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ASSESSING THE EFFECTS OF LANDSCAPE FEATURES AND GRAZING ON VEGETATION CONDITION IN GRAZING LANDS OF MOKHOTLONG DISTRICT, LESOTHO

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ABSTRACT

Grazing is an important factor determining the patterns of vegetation in mountainous rangeland ecosystems. However, other factors such as topography can also influence the rangeland in its ability to produce forage for grazing animals. This study aims to estimate the effects of landscape features (elevation, aspect) and grazing (presence or absence) on plant species richness, percent cover and plant height. The effects of these factors on vegetation condition were analysed and quantified to be used as a premise for developing sustainable grazing management plans. This study was conducted at the Phapong grazing area in the district of Mokhotlong and encompasses a total land mass of 1048 ha in the mountainous agro-ecological zone of the kingdom of Lesotho. The percent cover of each plant species was visually estimated based on the proportion of the quadrat occupied. The presence or absence of sheep and/or goat pellets within each quadrat was also recorded. The Disc Pasture Meter (DPM) was used to measure compressed grass height. The findings revealed that plants were taller in south-facing slopes than in north-facing slopes. Plant species richness and diversity were lower at areas of high elevation. The interaction between aspect and elevation had no significant effect on plant height, species richness, and plant diversity. The presence of low grazing density had no significant effect on the percent cover of plant species of different palatability in the study site.

Key words: landscape features, grazing density, plant species cover, species richness, plant diversity, plant height

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1. INTRODUCTION

Grazing is an important factor determining the patterns of vegetation in mountainous rangeland ecosystems (Davis & Goetz 1990). Other environmental drivers, like topography, also influence the rangeland in its ability to produce forage for grazing animals (Gyamtsho 2002). Thus, quantitative information about the effects of grazing and topography (aspect and elevation) on vegetation is crucial for developing sustainable grazing management plans. These plans aim to optimize forage production for livestock, conserve local biodiversity, reduce fire hazards and protect wetland areas (FAO 1993).

Surveys of rangeland condition are undertaken to determine the existing status of resources in a given grazing area. They generally focus on various features such as vegetation types, grazing intensities, landscape features (elevation and aspect), streams, and improvements such as water points. In conventional range management, this is usually followed by desktop-designed grazing plans. However, range management authorities are slowly shifting to design and implementation of people-oriented grazing management plans. To ensure the sustainability of these plans, authorities and resource users must have a basic understanding of rangeland systems at different landscape structures.

The conventional management of rangeland resources is based largely on controlling livestock numbers to achieve the desirable rangeland vegetation (Itzkan 2013). Recent studies on non-equilibrium systems indicate that overgrazing may not only be a function of stock numbers (Adler & Morales 1999). For example, high livestock numbers were identified as a poor indicator of the potential degradation in the communally managed rangelands of southern Africa (Petersen et al. 2004). Thus, other indicators of the condition of rangeland vegetation should be used.

Species diversity is one of the most important indicators used for assessing the condition of plant communities. Information on the species diversity of an area is essential for its management and conservation of biodiversity (Thakur 2016). In range management, plant species richness is frequently used as an indicator of biological diversity. Species richness is a measure of biodiversity that is simple and easy to interpret. There are several types of environmental factors, mainly aspect and elevation, that influence the processes that can either increase or reduce diversity (Sagar & Singh 2006; Sharma et al. 2009). Studies have suggested that different elevations and the nature of slopes influence the species richness and distribution of plant species on a rangeland (Sharma et al. 2009).

The other indicator is plant growth traits which provide key information to evaluate the condition of the rangeland vegetation. Plant height is a simple indicator that shows what happens to individual forage plants when exposed to different degrees of grazing by cattle, and in what way grazing changes growth habits and composition of the herbaceous vegetation in a rangeland. Finding answers to these fundamental questions will help the range managers and users to properly evaluate the current range management practices (Johnson 1956).

Landscape processes of mountainous grazing lands are dynamic (Gyamtsho 2002). The effects of landscape features on vegetation condition have not been thoroughly explored. However, changes in landscape attributes must inform decision-making (Andrade et al. 2015). Many landscapes provide a diverse range of values, goods, and services to different resource user groups. This underscores the need for a survey that examines the effects of varying landscape features and the relative contribution of herbivory on rangeland vegetation by exploring the relationships between rangeland plants, landscape features, and grazing livestock.

