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Original Research Article

Assessing Rangeland-Soil Degradation Induced By Over Grazing. In Case Of Yabello Rangeland Southern Ethiopia

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Abstract

In Yabello most of the range land was changed in to agricultural area and the remaining part were exposed to overgrazing and become seriously degraded. The aim of this study was in order to assess the impact of overgrazing on the soil characteristics of Yabello rangeland. The soil physico –chemical characteristics were evaluated by using three (3) grazing intensity level (ungrazed, moderate grazing and over grazing (each with 2 ha) were selected, which were located about 100 to 150m apart within a 10 ha area. This study indicates that Overgrazing homogenized soil characteristics. The ranges of spatial autocorrelation for soil organic C (SOC) and total N were at the HG site, which was considerably larger than that at the MG and OG sites. Soil nutrients such as organic C, N and K were show a small higher variation in the ungrazed areas than as compared to both moderately grazing and overgrazing, even though, a variation were generally low and differed non-significantly in all the study sites. Results on soil texture revealed that the sand, silt and clay contents were not much difference in the three land-use systems. In general, since the complex nature of soil nutrient patterns, which are largely dependent on land-uses and topography and also the current study were done based on small sample areas we call up researchers for a more broad-based additional research investigation to provide stronger and basic information in the Yabello rangelands in this regard.
Keywords: Over-grazing, soil-degradation, Yabello, Rangeland.

INTRODUCTION

Arid and semi-arid ecosystems are highly heterogeneous in space and time because of considerable variation in biotic and abiotic factors related to vegetation and soil properties and this is essential to provide multiple ecosystem functions and services [1]. The rangelands of southern Ethiopia (Yabello rangelands) are almost entirely occupied by a pastoral population, which employs a communal resource system for livestock production [2]. In this rangeland site maintaining spatial patterns of vegetation and soil heterogeneity should be primary goals for the sustainable management of grassland ecosystems [3, 4]. Grazing intensity of a certain area is a key management variable that influences the structure and composition of grassland ecosystems [5]. Livestock grazing alters soil conditions as a result of dung deposition as well as hoof trampling that reduces/increases soil compactness, structure and viability [6]. Improper cultivation further contributes to soil degradation that affects soil capacity to withstand adverse conditions [6]. Overgrazing has profound effects on important ecosystem characteristics, such as water erosion, soil water content, soil organic carbon (SOC), plant species richness and diversity, belowground bud bank and ecosystem stability [7]. Even though, the effects of livestock grazing on soil heterogeneity have not been consistent. That means, with some studies indicated that overgrazing increased soil heterogeneity of TN, SOC and fine soil proportion [8], while other studies reported that soil heterogeneity and vegetation diversity decreased from a patchy to a homogeneous distribution with increased grazing intensity [9]. Ungrazed grasslands exhibited no spatial in soil N distribution with no topographic correlation [10]. The effects of grazing intensity on soil heterogeneity may be positive, negative or negligible depending on the level of grazing intensity and scale of observation [11]. Grasslands are used for livestock grazing extensively in the dry area of Yabello, where grazing pressure may increase substantially in the future due to increasing demands for animal products. The effects of grazing on spatial heterogeneity of grassland ecosystems as related to soil properties have been inconsistent and need clarification. As a result, field sampling and soil testing become important tools for assessing soil properties for rangeland development [12]. The next subsection will elaborate on the soil sampling perception at the study areas, sampling protocols and methods carried out.

Therefore, the objective of this study was aimed to evaluate the status of soil chemical and physical characteristics in relation to grazing systems in Yabello rangeland of Southern Ethiopia.

MATERIALS AND METHODS

Study Area

The study was done at Did- Tuyura kebele of Yabello district Borana zone with in three different grazing intensity site (ungrazed (UG), moderate grazing (MG) and over grazing (OG)) of southern Ethiopia in 2019 (Fig-1). It is situated at 566 km south of Addis Ababa along Addis – Moyale road. The area of Yabello town is 5426 km^2, and located between 4°30′55.81″and 5°24′36.39″ north latitude and between 7°44′14.70″and 38°36′05.35″ east longitude, the altitude is about 1000-1500 m, maximum altitude of 2000 m. The rainfall of the area is characterized as bi-modal. Which is the 73% of rainfall occur in March to May, the 27% of rainfall occur in September to November [13]. The potential evapotranspiration is 700-3 000 mm [14]. The study area also dominated by savannah vegetation containing mixtures of perennial herbaceous vegetation. It is also confronted with the problem of bush expansion in the native savannah grass lands. Besides the area characterized by savanna grass land.

