** Relationships between mean SOC and SMC at exclosure (**a**) and grazing land (**b**) land

**Table 4 Summary of two-way ANOVA results for soil pH, soil organic carbon, total nitrogen and carbon to nitrogen ratio in relation to land use types and soil depths**

| Source of variation | df | pH | | SOC (%) | | TN (%) | | C/N | |
|---|---|---|---|---|---|---|---|---|---|
| | | MS | ρ | MS | ρ | MS | ρ | MS | ρ |
| Land use (LU) | 1 | 0.067 | 0.400 | 34.60 | 0.040 | 0.462 | 0.264 | 0.247 | 0.059 |
| Depth (D) | 1 | 0.100 | 0.305 | 66.96 | 0.010 | 0.397 | 0.300 | 6.15 | 0.170 |
| LU × D | 1 | 0.120 | 0.263 | 43.02 | 0.039 | 0.458 | 0.26 | 0.556 | 0.406 |
| Error | 44 | 0.093 | | 4.875 | | 0.362 | | 17.82 | |

*MS* mean square, *df* degree of freedom

**Table 5 Soil pH, soil organic carbon, total nitrogen and carbon to nitrogen ratios in relation to the land use types (mean ± SE)**

| Variables | Depth (cm) | Land use | | Overall |
|---|---|---|---|---|
| | | Exclosure | Grazing land | |
| pH | 0–10 | 7.15 (±0.05) | 7.18 (±0.09) | 7.17 (±0.05)$^{a}$ |
| | 10–20 | 7.16 (±0.07) | 6.99 (±0.11) | 7.07 (±0.07)$^{a}$ |
| | Overall | 7.16 (±0.04)$^{a}$ | 7.08 (±0.07)$^{a}$ | |
| SOC (%) | 0–10 | 3.45 (±0.33) | 3.06 (±0.21) | 3.25 (±0.19)$^{a}$ |
| | 10–20 | 3.12 (±0.24) | 2.74 (±0.21) | 2.93 (±0.16)$^{b}$ |
| | Overall | 3.29 (±0.20)$^{a}$ | 2.90 (±0.15)$^{b}$ | |
| TN (%) | 0–10 | 0.26 (±0.01) | 0.25 (±0.01) | 0.25 (±0.07)$^{a}$ |
| | 10–20 | 0.24 (±0.007) | 0.23 (±0.34) | 0.23 (±0.17)$^{a}$ |
| | Overall | 0.25 (±0.006)$^{a}$ | 0.24 (±0.17)$^{a}$ | |
| C/N | 0–10 | 13.26 (±1.41) | 12.24 (±1.11) | 12.74 (±0.88)$^{a}$ |
| | 10–20 | 13.03 (±1.04) | 11.91 (±1.27) | 12.46 (±0.87)$^{a}$ |
| | Overall | 13.12 (±0.86)$^{a}$ | 12.1 (±0.87)$^{a}$ | |

Overall means followed by the same letter (s) across columns and rows are not significantly different ($p = 0.05$) with respect to land uses and soil depth

*SOC* soil organic carbon, *TN* total nitrogen, *C/N* carbon to nitrogen ratio

*Acacia* species like *Acacia etbaica, Acacia tortilis, Acacia oerfota, Acacia Senegal* and *Acacia nilotica* which have increased the soil organic matter accumulation. The higher soil organic matter content in exclosure can potentially improve the soil physical properties such as soil structure and total porosity. This, in turn, increases accumulation of organic matter on the soil surface that may reduce the volume, velocity, and erosive capacity of surface run-off. *Acacia etbaica* tree in exclosure produces higher amount of woody litter, which has lower rate of decay (Descheemaeker et al. 2006). Conversely, the soil organic carbon content is significantly lower in the grazing land compared to the exclosure, probably the consequence of reduced amount of organic materials (litter fall) and exposure of micro-aggregate organic matter to microbial decomposition through weaker physical protection of organic matter in the soil. This is in line with Mikola et al. (2001) who justified a reduction of soil organic carbon as a result of lower biomass return in the grazing land due to very little (absence) of grass cover resulting from intensive grazing.