Specifically, this study focused on changes in plant species diversity and plant growth traits in relation to livestock use and landscape features. The major goal of this study was to evaluate the combined effects of grazing and landscape features on vegetation condition. The presence or absence of grazing by sheep and goats, as well as the independent effects of elevation and aspect, were analysed for a mountainous grazing area of Phapong in the Mokhotlong district of Lesotho to estimate the effects of landscape features (elevation, aspect) and grazing (presence or absence) on plant species richness, percent cover, and plant height. The findings of this study will provide a basis to improve management in topographically complex landscapes like the mountainous rangelands of Lesotho.

2. METHODS AND MATERIALS

2.1 Study site description

The study was conducted at the Phapong grazing area in the district of Mokhotlong and encompassed a total land mass of 1048 ha in the mountainous agro-ecological zone of the Kingdom of Lesotho (Fig. 1). Elevation in the project site ranges between 2775 m and 3090 m above sea level (a.s.l). This area forms part of the lower catchment of the River Khubelu, which is critical to phase II of the Lesotho Highlands Development Authority (LHDA). The Phapong rangeland also serves as a stable source of forage for livestock, mainly small stocks of merino sheep and angora goats which form part of the primary sector of the Lesotho economy (Central Bank of Lesotho 2016). The other rangeland resources user groups in this area include rangeland resource managers, artisans, herbalists, researchers, and policymakers.

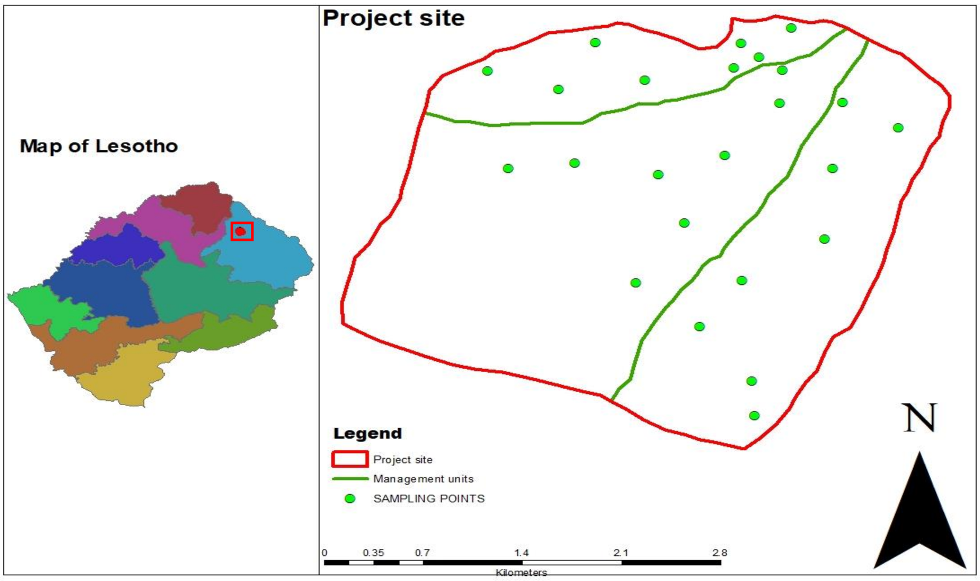

Figure 1. The project site of Phapong with 3 distinct management units (MU1, MU2, MU3) in the Mokhotlong district of Lesotho.

The main variability in environmental conditions occurs from north-facing slopes to south-facing slopes, and between high and low elevations. For the purposes of the study design, the area was divided into areas at low elevation (between 2775 and 2900 m a.s.l) and high elevation (over 2901 m a.s.l), on different aspects, north (N) and south (S). Thus, four main strata were defined as: low elevation area on N facing slopes (LEN), low elevation area on S facing slopes (LES), high elevation areas on N facing slopes (HEN), and high elevation areas on S facing slopes (HES).

The management unit (MU) describes a portion of land in the project site that is likely to experience the same grazing pressure under the current management system and location of cattle post huts, as shown in Figure 1. Each management unit comprises all four strata of LEN/S and HEN/S. Within each landscape stratum, 2 randomized sampling points were generated using the sampling design tool in ArcGIS 10.5. This made a total of 8 sampling points located at least 100 m apart in each management unit, and a total of 24 sampling points in the study area.

2.2 Data collection

At each sampling point, a 10 m transect line was established perpendicular to the orientation of the slope, as shown in Figure 2. Along the transect the measurements were taken in four quadrats (0.1 m^2; Fig. 3A) and placed sequentially at a 3 m interval (Schmutz et al. 1982). The data on percent cover of each plant species was visually estimated based on the proportion of the quadrat occupied and was recorded on the data form provided. Initially, the count of sheep and/or goat pellets within each quadrat was recorded as none (0), low (< 20), medium (20-40), or high (>50), to estimate herbivore density. However, medium densities were only recorded in one transect, and high densities in none, so the variable grazing intensity was recorded to presence or absence of grazing for further analyses.

