Effect of Exclosure on Soil Properties in Comparison with Grazing Land in Guder sub-Watershed, Southern Ethiopia

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Received: 23.08.2021; Revised: 07.11.2021; Accepted: 16.11.2021

Abstract: In Ethiopia, particularly the Guder sub-watershed in the Lemo District, land degradation is a severe challenge for agricultural output. Farmers in the Guder sub-watershed in southern Ethiopia employed exclosure to combat soil degradation issues. The aim of this study was to see how exclosure affected certain soil qualities.Exclosure and neighboring grazing land with similar background histories were randomly sampled for composite soil samples. The results revealed that except for silt, sand, BD, and EC, the exclosure exhibited significantly ($p<0.05$) greater SOC, CEC, TN, pH, and clay compared to nearby grazing area. Finally, an exclosure is a realistic technique for restoring degraded landscapes and should be implemented as soon as possible.

Key Words: Exclosure, Grazing land, Guder sub-Watershed,Soil Properties

Introduction

Land productivity, biodiversity, soil fertility and other ecosystem services all suffer from degradation of the land. For example, the deforestation, agricultural land expansion and overgrazing of Ethiopia caused a serious deterioration of the dry land vegetation (Lemenih et al., 2005; Mengistu et al., 2005). This is related to increasing population and depletion of natural resources (Mekuria et al., 2009, Hurni et al., 2005). As a result, there is an urgent need to adequately restore, manage, use, and maintain them, which requires a deep understanding of stand structures as well as the diversity and quality of woody species. To prevent further soil degradation, Ethiopia has undertaken a number of programs, including soil and water conservation and the establishment of exclosure (Nedessa, 2003). About three decades ago, communities in Ethiopia's highlands began restoring biodiversity and managing their environmental services entirely, and forestry was identified as one of the primary pillars of climate-resilience strategy in green economy (Mekuria and Yami, 2013; Mekuria and Aynekulu, 2011). At the same time, Ethiopia's government has committed to restoring 15 million hectares of deteriorated soils, or nearly a sixth of the country's land, by 2025, probably using 1,42 Gt of CO_2.When compared to communal grazingland , exclosure has a significant impact on species richness (Emiru et al., 2006; Tefera, 2001), soil nutrient supply (Mekuria et al., 2007; Tekalign et al., 2005; Mekuria, 2013), soil organic carbon (Tizita, 2016; Gebregergs, 2019), and moisture availability (Qasim et al., 2019).Soil organic matter is a significant soil component to change soil conditions, improve soil water holding capability, limit soil erosion, give plant accessible nutrients and enhance soil cation exchange capabilities (Pietrzykowsk et al., 2017). Exclosure also promotes soil structure and moisture and soil variation and movement (Bot, 2005).

Exclosure effects on soil property were found to be site specific in various investigations. Differences in temperature, vegetation type, and soil qualities could all play a role in regenerating degraded lands (Allen et al., 2013; Anderson et al., 2007). The community in the Guder sub-watershed of the Lemo district implemented a 10-year old exclosure to address land degradation issues and provide a sustainable environment. In the Guder sub-watershed, however, the impacts of exclosure on the advancement of soil qualities are not taken into account. In this context, generating scientific data for long-term soil resource management is critical. In order to examine the impacts of exclosure on selected soil chemical (pH, EC, SOC, TN, and Av.P) and physical (texture and bulk density) parameters to neighboring grazing land, this study was done.

Materials and Methods

Study area description

The research was carried out in the Guder sub-watershed in the Lemo district of Hadiya Zone in southern Ethiopia. The study site is around 15 kilometers from Hossana town in northwest Ethiopia, and 232 kilometers from Addis Ababa, Ethiopia's capital. Lemo District is located between 7°22'00" and 7°45'00"N latitude and 37°40'00" and 38°00'E longitude, with altitudes ranging from 1900 to 2700 meters above sea level. The administrative boundary of Lemo District is Silte Zone in the North, Kembata Tembaro zone in the South, Gombora District in North West, Anlemo District in the North East, and Shashogo District in the East (LWARDO, 2017). The mean annual rainfall is 900 - 1400mm and temperature between 13^{O}C to 23^{O}C. Mixed agriculture (crop and livestock) is the main livelihood (LWARDO, 2017).