Soil organic carbon content decreases with soil depth. In agreement with this study, Hiederer (2009) explained the relationship between soil organic carbons with soil depth—as depth increases, soil organic carbon decreases in the soil profile. This can be justified with the presence of lower accumulation of organic matter resulting from lower below-ground root biomass in the sub-surface layer.

### *Total nitrogen (%) and carbon to nitrogen (C/N) ratio*

The overall mean total nitrogen (%) content and the C/N ratios did not show any variation with land use types ($p = 0.264$ and $p = 0.059$, respectively) and soil depths ($p = 0.300$, and $p = 0.170$, respectively) (Tables 4). The higher total nitrogen content in the exclosure is the result of higher soil organic matter content and the presence of leguminous plants which have the capacity to fix nitrogen from the atmosphere through the roots' nodules. The Pearson correlation result also showed a significant positive relationship with soil organic carbon ($r = 0.819$; $p = 0.01$). Carpenter et al. (2001) indicated that increasing amount of legumes in the exclosures improves nitrogen availability with exclosure age that contributes to the biomass accumulation. Mekuria and Veldkamp (2005) explained that total nitrogen is higher in exclosure than in free grazing land. Whereas, soils under grazing land have lower total nitrogen due to continuous overgrazing that results in the removal of grasses and organic matter from the soil. Islam and Weil (2000) explained the lower content of total nitrogen in open grazing land to be resulted from a combination of low organic matter inputs and greater carbon losses due to aggregate disruptions, microbial disturbance and continuous grazing.

The higher carbon to nitrogen ratio in soil of the study area can be related to high temperature and low precipitation that limits the decomposition or mineralization rate of organic matter. According to Landon (1991), the higher carbon to nitrogen ratio indicates that organic matter is not fully decomposed through microbial activities. However, the lower carbon to nitrogen ratio in grazing land relative to the exclosure could be due to the low amount of organic materials accumulation through the litter fall from the immature grasses/shrubs, and addition of cow dung, which is enriched with total nitrogen. The Pearson correlation result also showed a significant inverse relationship with total nitrogen ($r = -0.860$; $p = 0.05$). The lower carbon to nitrogen ratio in grazing land relative to exclosure was due to the breakdown of litter fall and the organic matter that enhance microorganisms to decompose into fine particles, which eventually decreases soil organic carbon in grazing land (Caravaca et al. 2002).

## Conclusions

In the rift valley of Ethiopia, owing the rapid woodland conversion for expansion of agricultural and grazing lands there is a sharp decline of soil fertility due to low level of organic residues returned to the soil system and thereby high erosion processes. Besides the poor land management, there are no strict policy guidelines enforcing replanting of trees in the degraded landscapes. Hence, land degradation continues unabated resulting in loss of soil and soil organic carbon and ultimately deterioration the soil quality and poor agricultural performances.

Exclosure land use type has shown an improvement in soil organic carbon against the findings by Mekuria et al. (2014). The positive impacts of exclosure on selected soil properties (mainly on SOC and SMC) obtained in the present study witnessed that exclosure could be considered as an important practice in soil nutrient improvement. Thus, highly degraded grazing in the sloppy landscape should be designated as exclosure land management zone to improve soil organic matter (carbon) and other more sensitive soil physical and chemical properties. Besides improving the soil quality and productivity, such information is needed during the establishment of carbon projects and helps improve the livelihood of the local community through improved ecosystem services. Since the focus of this research was limited on few soil properties, further studies are needed to evaluate exclosure impacts on the other physical and chemical properties which are not considered in this study to have a complete understanding of the change as impacted by exclosure establishment.

#### Authors' contributions

FY has substantially contributed in the design, drafting the manuscript, and critically revising the manuscript for important intellectual content. He has given also the final approval of the version to be published. GA has made substantial contributions in acquisition of data, data collection, entry, coding, and analysis, interpretation of results, writing and leading the overall activities of the research. AA has also been involved in sampling design, critically reviewing the manuscript and suggestions. All authors read and approved the final manuscript.

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#### Compliance with ethical guidelines

#### Competing interests

The authors declare that they have no competing interests.