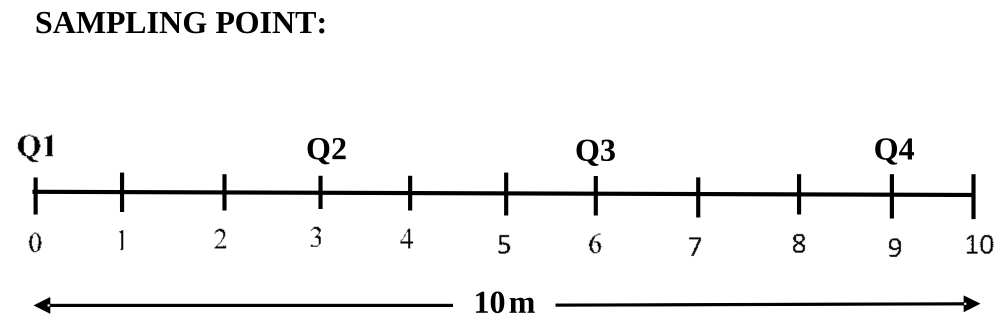

Figure 2. At each sampling point a 10m transect was established, perpendicular to the prevalent slope. Quadrats for assessing vegetation and herbivore density were placed at 4 positions (Q1, Q2, Q3, Q4) along a transect line.

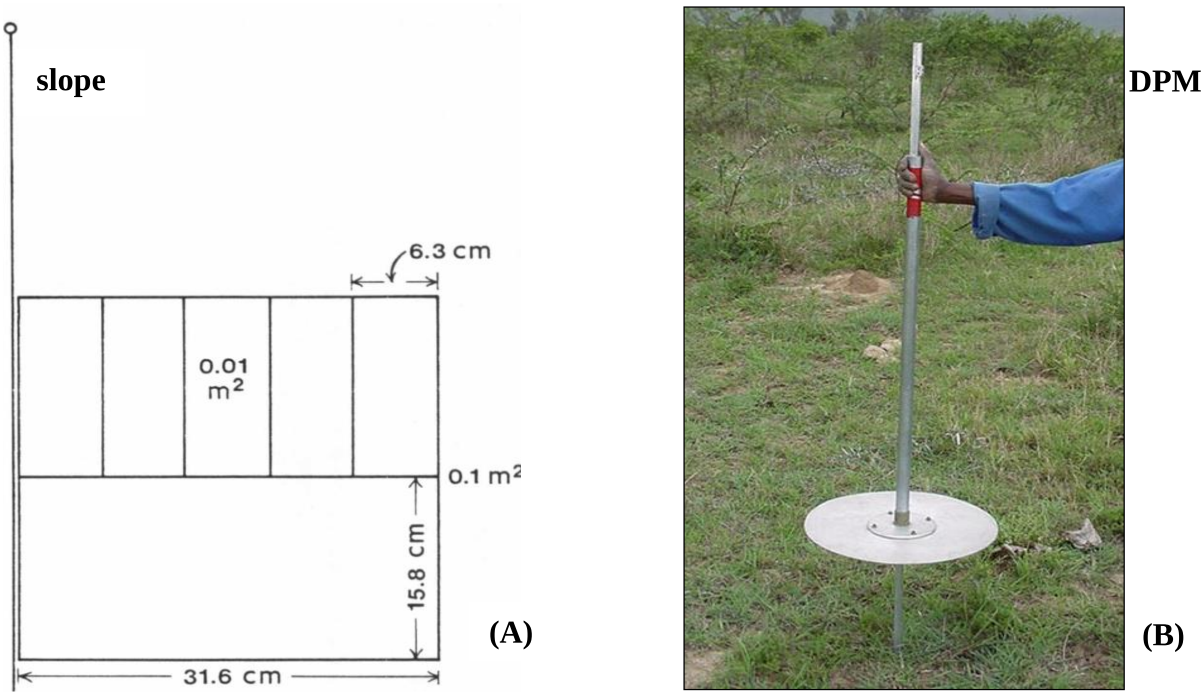

Figure 3. A) Quadrats were placed along the 10 m transect, perpendicular to the prevailing slope, to assess plant vegetation cover and herbivore density. B) The disc pasture meter (DPM) was used for measuring compressed grass height.

The Disc Pasture Meter (DPM; Fig. 3B) is widely used in South Africa as a simple and rapid method of measuring compressed grass height (Zambatis et al. 2006). In this study, one hundred DPM readings were recorded along the same transects used for recording the botanical composition and basal cover of the vegetation (i.e. every 10 cm). The measurements were taken consistently to one or the other side of the transect line. Readings recorded the height of the grass sward in centimeters (Zambatis et al. 2006).

