

# Effects of Grazing Intensity on Soil Properties of Rangeland in Semi-Arid Rangeland of Borana Zone, Southern Ethiopia

Asfaw Ejo Feyisa

1Oromia Agricultural Research Institute - Yaballo Pastoral and Dryland Agriculture Research Center, P. O. Box 85, Yaballo, Ethiopia

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**Abstract:** *The study was conducted in three districts of Borana Zone to determine the impacts of grazing on soil nutrients of Borana rangelands under the traditional enclosure and continuous grazing rangeland types. Within both rangeland types of each district, 20 m x 20 m plots were placed at 200 m distances intervals with three replications used to collect soil samples from four corners and a center of main plot within three depths (0-10 cm, 10-20 cm and 20- 30 cm) to analysis its soil physio-chemical properties. Totally 54 soil samples were collected from three districts, two rangeland types, and three depths to determine the effect of grazing on soil properties. The collected data were analyzed using a three-way factorial ANOVA to compare the effect of grazing pressure by using traditional enclosures and continuous grazing rangeland types of each study site on rangeland soil properties. The study sites of soil texture class were loam, sandy loam, and silt clay. The soil pH value was significantly different ( $P > 0.05$ ) among study sites, but there was no significant difference between rangeland types and soil depths. The soil total nitrogen was significantly different ( $P > 0.05$ ) between districts, rangeland types, and soil depth, due to the impact of grazing pressure, was differed between rangeland types. Grazing intensity has a great impact on rangeland soil physico-chemical properties. Therefore, rangeland users should consider an appropriate grazing system to improve and sustain the soil health and ecosystem of rangeland.*

**Keywords:** grazing pressure, rangeland type, and soil physico-chemical properties

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## INTRODUCTION

Grazing land ecosystem services, including food provision and climate regulation, are greatly influenced by soil health (Xu, 2018). In Ethiopia, rangeland accounts place the largest total land

area as compared to other types of land use in the nation (Dawit, 2000) on where a major part of renewable natural resources, which play the main role in providing feed resources. Most of these rangeland ecosystem services have been found under threat due to natural (recurrent drought) and anthropogenic-induced factors (Amaha, 2006). The study area of Borana rangeland is the largest rangeland of Oromia state, which is found within the above constraints. This rangeland has different land use types, while not suitable for cropping due to its irregular rainfall and high temperature, while cropping practices are increasing than normal phenomena, which also exposes rangeland soil to erosion. Currently, most rangelands are under pressure from a growing population, which is increasing grazing lands to risk of conversion to other land use types (Cameron et al., 2014).

Indeed, rangeland has multiple disciplines of land use type's especially massive amounts of ecosystem services like restoration of water, nutrient cycling, and carbon sequestration, which play key roles in the regulation of climate change. Rangeland physico-chemical properties of soil are responses to livestock grazing because over defoliation can affect plant food synthesis tissues, root to shoot ratios that play chief roles in grassland biogeochemical cycles (Gong et al., 2015; Gitau, 2020). However, light to moderate grazing may increase the carbon of the ecosystem through increased plant productivity by replacing aging plant tissues with active photosynthetic tissues (Zhang et al., 2015 b).

Many researchers and developments have been involved in solving several problems of Borana rangeland, while the degradation of rangeland resources is continuing. In many arid and semi-arid parts of the country, improper grazing and climatic factors are the main causes of rangeland resource degradation (Abate and Abule, 2009). Also, Pulido et al. (2016) report that overgrazing and trampling of livestock increase the load of soil compaction, which reduces soil pore space, infiltration, and availability of water for plant requirements. Grazing intensity can affect the infiltration rate of the soil, which regulates the ecosystem water cycles and soil erosion (Centeri, 2022.. The soil organic matter, phosphorus, and total carbon were reduced, but total nitrogen, acidity, and bulk density were increased as increasing grazing intensity increased (Dormaar et al., 1989).

Currently rangeland of the study sites has been highly deteriorated due to overgrazing and bush encroachment (Gemedo et al., 2006). Overgrazing is the removal of ground cover that can alter the physical and chemical properties of soil that reducing the soil nutrients and its cycle (Tessema, 2012). Impacts of grazing are the most important destructive factors of arid and semi-arid rangelands. While its management system had less consideration during rangeland administration

and utilization of rangeland resources. To improve rangeland floristic composition/forage species, the effect of grazing on soil properties should be investigated.