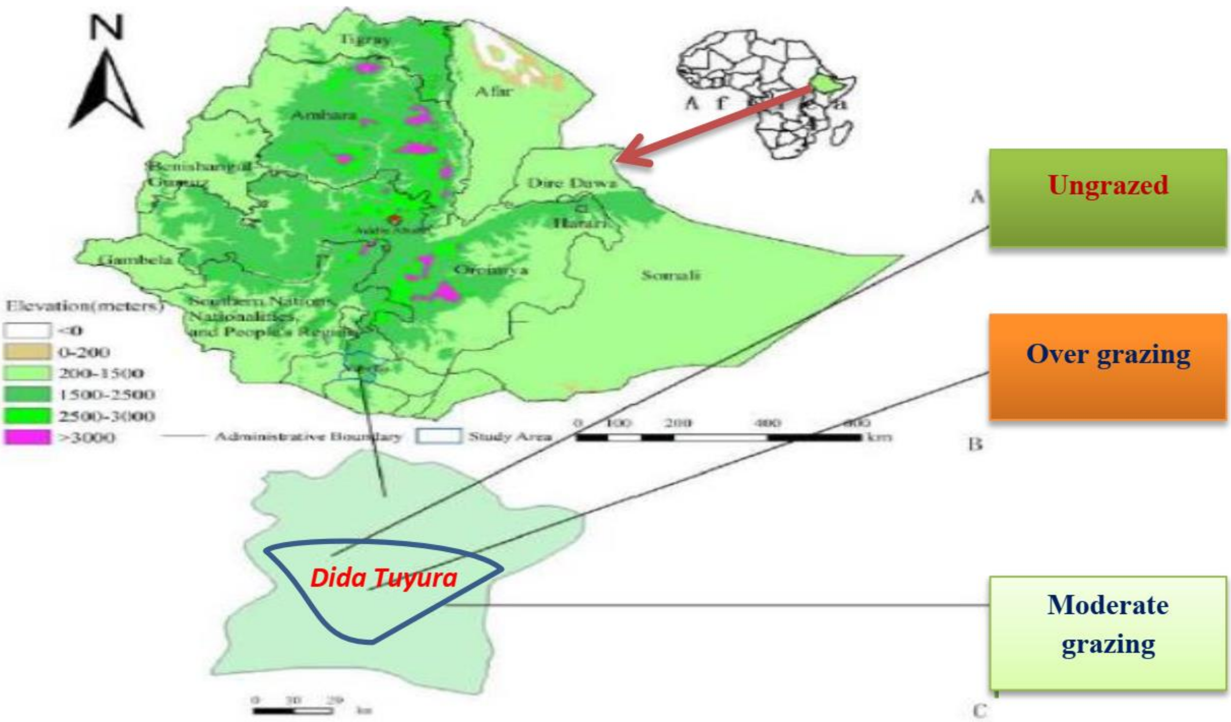

Fig-1: Location map of the study area

Site Selection

A reconnaissance survey and discussions were made with local pastoralists and district Pastoral Development Offices on the issues of grazing intensity and identification of areas most affected by this phenomenon was selected. Based on field observation three grazing intensities sites (ungrazed, moderate grazing and over grazing (each with 2 ha) were selected and used in this study, which were located about 100 to 150m apart within a 10 ha area. The study region had been free grazed by all livestock types that are found within the study area [15]. The grazing gradient used in this study represented the range of grazing pressures that can be found in this region.

Fig-2: Sampling site with different grazing intensity (ungrazed (A), moderate grazing (B) and over grazing (C). ***Photo taken by Yeneayehu F. Jan/2019.***

Experimental layout for soil Sampling

From each sample site, 3 soil samples were taken from the 1 m^2 quadrant with in depth from 0-20cm located within 250m^2 plot yielding 45 soil samples (3 plots with 10mX10m with 5m buffer zone X 5 quadrate (In each plot) X 3 sample sites.