Soil sampling and laboratory analysis

Before beginning operations, a reconnaissance study was done to determine the presence of neighboring grazing land with a similar history of exclosure in the Guder sub-watershed. Social standards among stakeholders have been created to limit the disturbance caused by humans and livestock on grazing area. The exclosure is roughly 10 acres in size, with an elevation of 2200–22300 meters above sea level. It is free of domestic animals and humans, and it is maintained by natural regeneration, which began in 2011.

The exclosure region being part of the grazing land used before it was established, the exclosure was similar to the grassing land before the land was established, implying natural rehabilitation of a piece of degraded grazing ground by exclusion in the past. After that, the exclosure and the pasture fields were believed to be almost homogeneous before the exclosure. Then three transect lines were established across the pit at 100 meters to reduce variability in soil qualities due to changes in elevation on each exclosure and grazing soil.On both land management measures, three sampling quadrants (20 m 20 m) were randomly established along each transect line. Five points (four from the corners and one in the center of each quadrant) were taken from surface soils at a depth of 0–30 cm to produce one composite soil. These samples were carefully mixed, and a composite soil sample of approximately 1 pound was created. For bulk density analysis, undisturbed samples were obtained from the exclosure and grazing ground using a core sampler.

A plastic bag packaged, labeled and transmitted the composite soil samples to the laboratory. Soil samples were air-dried at room temperature and sieved through 2 mm for laboratory investigation of selected physicochemical parameters of soil, except for soil bulk density. After organic matter has been removed by hydrogen peroxide (H_2O_2), soil texture was evaluated using the hydrometric method and the soil was dispersed with sodium hexametaphosphate (Boyoucos, 1962) ($NaPO_3$).The quantity of oven-dried soil (105°C) divided by its volume was used to compute soil bulk density using the core technique (Chen et al., 2010). In a supernatant suspension of 1:2.5, soil: water suspension, the soil pH was measured potentiometrically with a digital pH meter (Carter, 1993). A conductivity meter was used to measure electrical conductivity (EC) in saturated soil paste extracts after suction was applied (Okalebo et al., 2002).The soil organic carbon (SOC) content was determined using the Walkley and Black (1934) method. The available phosphorous (Av.P) was evaluated using Olsen's extraction (1965) method, and the cation exchange capacity (CEC) was determined using 1M NH_4OAc at pH 7 extraction (Jackson, 1958).

Statistical Analysis

A student's t-test for independent variables ($p< 0.05$) confirmed differences in mean values of physico-chemical parameters from the exclosure and its surrounding grazing field. Pearson correlations between soil physico-chemical parameters in the exclosure and neighboring grazing field were also investigated ($p <0.01$ and 0.05).

Result and Discussion

Effects of exclosure on soil physico-chemical properties

Soil pH:The results showed that with the exclosure, soil reaction (pH) was significantly ($p<0.05$) improved, followed by grazing land (Table 1). The exclosure had the greatest mean pH value (5.63±0.26), while the gazing land had the lowest (5.34±0.08) (Table 1). The lower mean pH value on grazing land could be due to the lower soil organic matter content and lower base saturation percentage. This conclusion contrasts with Tamrat and Dinsa (2021); Fantaw et al. (2015); and Mekuria et al. (2007), who found no significant variation in soil pH between exclosure and degraded pastures.

Electrical conductivity (EC):The exclosure had the highest mean (0.128±0.03) value of EC, whereas the grazing land had the lowest mean (0.067±0.02) (Table 1). The statistical results showed that there was no statistically significant (p>0.05) difference in EC between exclosure and grazing land in the studied area. The lack of salinity or/and sodicity, as well as the study site's location in a high-rainfall area, are likely reasons. The association between pH and EC (r=0.50**) was found to be positive and highly significant.