Plant species react differently to different grazing densities and environmental factors, and the difference in response between the palatable and unpalatable species provides information for appraising range management practices (Johnson 1956). For the purposes of this study, the percent cover of unpalatable *Merxmuellera disticha* (A) and palatable *Themeda triandra* (B) at different landscapes features and grazing density was assessed. Data were collected over 5 days in July 2018 by a team of field assistants, with the guidance of the project manager (see Appendices for a detailed protocol for data collection).

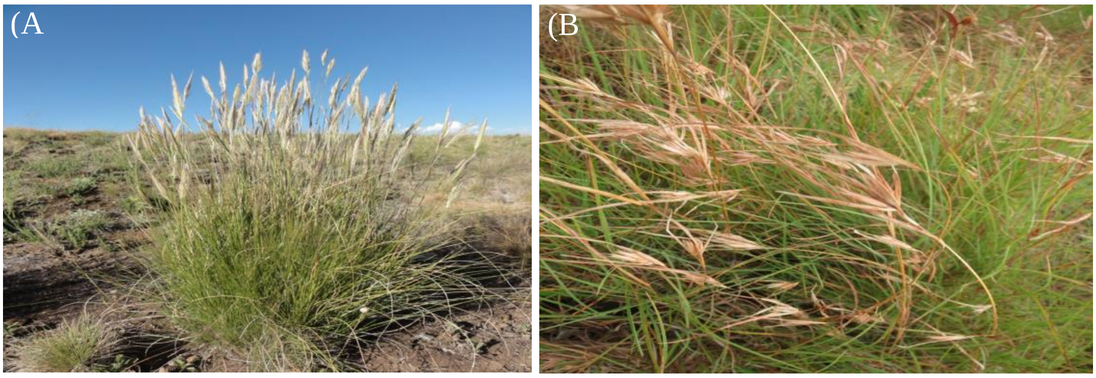

Figure 4. Merxmuellera disticha (A) and Themeda triandra (B). (Source: www.ispotnature.org).

2.3 Data analysis

A descriptive analysis was undertaken to establish the overall distribution of the various plant species across the entire watershed and within each landscape feature (see Appendices). The percent cover of plant species and other surfaces such as litter, bare soil, and rock were also determined at different strata.

Species richness and plant species diversity (Shannon index) were calculated for each transect. Linear models (LMs) were used to test the effects of landscape variables (elevation, aspect and their interaction) and grazing density on (i) plant height, (ii) plant species richness, (iii) plant species diversity. We also tested the influence of elevation and aspect on the percent cover of *Merxmuellera disticha* and *Themeda triandra* and their estimated response to grazing and determined if there was a significant difference in vegetation condition at different aspects and elevation (Meentemeyer & Moody 2000).

3. RESULTS

3.1 Effects of landscape variables and grazing on plant height

Aspect had a marginally significant effect on plant height, with taller plants on southern slopes ($t = 1.794$, $p = 0.087$), as in Figure 5. Plant height was similar across elevations ($t = 0.272$, $p = 0.789$).