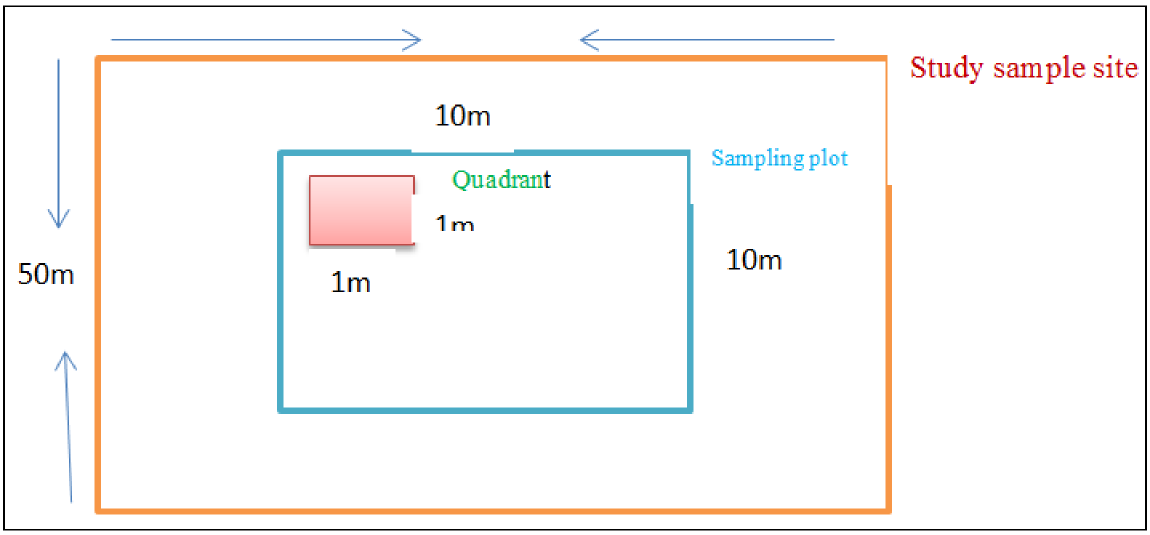

Fig-3: Experimental layout for soil Sampling

The soil samples were dug out with an Auger at a depth of 0–20 cm and the samples at each site were pooled to form one composite soil sample per sampling site yielding a total of 3 soil samples (from 3 sample sites) and placed in separate bags (paper and plastic bags were used). The samples were stored at room temperature after air-dried.

Fig-4: Soil samples collected from study area stored at room temperature

Finally, the soil PH, Total Nitrogen (N), Soil Organic Mater (SOM), Soil Organic Carbon (SOC), the availability of phosphorous (P), exchangeable potassium (K+), Mg, Ca ,texture and bulk density were analysed in the soil laboratory at Yabello Pastoral and Dryland Agricultural Research Center.

Table-1: Summary of tested soil nutrients and variables with different laboratory methods

Soil nutrient elements and other variables		Analytical methods and extractants
Soil nutrients	Organic/Total Nitrogen	Kjeldahl method (Kjeldahl 1883) [16]
	Nitrate (NO3--N)	Phenoldisulphonic acid method (Charles 1917) [17]
	Exchangeable ammonia (NH4+-N)	Indophenol blue method (Tzollas *et al*., 2010) [18]
	Phosphorus (P)	Phosphorus (P)
	Bray's method No. 1 (Bray & Kurtz 1945)	Bray's method No. 1 (Bray & Kurtz 1945) [19]
	Potassium (K)	Potassium (K)
	Flame photometer (Toth & Prince 1949)	Flame photometer (Toth & Prince 1949) [20]
	Zinc (Zn)	EDTA + ammonium acetate, EDTA + ammonium carbonate, DTPA + CaCl2, HCl, HNO3 and dithiozone + ammonium acetate (Lindsay & Norvell 1978) [21]
Variables	pH	pH
	(see text for details)	(see text for details)
	Exchange acidity and acid saturation	Exchange acidity and acid saturation