Soil organic carbon (SOC %):Exclosure had a significant (p <0.05) impact on soil organic carbon than grazing land, as shown in Table 1. Exclosure and grazing land had mean SOC values of 2.33±0.44and 1.85±0.37, respectively. Exclosure soil has significantly (p<0.05) higher soil organic carbon than grazing land, owing to improved management, establishment, and subsequent increased organic matter input derived from woody species biomass, as well as reduced soil erosion through effective ground cover.This finding is supported by Mekuria and Veldkamp (2005); Tamrat and Dinsa, (2021) 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.Enclosures, according to Descheemaeker et al. (2005), improve the hydrology and soil inside forested land in several ways, including preventing physical soil loss, maintaining or increasing soil water holding capacity, protecting or increasing top soil depth, preventing soil nutrient loss, and increasing soil organic matter.

Soil total nitrogen (TN %):The statistical results revealed that the difference in TN between exclosure and grazing land was substantially significant (p <0.05) (Table 1). Exclosure had the highest mean (0.20±0.03) value, while grazing land had the lowest average (0.190±03) value. This could be due to differences in soil organic content and soil erosion intensities, implying that the biophysical conservation measure of exclosure has indirectly contributed to land management sustainability by replenishing soil nutrients.The exclosure's higher total nitrogen content is due to higher soil organic matter content and the presence of leguminous plants with the ability to fix nitrogen from the atmosphere through their roots' nodules. Abiy (2008) and Katrien (2007) found that when exclosure was compared to grazing pasture and degraded land in different parts of Ethiopia, there was a substantial difference in total nitrogen.

Available Phosphorous (Av.P**)**:The findings revealed a substantial (p <0.05) difference in soils between the exclosure and neighboring grazing field (Table 1). The highest mean (6.12±0.78) and lowest mean (4.84±0.81) values of the Av.P were found in exclosure and grazing land, respectively (Table 1). The greater clay content and organic carbon accumulation in exclosure could be the cause. Organic carbon was favorably and significantly associated with total nitrogen (r = 0.91**) and positively associated with Av.P and clay content (r = 0.17 & r = 0.30), according to the correlation (Table 2).

Cation Exchange Capacity (CEC**)**:Exclosure and grazing land had a substantial ($p < 0.05$) impact on CEC, as shown in Table 1. The highest mean value (28.82±2.99) was found in exclosure, whereas the lowest mean value (26.92±2.17) was found on grazing land. The exclosure may have collected significant levels of organic carbon, clay, and has a larger capacity to store cations, resulting in increased potential fertility in the soil. Furthermore, soil CEC is projected to rise when the organic carbon content of the soil improves. Furthermore, soil CEC was shown to be favorably linked with clay (r= 0.34) and organic carbon (r= 0.72**) (Table 2). This discovery is backed up by Tamrat and Dinsa (2021) and Kibret (2008), who found that soil CEC is linked to clay and organic colloids, and that organic matter, in particular, improves soil CEC. Similarly, Abiy (2008) found that the mean CEC in exclosure was higher than in the adjacent deteriorated site.

Table 1: The effects (mean ± MSD) of exclosure on soil physicochemical properties in the Guder sub-watershed

Soil Parameters	Land management measures		P-value
	Exclosure	Grazing land	
pH	5.63±0.26	5.34±0.08	0.0001*
EC (ds/m)	0.128±0.03	0.067±0.02	0.0623 ns
SOC (%)	2.33±0.44	1.85±0.37	0.0010*
TN (%)	0.20±0.03	0.19±0.03	0.0001*
Av.P (ppm)	6.12±0.78	4.84±0.81	0.0001*
CEC(cmol(+)/kg	28.82±2.99	26.92±2.17	0.0218*
Sand (%)	19.75±3.19	21.00±2.82	0.0001*
Silt (%)	33.25±2.76	34.25±2.81	0.4421ns
Clay (%)	43±3.85	41 ±4.11	0.0005*
BD(g/cm^3)	1.08±0.05	1.16±0.03	0.0006*