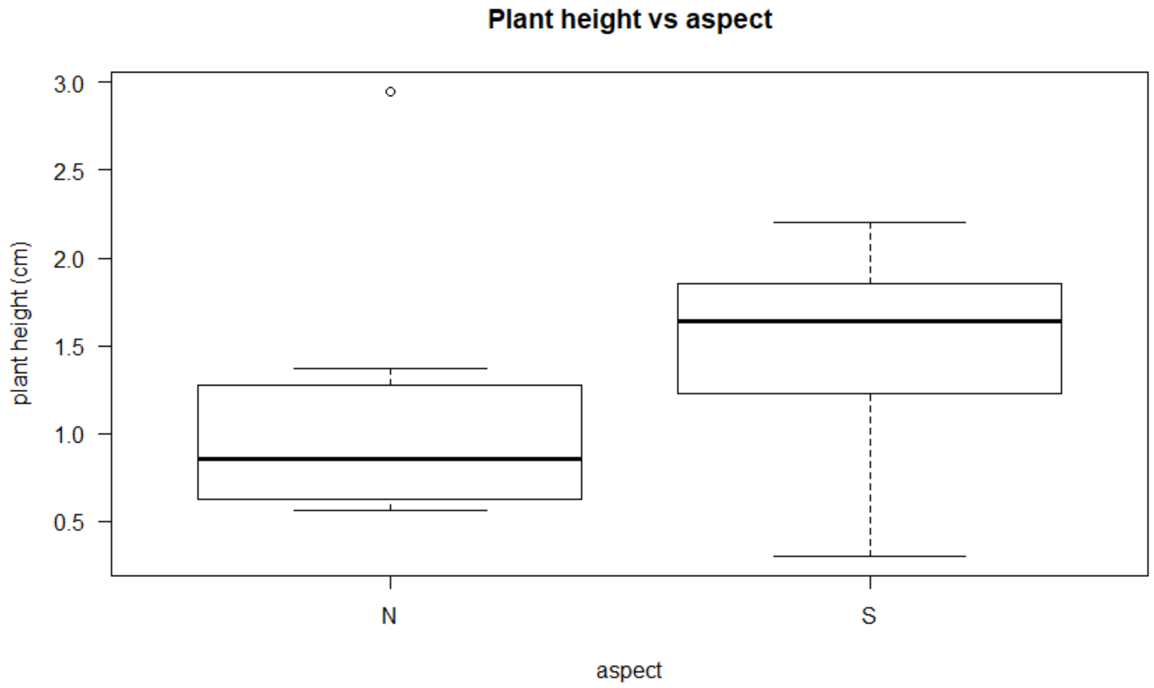

Figure 5. The relationship between north (N) and south (S) slope aspects and plant height.

Grazing had a marginally significant effect on plant height ($t = -2.050$, $p = 0.0524$), with taller plants in areas where grazers were absent (Fig. 6).

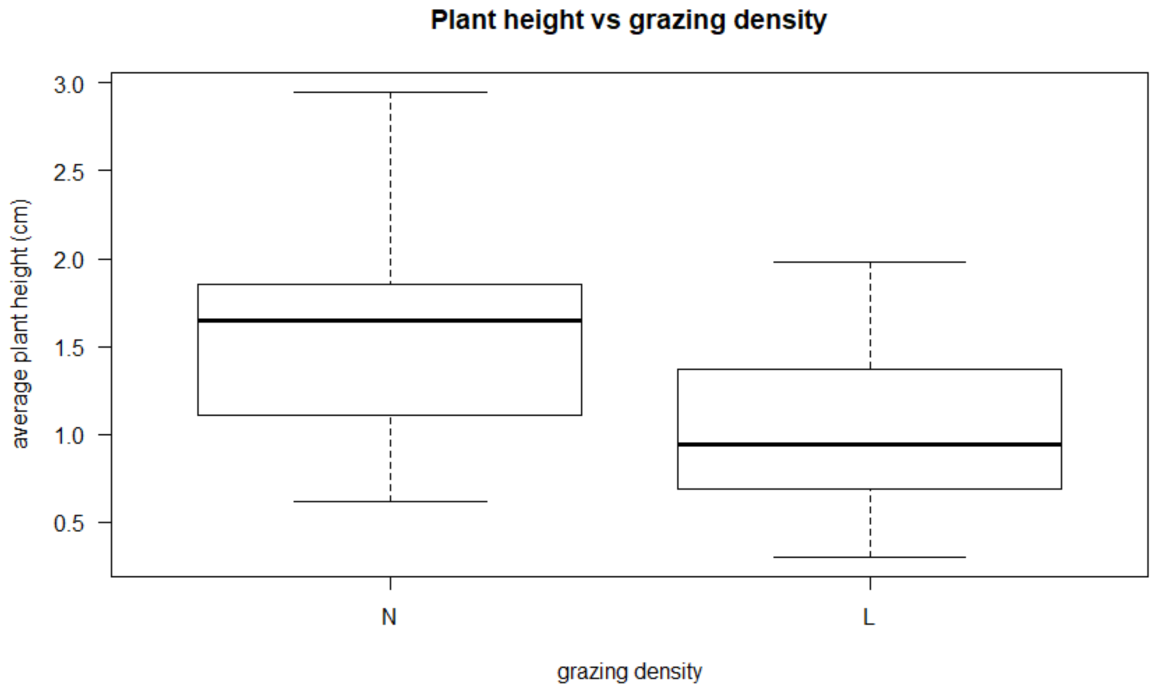

Figure 6. The effect of the presence of low (L) and no (N) grazing density on average plant height.

3.2 Effects of landscape variables and grazing on plant species richness

There was a highly significant effect of elevation on plant species richness. Plant species richness was lower at higher elevations (i.e. negative effect) ($t = -2.884$, $p = 0.009$; Fig. 7). The interaction between species richness and grazing density was not significant ($t = -0.823$, $p = 0.419$).