(***Source:*** *- Motsara and Roy (2008).*

Soil sample Analysis

Total nitrogen (N) includes inorganic N ($NH4^{+}$-N and $NO3^{-}$-N) and organic N compounds (amino acids, protein and other derivatives) and was analysed using the kjeldahl method. There are mainly two methods, namely the Bray's method No. 1 and Olsen method, for obtaining available phosphorus (P) in soils, but the former method was chosen because of assumed acidity of the sampled soils [22, 23]. Plant-available potassium (K) was extracted from soil samples with one-molarity of ammonium acetate using a flame photometer. Calcium (Ca) and magnesium (Mg) are grouped as exchangeable cations among other positively charged nutrients such as potassium (K), sodium (Na), hydrogen (H) and aluminium (Al). Exchangeable cations were determined in neutral normal ammonium acetate extract of the soil samples; however Ca and Mg were measured using a titration method which was selected based on its exactness, speediness and simplicity. Zinc (Zn) was concurrently analysed using a combination of methods and series of extractants (Table-1).

Soil pH, the negative logarithm of hydrogen ion (H^+) measures the acidity, alkalinity and neutrality in soil solution. It affects nutrient transferability between plant-soil relationship [22] but is the simplest method of estimation [12]. The major apparatus, pH meter (with a pH range of 0 – 14) and basic reagents (water, buffer and calcium chloride solutions of pH 4, 7, 9 and 0.01M, respectively) were used to rate the soil reactions to pH scale as described in Table-2 below.

Table-2: Range of pH values describing the soil reaction rating when measured

pH color	Purple	Yellow	Purple	Blue	Purple	Blue-green	Red-violet
pH range values	< 4.6	4.6 – 5.5	5.6 – 6.5	6.6 – 6.9	7.0	7.1 – 8.5	> 8.5
Soil rating	Extremely acidic	Strongly acidic	Moderately acidic	Slightly acidic	Neutral	Moderately alkaline	Strongly alkaline

Source: Motsara & Roy [12]

Exchange acidity in soils or cation exchange capacity (CEC) (containing hydrogen and aluminium cations, (often called titratable acidity) can be exchanged by a neutral salt in solution. This is an indicator used to measure lime requirement (quantity of alkali) for neutralising soil acidity. Exchange acidity is usually less than the lime requirement as some part of the acidity cannot be interchanged. The exchange acidity was measured using an indirect method similar to pH estimation, but at pH range of 6.6. Acid saturation, also an indicator of soil buffering capacity, determines liming potential suitable to alter the pH range and was estimated using the exchange acidity method described above. Measuring the dry weight of each sample volume determined soil compaction. Sample bulk density was measured by simply drying and weighing soil samples. Due to their flexibility, software packages such as R [24] and Microsoft Excel [25] were used for the data analysis and computation. Sample mean values were used to extrapolate the population mean from which the sample sizes were obtained to enable empirical deductions of soil chemical compositions. Standard deviation estimated the population variability as well as normality of the sample distributions. Standard error of the mean determined the uncertainty surrounding mean dimensions and the confidence interval (conf. interval = 95%), i.e. the P-value and the significance level ($P<0.05$, $P>0.05$) was analysed using one-way analysis of variance (ANOVA).

Fig-5: Some of the pictures that were taken during sample analysis in the laboratory (*photo taken by Yeneayehu F. Jan/2019)*

RESULTS AND DISCUSSION

Soil physico-Chemical Attribute Ordination and Analysis

Principal component analysis of soil physico-chemical attributes revealed distinct separation between the different grazing Intensity area (ungrazed, moderate grazing and over grazing) area.

Chemical Analysis

Results on the exchangeable cations are presented in Table-3. Significant differences (P>0.05) did not occur in the Ca, Mg, K and Na content of soil under the three land-use systems. Results of the organic C and total nitrogen percentages were also remarkably similar (P>0.05) in the three land-use systems.