**= indicates that there was a significant difference in means and that means within a row were not substantially different at the p>0.05 threshold of significance. BD stands for bulk density. pH stands for soil pH, EC stands for electrical conductivity, SOC stands for soil organic carbon, TN is for total nitrogen, and Av.P stands for available phosphorus.*

Table 2: Correlations among the soil physico-chemical properties of the exclosure and grazing land

	OC	TN	CEC	EC	pH	Av.P	Sand	Clay	Silt	BD
OC	1									
TN	0.91**	1								
CEC	0.72**	0.56*	1							
EC	0.56*	0.43	0.82**	1						
pH	0.55*	0.38	0.50*	50**	1					
Av.P	0.17	-0.05	0.13	0.34	0.36	1				
Sand	-0.23	-0.21	-0.31*	-0.05	-0. 46	-0.15	1			
Clay	0.30	0.27	0.34	0.04	-0.03	-0.51*	-0.73**	1		
Silt	-0.18	-0.16	0.31	-0.01	0.22	0.29	-0.00	-0.67**	1	
BD	-0.99**	0.77**	-0.76	-0.64**	-0.57*	-0.19	0.33	-0.30	0.87	1

Soil particle size fractions (sand, silt and clay): Exclosure had a substantial ($p < 0.05$) effect on the clay and sand fractions of the soils, but there was no significant ($p > 0.05$) variation in silt concentration (Table 1). The clay had the highest mean value (43±3.85) in the exclosure and the lowest mean (41±4.11) in the neighboring grazing land. In contrast, the greatest mean (21.00±2.82&34.25±2.81) sand and silt values were found in grazing land, whereas the lowest mean (19.75±3.19&33.25±2.76) values were found in the exclosure.The higher clay content in the exclosure could be due to relatively low soil erosion in the site, whereas the lower clay in the grazing land could be due to relatively higher sheet erosion, which could reflect low organic matter, livestock trampling, and sparse vegetation aggravate soil erosion, removing clay from the adjacent degraded land selectively. This conclusion supports Tamrat and Dinsa (2021) and Gachene and Kimaru (2003) findings that clay particles are lighter than sand particles and can be easily moved once detached by erosion.

Soil bulk density (BD): Exclosure (Table 1) had a significant ($p<0.05$) effect on soil bulk density, with grazing land having the highest mean (1.16±0.03) value and exclosure having the lowest mean (1.08±0.05) (Table 1). Grazing land has the highest mean value of bulk density due to the higher compaction effect of grazing and erosion of the top soil due to a lack of vegetation cover. A negative link was

DOI:https://doi.org/10.51220/jmr.v16i3.1

discovered between soil bulk density and clay content (r=-0.30), as well as a negative relationship between bulk density and organic carbon (r=-0.99**). Open grazing land has a larger soil bulk density than enclosed grazing land, according to Bewket &Stroosnijder (2003). In the Guder sub-watershed, the establishment of exclosure on the degraded land can improve the soil physico-chemical properties by enhancing natural regeneration of vegetation. For instance, soil organic carbon, total nitrogen, available phosphorus, soil pH, cation exchange capacity, and clay content were significantly higher in the exclosure of the 10 years except for silt, sand, and electrical conductivity. This study also shows that it is possible to generate baseline information by taking selected soil physico-chemical properties of the exclosure. This information is critical for evaluating the effectiveness of exclosure rehabilitation of degraded lands and for assisting policymakers. In conclusion, exclosure is a feasible strategy for the restoration of degraded landscapes and should be followed.

Acknowledgements

The authors would like to express their gratitude to the farmers of the Guder sub-watershed for their assistance with data collection.

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