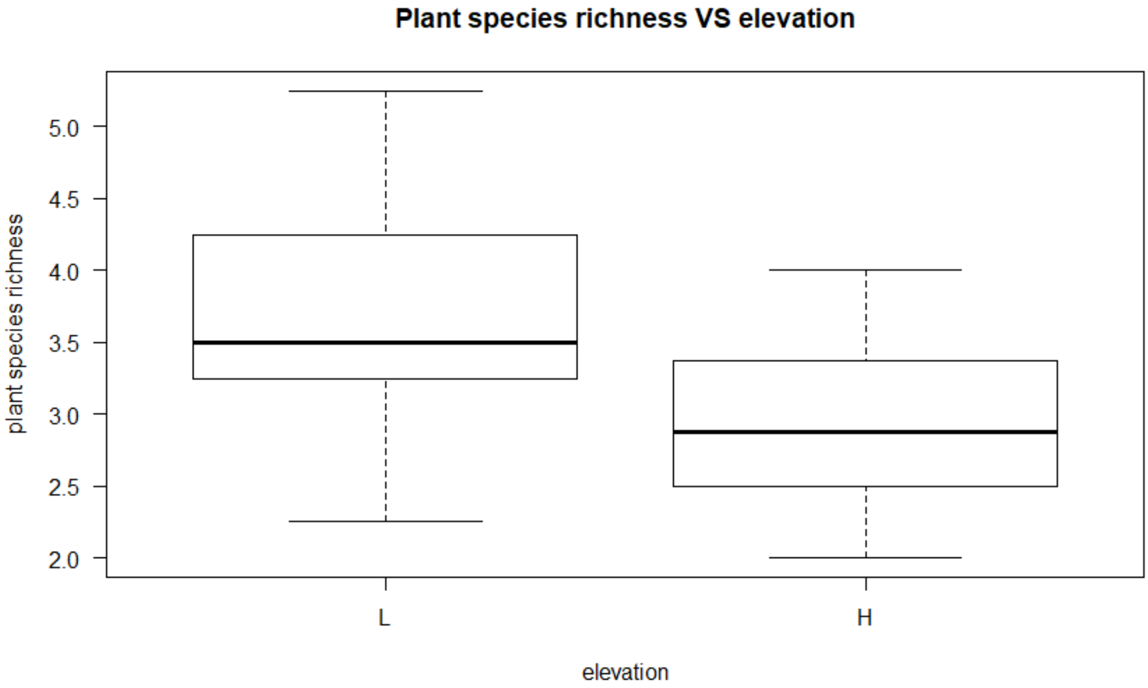

Figure 7. Plant species richness observed at areas of low (L) and high (H) elevation (m a.s.l).

3.3 Effects of landscape variables and grazing on plant species diversity

Elevation had a significant effect on plant species diversity ($t = -2.702$, $p = 0.013$) with lower plant diversity in areas at high elevation (>2900 m.a.s.l; Fig. 8). The effect of low grazing density on plant diversity was not significant ($t = -0.623$, $p = 0.540$).

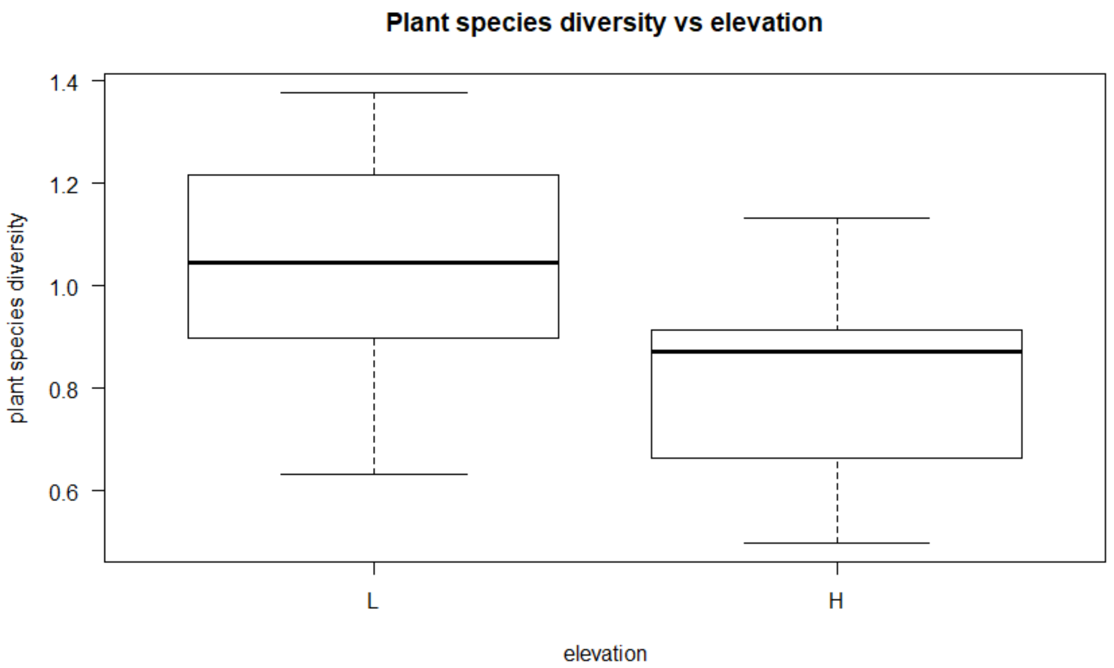

Figure 8. The plant species diversity at the low and high elevation areas.