Table-3: Soil characteristics for ungrazed (UG), moderate grazing (MG) and over grazing (OG) sites (mean ±standard error) at 10 cm soil for all sample area

Grazed site	Soil properties					
	% Organic C	% Nitrogen	Ca	Mg	K	Na
UG	1.62±0.18	0.33±0.03	8.02±2.97	3.08±0.02	1.95±0.09	1.66±0.22
MG	1.38±0.10	0.29±0.01	11.00±3.01	3.96±0.10	1.79±0.02	1.77±0.03
OG	1.27±0.11	0.21±0.02	10.92±1.4	4.01±0.21	1.69±0.11	1.49±0.14

In the present study, we determined the magnitude of soil heterogeneity under three grazing intensities. Soil nutrients such as organic C, N and K were show a small higher variation in the ungrazed areas than as compared to both moderately grazing and overgrazing, even though, a variation were generally low and differed non-significantly in all the study sites. This is due to the higher vegetation coverage and the role of increased biomass in nutrient cycling in enclosure areas, which result in higher litter input and improved content of organic matter in the soil. In line with this study, Reeder and Schuman [25] reported the existence of higher soil organic carbon in lightly grazed sites compared to heavily grazed ones. Among the soil properties, the total organic C is a sensitive soil quality indicator. This means that within a narrow range of soil the organic C may serve as a suitable indicator of soil fertility [27]. Furthermore, this organic C fraction may offer further insight into soil fertility changes and the sustainability of land-use and management practices [28] and also the markedly deficient of most nutrients in the over grazing rangeland area become the common issue in the Yablello rangeland as a result of poor grazing management approach, those limits the yield of rangeland grasses. Grazing had a strong influence on the spatial patterns of soil characteristics and was the main reason for changed spatial autocorrelation in grasslands of Yabello, which may have resulted in soil and vegetation characteristics being relatively homogeneous at grazed sites and heterogeneous at ungrazed sites. This can be due to heavy grazing reducing the input rate of organic matter, decreasing plant cover, trampling damage to plant tissue, increasing soil bulk density and decreasing soil water infiltration.

Soil texture, bulk density and pH

Results on soil texture, bulk density and pH are presented in Table-4. Results on soil texture revealed that the sand, silt and clay contents were not much difference in the three land-use systems. Concerning the bulk density and soil pH, differences between land-use systems not significant (P>0.05).

Table-4: Texture composition (%), bulk density (g cm[3]) and pH (mean±SE) of topsoil sampled from land use systems in the Yabello rangelands

Grazed site	Texture Composition				
	Sand	Silt	Clay	Bulk density	pH
UG	67.09±2.12	25.99±1.81	6.92±0.07	1.29±0.04	6.53±0.19
MG	63.80±3.19	25.08±2.00	6.38±1.36	1.27±0.98	6.31±0.13
OG	65.50±4.12	28.99±2.09	6.16±1.01	1.27±0.89	6.09±0.18