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#### References

Amusan AA, Shitu AK, Makinde WO, Orewole O (2001) Assessment of changes in selected soil properties under different land use systems in Nigeria. Journal of Environmental, Agricultural and Food chemistry 8:3–23

Bewket W, Stroosnijder L (2003) Effects of agro ecological land use succession on soil properties in the Chemoga watershed, Blue Nile basin, Ethiopia. Geoderma 111:85–98

Bouyoucos GJ (1962) Hydrometer method improvement for making particle size analysis of soils. J Agron 54:179–186

Bremner JM, Mulvancy CS (1982) Nitrogen total methods of soil analysis, part two chemical and microbiological properties. Am Soc Agron Madison Wis 2:595–624

Caravaca F, Masciandaro G, Ceccanti B (2002) Land use in relation to soil chemical and biochemical properties in a semiarid Mediterranean environment. Soil Tillage Res 68:23–30

Carpenter FL, Mayorga SP, Quintero EG, Schroeder M (2001) Land use and erosion of a Costa Rican Ultisols affect soil chemistry, mycorrhizal fungi and early regeneration. For Ecol Manage 144:1–17

Carter MR (1993) Soil sampling and methods of analysis. Lewis Publishers, Boca Raton

Celik I (2005) Land use effects on organic matter and physical properties of soil in a southern Mediterranean highland of Turkey. Soil Tillage Res 83:270–277

Chen C, Xu Z (2010) Forest ecosystem responses to environmental changes: the key regulatory role of biogeochemical cycling. J Soil Sediment 10:210–214

Chen DD, Zhang SH, Dong SK, Wang XT, Du GZ (2010) Effect of land-use on soil nutrients and microbial biomass of an alpine region on the northeastern Tibetan plateau, China. Land Degrad Dev 21:446–452

Cuenca HR (1989) Irrigation system designs an engineering approach. Prentice-Hall Inc, Englewood Cliffs, p 552

Dereje M (2006) Woody species composition of Dilfaqar Regional Park and its socioeconomic importance in Dodota sire, Ethiopia. MSc thesis, pp 75

Descheemaeker K, Muys G, Nyssen J, Poesen J, Raes D, Mitiku H, Deckers J (2006) Litter production and organic matter accumulation in exclosures of the Tigray highlands, Ethiopia. For Ecol Manage 233:21–35

FAO (2006) Global Forest Resource Assessment 2005. Progress towards sustainable forest management. Food and Agriculture Organization of the United Nations, Rome

Fua L (2004) The effects of land use on soil moisture variation in the Danangou catchment of the Loess Plateau in northern Shaanxi, China. Catena 36:69–78

Fusun S, Huai C, Yan U, Ning W (2010) Effects of livestock exclusion on vegetation and soil properties under two topographic habitats in an alpine meadow on the eastern qinghai-tibetan plateau. Pol J Ecol 58(1):125–133

Hiederer R (2009) Distribution of organic carbon in soil profile data. Office for Official Publications of the European Communities, Luxembourg, p 126

Houghton RA, Hacker JI, Lawrence KT (2000) The U.S. carbon budget: contributions from land use change. Soil Sci 285:574–578

Islam KR, Weil RR (2000) Land use effects on soil quality in a tropical forest ecosystem of Bangladesh. Elsevier Science B.V. emissions of NO and N2O in a seasonally dry tropical forest. Agric Ecosyst Environ 79:9–16

Jaramillo VJ, Kauffman JB, RenteíaRodríguez L, Cummings DL, Ellingson LJ (2003) Biomass, carbon nitrogen pools in Mexican tropical dry forest landscapes. Ecosystem 6:609–629

Kevin ZM, Nashon KRM, Dickson MN, Moses MN, Wellington NE, William MM, Agnes WMO (2011) Different land use types in the semi-arid rangelands of Kenya influence soil properties. University of Nairobi, Uganda. J Soil Sci Environ Manag 2(11):370–374

Lal R (2005) Forest soils and carbon sequestration. For Ecol Manage 220:242–258

Landon JR (1991) Tropical Soil Manual: a handbook of soil survey and agricultural land evaluation in the tropical and subtropical. Longman Broak, pp 447

Lemma B, Kleja DB, Nilsson I, Olsson M (2006) Soil carbon sequestration under different exotic tree species in South-western highlands of Ethiopia. Geoderma 136:886–898