3.4 Effects of landscape variables on *Merxmuellera disticha* and *Themeda triandra* and their response to grazing

The effects of *grazing* on percent cover of *Merxmuellera disticha* was not significant (t = 0.221, p = 0.971; Fig. 9), and the interaction between aspect and elevation (t = 0.644, p = 0.526) was not significant.

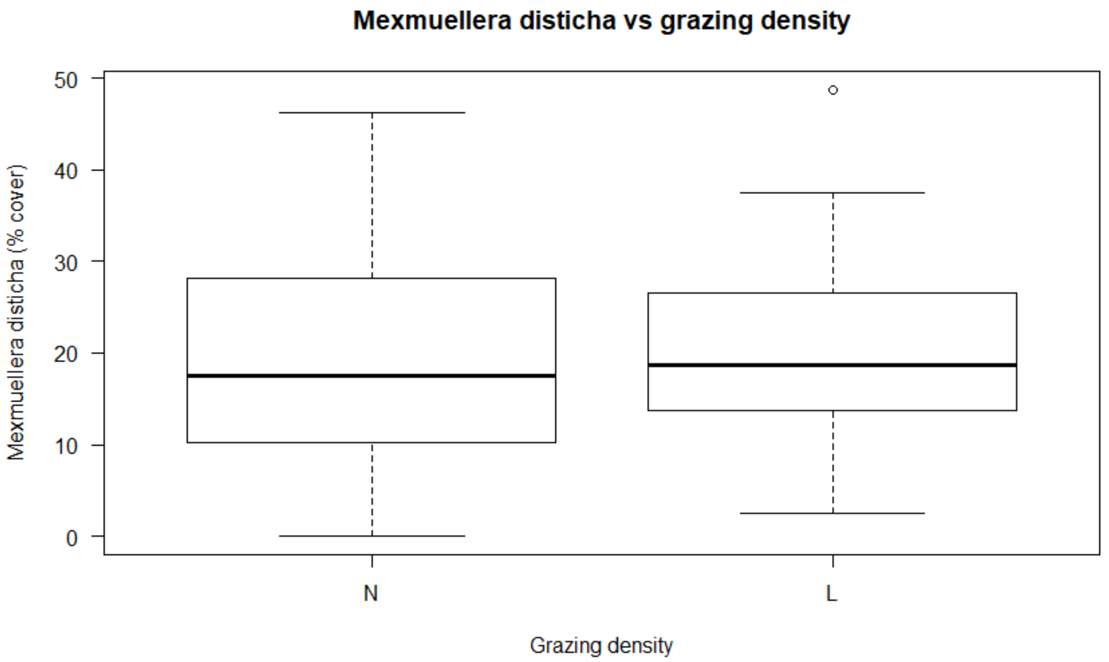

Figure 9. The relationship of no (N) and low (L) grazing density and percent cover of *Merxmuellera disticha*.

The effects of low grazing density on percent cover of *Themeda triandra* was not significant (t = -0.760, p = 0.4475), with Figure 10 showing a decrease in the presence of grazers.