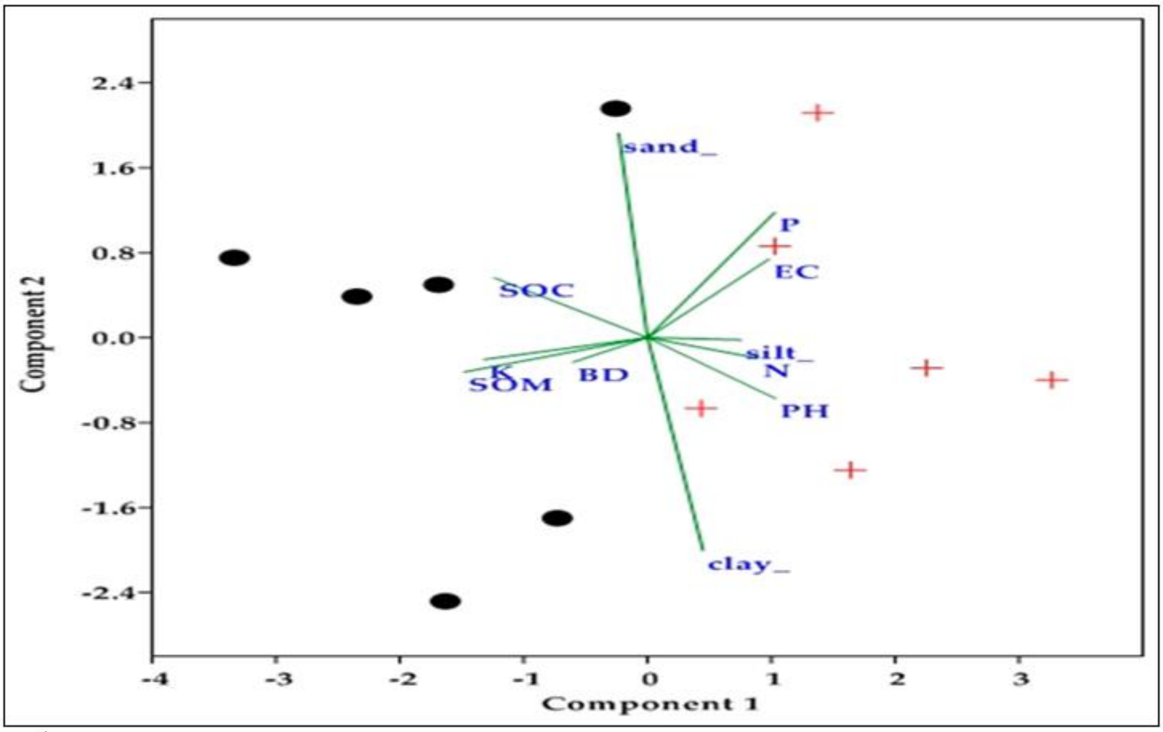

Fig-6: Principal component analysis correlation (% variance) diagram based on soil physico-chemical attributes in Yabello rangelands of Southern Ethiopia. Chemical attributes (N = Nitrogen; P = Phosphorous; K = Potassium; SOM = Soil organic matter; SOC = Soil organic carbon; EC = Electric conductivity)

From the current findings we can understand that there is variation of soil texture observed in different grazing intensity site and we can hypothesize, based on this finding, that most parts of the Yabello rangeland are sandier and shallower. Therefore, the soil of grazing area have low capacity to store nutrients and water, that resulted from the current expanding practice of opportunistic cultivation and/or heavy grazing pressure in the communal areas. From the above Table-4 we can see that in all the three grazing area, major part of the soil was sandy (≥65%) followed by silt and when we compared the grazing site there is no much difference with in the proportion of soil texture across the study area even though, since there is no more animal movement in the ungrazed area resulted somewhat sandy soil become observed greater. The nutrient pool to be remediated for soil fertility among tested variables basically includes the enhancement of soil pH. The soil pH showed negative correlative behaviour with all the variables, where the *pH* elevation in the soil lowers the availability of other soil nutrients, and contrariwise. Soil acidity limits nutrient-exchange between plant-soil interaction that affects plant fecundity as well as soil community [22]. Most nutrient elements become available in the pH range of 5.5 – 6.5 [29]. pH values recorded in this study ranged from 6.09-6.53 (Table-4). From this recorded pH result we can understand that among the three grazing rangeland site the overgrazing area slightly become acidic as compared to ungrazed area, even though, there is no much significant difference. This is due to increments of some soil parameters concentrations like P, PH, EC and soil silt content were observed in the over grazing areas. Increase in the concentrations those soil parameters in the over grazing range land area was probably due to the existence of high animal grazing that contributes to increasing animal dung, urine and defoliation of plants during grazing. This result is in agreement with the study conducted by Haftay Hailu [28] afar rangeland Eastern part of Ethiopia. And also in the long run this over grazing activity reducing the input rate of organic matter, decreasing plant cover, trampling damage to plant tissue and as a result increasing soil bulk density that led to decreasing soil water infiltration.

CONCLUSION

This study contributes to the understanding of the ecological effects of grazing on the soil-degradation in the Yabello range land area in southern Ethiopia. From this result we can understand that if we manage the livestock grazing intensity, the soil heterogeneity character become increased as a result of vegetation biomass become increased observed from sampling density. For this over- grazing of range lands in Yabello should have long term and great impact on rangeland soil degradation and heterogeneity and this become bottleneck problem for alarming rate of increasing the rangeland degradation over time to time and challenging for restoration of it. Since the complex nature of soil nutrient patterns, which are largely dependent on land-uses and topography and also the current study were done based on small sample areas we call up researchers for a more broad-based additional research investigation to provide stronger and basic information in the Yabello rangelands in this regard. This would help to understand the interactive relationship of over-grazing with topography, soil erosion, soil nutrients, land-use and history and manage this area better.

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Conflicts of Interest

The authors declare that there is no competing of interest.

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