Liu X, Herbert SJ, Hashemi AM, Zhang X, Ding G (2006) Effects of agricultural management on soil organic matter and carbon transformation. Soil Environ 53:531–543

Mekuria W (2013) Conversion of communal grazing lands into exclosures restored soil properties in the semi-arid lowlands of Northern Ethiopia. Arid Land Res Manag 27:153–166

Mekuria W, Aynekulu E (2011) Exclosure land management for restoration of the soils in degraded communal grazing lands in northern Ethiopia. Land Degrad Dev 24(6):528–538

Mekuria W, Veldkamp E (2005) Impacts of land use changes on soil nutrients and erosion in Tigray. Proceedings on International Agricultural Research for Development, Ethiopia, pp 11–13

Mekuria W, Veldkamp E, Mitiku H, Nyssen J, Muys B, Kindeya G (2007) Effectiveness of exclosures to restore degraded soils because of overgrazing in Tigray, Ethiopia. J Arid Environ 69:270–284

Mekuria W, Veldkamp E, Corre MD, Mitiku H (2011) Restoration of ecosystem carbon stocks following exclosure establishment in communal grazing lands in Tigray, Ethiopia. Soil Sci Soc Am J 75:246–256

Mekuria W, Langan S, Noble A, Johnston R (2014) Soil Organic Carbon and Nutrient Contents are not influenced by Exclosures established in communal grazing land in Nile basin, Northern Ethiopia. International Conference on Advances in Agricultural, Biological & Environmental Sciences (AABES-2014) Oct 15-16, 2014 Dubai (UAE)

Mengistu T, Teketay D, Håkan H, Yemshaw Y (2005) The role of exclosures in the recovery of woody vegetation in degraded dryland hillsides of central and northern Ethiopia. J Arid Environ 60:259–281

Mikola J, Yeates GW, Barker GM, Wardle DA, Bonner KI (2001) Effects of defoliation intensity on soil food-web properties in an experimental grassland community. Oikos 92(2):333–343

Nedessa B, Ali J, Nyborg I (2005) Exploring ecological and socio-economic issues for the improvement of area enclosure management: a case study from Ethiopia. Dry lands Coordination Group Report No. 38, pp 63

OPEDB (2000) Physical and socio-economic profiles of 180 districts of Oromia. Physical Planning Department, Finfinne, p 75

Sandor JA, Gersper PL, Hawley JW (1986) Soils at prehistoric agricultural terracing sites: site placement soil morphology and classification, in New Mexico. Soil Sci Soc Am J 50:166–173

Soares JLN, Espindola CR, Pereira WLM (2005) Physical properties of soils under soil acidity effects on nutrient use efficiency in exotic maize genotypes. J Plant Soil Sci 192:9–13

Solomon D, Fritzsche F, Lehmann J, Tekalign M, Zech W (2002) Soil organic matter dynamics in the sub humid agro ecological systems of the Ethiopian Highlands: evidence from 13C abundance and particle size fractionation. Soil Sci Soc Am J 66:969–978

Tesfaye MA, Bravo F, Ruiz-Peinado R, Pando V, Bravo-Oviedo A (2016) Impact of changes in land use, species and elevation on soil organic carbon and total nitrogen in Ethiopian Central Highlands. Geoderma 261:70–79

Toy TI, Foster GR, Renard KG (2002) Soil erosion: processes, prediction, measurement, and control. Wiley, New York **p338**

Walkley A, Black CA (1934) An examination of different methods for determining soil organic matter and the proposed modification of the chromic acid titration method. J Soil Sci 37:29–38

Wei L, Hai-Zhou H, Zhi-Nan Z, Gao-Lin W (2011) Effects of grazing on the soil properties and C and N storage in relation to biomass allocation in an alpine meadow. J Soil Sci Plant Nutr 11(4):27–39

Yimer F, Ledin S, Abdelkadir A (2007) Changes in soil organic carbon and total nitrogen contents in three adjacent land use types in the Bale Mountains, south-eastern highlands of Ethiopia. For Ecol Manage 242(2–3):337–342

Young-Zhong S, Yu-Lin L, Jian-Yaun C, Wen-Zhi Z (2005) Influences of continuous grazing and livestock exclusion on soil properties in degraded sandy grassland, Inner Mongolia, northern China. Catena 59:267–278

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