In the past studies, the effort made so far was not satisfactory in protections and controlling the degradation of rangeland. Hence, studies on the effect of soil properties on grazing intensity were very few and often conducted in specific districts of rangeland types, which are not representative of the entire rangeland of the study areas. This encourages the pastoralist who intensively depends on rangeland resources to be vulnerable to a serious livestock feed shortage, which resulted in the gradual disappearance of desirable feed resource species. The studies on rangeland soil properties are necessary to investigate the response of soil nutrients to grazing intensity in areas where their ecosystem is sensitive and fragile.

So, further study and understanding of the interrelationships of soil properties and local grazing strategy (traditional enclosure and open grazing) are the most important tools to approve appropriate management measures in rangeland areas. Hence, this study was designed to generate information with the general objective of evaluating the current soil physico-chemical properties of traditional enclosure and open grazing rangelands to generate information for sustainable rangeland resource improvement in Borana rangeland, southern Ethiopia. We hypothesized that the soil physico-chemical properties would differ or be similar between traditional enclosure and open/continuous grazing rangeland types of study sites.

## **MATERIALS AND METHODS**

### **Description of the Study Area**

The study was conducted at Yabello, Arero, and Teltele districts of Borana zone, Southern Ethiopia. Yabello is located 563 km from Addis Ababa in the southern part of Ethiopia. Arero and Teltele are located at an equidistant (100 km), each to the east and west of Yabello town respectively. The climate of study areas has a bimodal nature of rainfall, namely long and short intensity rain seasons which falling between March and May and between September and November, respectively, with 16.80 °C of the minimum and 29.08 °C of the maximum annual mean temperature. Soil types of the region comprise 53% sand, 30% clay, and 17% silt, which is sandy clay loam (Coppock 1994). While cracking black clay and volcanic light-colored silt clay soils predominate in the bottom valley, well-drained red sandy soils are predominant on the flat and hilly lands (Pratt and Gwynne, 1977).

### **Soil Sampling and physio-chemical Analysis**

Soil samples were collected from three soil depths, i.e., 0-10 cm, 10-20 cm, and 20-30 cm using soil core samples from four corners and the center of the main plot in which woody plant parameters were determined. Soil collected from the same depth of a plot was mixed to form a composite sample and was transported to a soil laboratory for further processing. From overall 18 plots, fifty-four soil samples were taken at a fixed distance along with the located on one transect (200 m intervals) and were transported to a soil laboratory for further processing. The collected soil samples were air-dried, crushed, and sieved using 2 mm-sized sieves. Then, labelled and sealed in polythene bags and taken to the soil laboratory of Yabello pastoral and dry land agriculture research center for analysis physical and chemical properties of soil. Soil texture was analyzed by the hydrometer method (Sahlemedhin and Taye, 2000). The percentage of organic matter was determined using the Walkley-Black and total nitrogen (TN) was determined using the Kjeldahl (Bremner and Mulvaney, 1982). Exchangeable calcium and magnesium concentrations were determined during ethylene diamine tetra acetate titration, and potassium was determined by flame photometer. pH and EC were determined during a suspension of a 1:5 soil: water ratio by the Walkley-Black method.

### **Data Analyses**

Data procedures from soil attributes were analyzed using RCBD to compare the effect of grazing pressure on soil properties of rangeland by using traditional enclosure and open grazing rangeland types. All statistical analysis was performed within the SAS software (version 9.1; SAS Institute, 2002). LSD (least significant differences) test with  $P < 0.05$  was used for means comparison.

## **RESULTS AND DISCUSSION**

### Effect of grazing on soil texture

The soil physical properties of the three district rangeland types of the study areas are shown in Table 1. The soil analysis result indicated that there were significant differences ( $P < 0.05$ ) in soil texture between grazing pressures. Due to heavy grazing, continuous grazing has more sandy than traditional enclosure rangeland types. The traditional enclosure rangeland type had less exposure to erosion by livestock trampling as continuous grazing during the rainy season due to its resting periods. There was a significant difference ( $P < 0.05$ ) in soil texture among the three districts of the study sites due to soil type differences. The soil texture of Arero, Yabello, and Teltele sites of rangeland types was classified into sandy clay loam, sandy loam, and silt clay, respectively. The soil types of the three study sites also differed by their color, i.e., the Teltele site had black color types of soil, while the Arero study site had red and the Yabello study site had red-brown. This dissimilarity of soil texture and color was determined by the soil properties while they were

affected by heavy grazing and climatic factors through the reduction of their soil parent materials. Similarly, FAO (2002) reported that environmental factors and anthropogenic activities affect soil living organisms that maintain soil health and function.

Depth wise the study sites of soil texture (sand, clay, and silt) contents of soil were not significantly different ( $P>0.05$ , Table 1) might be due to impacts of heavy grazing, as the most organic part of the top layer of soil was exposed to erosion. Similarly, Getachew (2007) reported that high sand and low contents of clay and silt can be expected in erosion vulnerable parts of land use/cover systems. The soil textures of rangeland types are different under the three districts of traditional enclosure and continuous grazing rangeland types. This might be due to management difference (grazing intensity) and their soil types. Yabello rangeland types contained a relatively high proportion of sand and low content of clay and silt soil, followed by Arero rangeland type, while Teltele rangeland type had high clay and silt and the lowest content of sand as compared to the other.

These indicators, Yabello rangeland type of study site was highly affected by soil erosion, followed by Arero site and little in Teltele site due it has low sand and high clay and silt contents. However, the soil texture of the study areas was affected heavy grazing intensity through removing the ground cover and trampling i.e. the primary factor in induces loose soil structure for other factors like runoff and wind erosion.

Table 1: Mean values of grazing effect on soil physical properties within three districts, two rangeland types, and three soil depths (n=54).

Parameters		Sand	Clay	Silt	Textural Class
Districts	Arero	47.17b	31.89b	19.22b	Sandy clay loam
	Teltele	4.67c	48.44a	44.11a	Silt clay
	Yabello	74.83a	13.73c	12.00c	Sandy loam
Rangeland type	Trad. enclosure	39.30b	34.78a	24.41a	Clay loam
	Open grazing	45.15a	27.93b	25.81a	Sandy clay loam
Soil depth	0-10 cm	43.06a	34.22a	27.83a	Sandy clay loam
	11-20 cm	42.39a	30.61a	24.61a	Sandy clay loam
	21-30 cm	41.22a	29.22a	22.89a	Sandy clay loam
P Value	SEM	10.48	9.77	7.16	
	District	***	***	***	
	Rangeland types	*	*	Ns	

Soil depth	Ns	Ns	Ns	
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\**a, b, c* Means with different superscripts in column are significantly different \*\*\* =  $P < 0.0001$ ; \* =  $P < 0.05$ ; ns = not significant ( $P > 0.05$ ); SEM=Stander error mean; Trad. = Traditional

### Effect of grazing on soil pH

The statistical analysis pointed out that the soil pH of rangeland types was not significantly different ( $P > 0.05$ ) within soil depth and rangeland type (traditional enclosure and continuous grazing) of each study site, while significantly different among districts study sites ( $P < 0.05$ ). This result may be due to the effect of grazing pressure, both rangeland types have the same poor ground cover or biomass of herbaceous species, while it is different in soil types between the study districts. The current result was agreed with Fernandez-Lugo et al. (2013) who reported that heavy grazing increases soil pH values due to the reduction of total plant biomass (below and above ground) and soil organic matter which secrete organic acid by their root and release CO<sub>2</sub> by their soil microorganisms. Mofidi et al. (2013) reported that soil pH had a strong negative correlation with plant root biomass and the accumulation of organic matter. However, Shan et al. (2011) reported that no correlation between soil pH values in moderate and intensive grazing of north China grassland. On the other hand, the pH value was raised with increasing the intensity of grazing Javadi et al. (2006) and Hosseinzadeh et al. (2010) due to an increase in soil salinity. Therefore, in study sites, the increment of livestock population and shrinkage of grazing land were leading both rangeland types (traditional enclosure and open grazing) for overgrazing which had great impacts on the soil pH of the study rangeland site through removing the ground biomass and litter covers of rangeland types.

Table 2: Mean values of grazing effect on soil chemical properties within three districts, two rangeland types, and three soil depths (n=54).

Parameters		EC	OC	OM	PH	TN	Ex.Ca	Ex. Mg	Ex. K
Districts	Arero	0.64b	1.02b	1.75b	6.45b	0.11b	6.17b	2.77c	0.06b
	Teltele	3.52a	1.35a	2.33a	8.28a	0.16a	76.89a	18.22a	0.17a
	Yabello	0.47b	1.06b	1.79b	6.36b	0.07c	8.27b	7.05b	0.15a
Rangeland type	Trad. Ecllosure	1.28b	1.16	2.00	7.00	0.10b	31.36	8.43b	0.10b
	Open grazing	1.81a	1.12	1.90	7.05	0.12a	29.53	10.26a	0.15a
Soil depth	0-10	1.56	1.22	2.04	7.04	0.14a	31.69	10.24	0.14
	11-20	1.58	1.14	1.96	7.01	0.12b	29.89	9.4	0.13
	21-30	1.49	1.06	1.86	7.03	0.08c	29.75	8.41	0.11
P value	SEM	0.51	0.26	0.44	0.31	0.02	5.43	2.95	0.03
	Districts	***	**	**	***	***	***	**	***

Rangeland types	**	ns	Ns	Ns	Ns	ns	*	**
Soil depth	Ns	ns	Ns	Ns	**	ns	Ns	ns

1. <sup>a, b, c</sup> Means with different superscripts in row are significantly different, \*\*\* =  $P < 0.0001$ ; \*\* =  $P < 0.001$ ; \* =  $P < 0.05$ ; ns = not significant ( $P > 0.05$ )

2. EC = Electro-conductivity (dS/m), pH = Soil power of hydrogen, OM = Organic matter (%), OC = Organic carbon (%), TN = total nitrogen (%), Ex. Ca = Exchangeable Calcium (cmol/kg), Ex. Mg = Exchangeable magnesium (cmol/kg) and Ex. K = Exchangeable potassium (cmol/kg); Trad. eclosure. = Traditional enclosure

Due to the effects of soil types and higher, warmer air conditions, the soil pH values of the Teltele rangeland type differ from both Arero and Yabello rangeland types. Teltele study site has higher air-dried, more clay soil types with higher amounts of exchangeable cations, which enhances the value of soil pH. The results also indicate that the soil of Teltele rangeland types was characterized by a more alkaline soil type than both study sites. Similarly, Habtamu et al. (2013) reported that the soils in the area were generally alkaline with a mean pH value of seven. The pH value or soil reaction tells whether the soil is acid or alkaline, i.e., between 6.5 and 7.5 is consider neutral, whereas values below 6.5 are acidic and values above 7.5 are alkaline (Hoskins, 1997). The gradual increment of soil pH value of rangeland types of study environments has an impact on livestock feed production biomass yield which reduces the potential productivity of rangeland resources.

### Effect of grazing on soil organic matter, organic carbon, and total nitrogen

The result of grazing impact on organic matter, organic carbon and total nitrogen of rangeland type of the study sites offered in table 2. Soil organic matter and carbon were significantly difference ( $P > 0.05$ ) between study sites but not among rangeland types and soil depths. However, Teltele site of rangeland types has higher in soil organic matter and carbon due to its soil type (more clay soil) that had well-bound of the parent material.

The Statistical analysis pointed out that the soil total nitrogen was significantly different ( $P > 0.05$ ) between districts, rangeland types, and soil depth due to differences in grazing pressure effect and soil types that induced different intensities of Fabaceae family of plant species. Teltele rangeland type has higher soil total nitrogen than other study sites due to the soil type effect that is present in the soil texture. Whereas the percentage of soil organic matter and carbon and total nitrogen of all study sites of rangeland types were lower than the standard requirement for forage production, i.e., 7, 3.1 and 0.175 are medium average content of the soil in their soil organic matter and carbon and total nitrogen respectively (Frank, 1990). This is due to the effect of overgrazing and increasing the frequency of recurrent drought outbreak, which reduce the plant material that serves for

increasing soil decomposition, resulting in lower in both rangeland types. The result agreed with Kumasi et al. (2010) that concluded the removal of vegetation by herbivores reduces ground covers and soil organic matters and nitrogen. Tessema et al. (2011) also reported that the concentration of total nitrogen was higher in light grazing as compared with sites exposed to heavy grazing. Therefore, overgrazing was not only affecting rangeland feed resource production yields but also in indirect affecting basic elements that required for growth of forage plant species. The indirect factor of grazing pressure of study sites have a great impact on soil nutrients due to lower litter covers levels and consequently lowers soil organic matter.

### **Effect of grazing on soil electroconductivity**

The result of grazing on soil electroconductivity of rangeland was analysis for both rangeland types of three districts offered in table 2. The result showed that the soil electroconductivity was significantly different ( $P < 0.05$ ) between study districts and rangeland types but not in soil depth. Yabello and Arero rangeland types do not differ in soil electroconductivity between their traditional enclosure and continuous grazing. A Teltele rangeland type has a high in soil electroconductivity than Arero and Yabello rangeland types due to Teltele study site has high in soil pH and exchangeable cation and air temperature than Arero and Yabello sites that had positively related to electric conductivity. The soil electric conductivity of continuous grazing rangeland type also had high as compared to its traditional enclosure rangeland type due to the impact of heavy grazing higher in base cation than traditional enclosure rangeland type. Similarly, Jeddi and Chaieb (2010) and Steffens (2008) reported soil electroconductivity increases in heavy grazing than light grazing due to grazing pressure reduce soil litter cover and increase the soil temperature and soil moisture evaporation rate.

Generally, the soil electroconductivity of Arero and Yabello sites better for plant growth because of lower than 2 dS/m that is none saline while Teltele site of rangeland types characterized as slight saline due to its soil types and environment effects (has high dried air condition).

### **Effect of grazing on soil exchangeable Calcium, Magnesium, and Potassium**

Heavy grazing pressure is an increase in soil exchangeable cation in semi-arid and arid environments of rangeland types. As shown the result of soil exchangeable of Calcium, Magnesium, and Potassium of rangeland types of study sites existing in table 2. The soil exchangeable of Calcium, Magnesium, and Potassium were significantly differed between study sites due to soil type different. Due to differences in management like overgrazing, and soil type (high in clay contents) effect, the exchangeable cation of Teltele site was high than Arero and

Yabello site. The exchangeable potassium and magnesium of Yabello and Arero site was a significant difference ( $P < 0.05$ ) between rangeland types but not in Teltele site.

The high amount of potassium recorded in the continuous grazing land of Teltele and Yabello site is due to impacts of heavy grazing that encourages on rangeland resource production. The result agreed with Garcia (2011) and Javadi (2006) who reported that the average content of potassium was higher in continuous grazing land than controlled and rotational grazing land. Similarly, Zarekia (2012) reported that the grazing areas increase in potassium have been related to livestock's positive effect on the accumulation of K via trampling and their excreta. Also, Haynes and Williams (1993) reported that the rise of potassium in continuous grazing land might be due to the amount of consumed potassium by cows is returned to the soil through their urine and dung. Whereas Tessema et al. (2011) reported that heavy grazing had lower soil nutrients where animal excreta were used for fuel and other purposes.

## **CONCLUSIONS**

Grazing pressure is the main factor of soil degradation in semi-arid and arid environments through both direct and indirect effects. The increasing year-to-year livestock population and variability of climate at the study sites loaded great pressure on rangeland resources to induce loss of topsoil. This circumstance was the main problem of herder in the study sites through enhancing the shortage of livestock feed resources. Hence, the higher amount of topsoil loses that sustained rangeland feed resources were decreased and replaced by less infertile soil. As a result, revealed, the rangeland production of study site special continuous grazing rangeland types was faced to endanger condition. Because the deteriorations of perennial herbaceous species (grass species) on soil surface through the impact of heavy grazing and harsh climatic condition were aggravating soil erosion and reduce soil nutrients of the study sites of rangeland types. Therefore, rangeland users should be considering an appropriate grazing system to improve and manipulate soil health of rangeland to sustain rangeland resource services.

## **Recommendations**

Appropriate grazing land management strategies should be applied for improving and sustaining soil health of rangeland which detriment ecosystem functions like forage productivity.

Soil and water conservations practices should be applied in degraded areas to secure soil health of rangeland that can accomplish the sustainability of rangeland productivities.

An applicable policy of rangeland management and utilization should be a pre-request for improving and sustaining rangeland soil health.

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