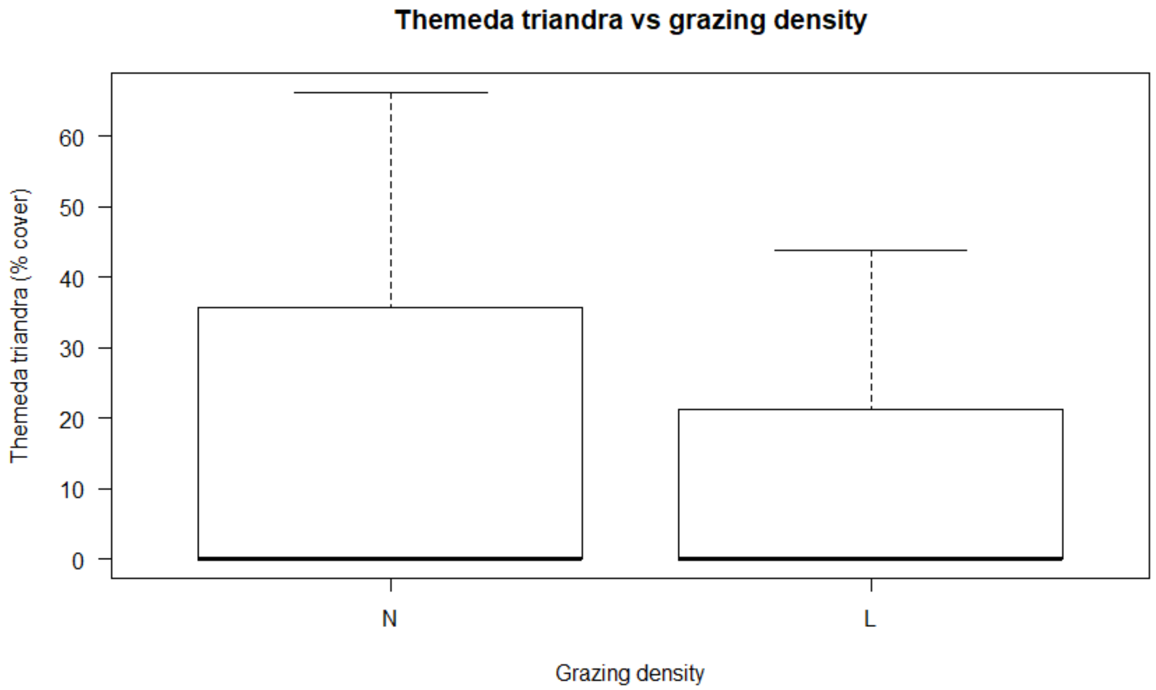

Figure 10. The relationship of no (N) and low (L) grazing density and percent cover of *Themeda triandra*.

There was a significant effect of aspect on the percent cover of *Themeda triandra* (t = -2.287, p = 0.0327). From Figure 11, it is evident that percent cover of *Themeda triandra* was lower on south-facing slopes.

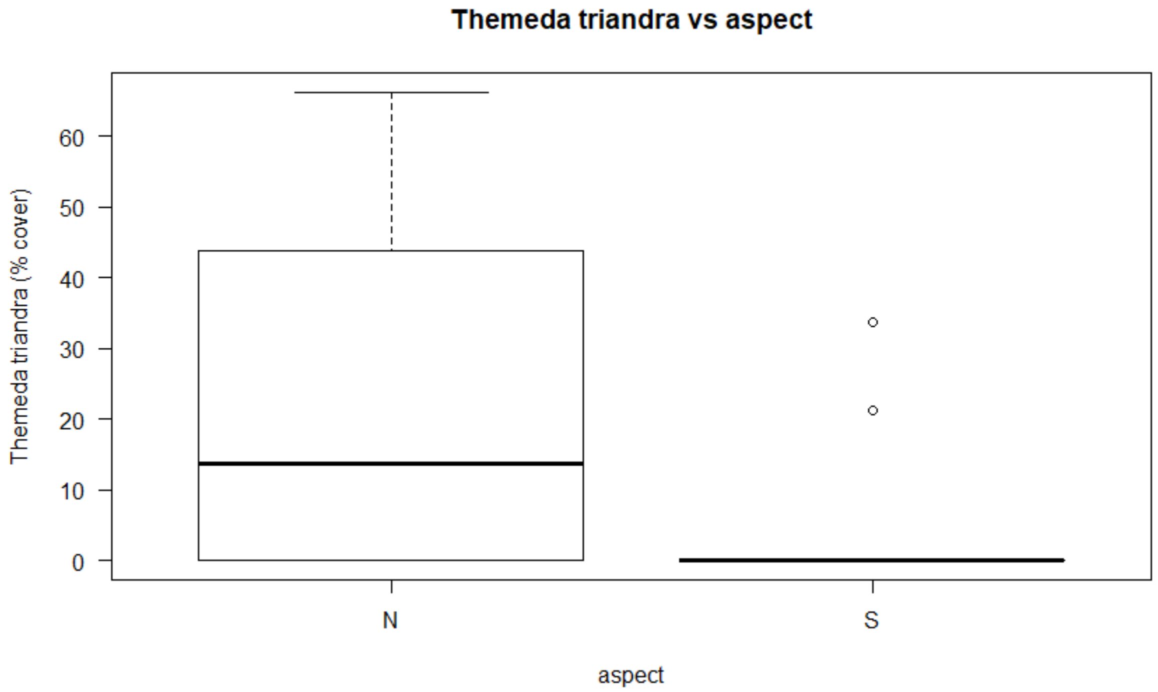

Figure 11. The influence of slope aspect on percent cover of *Themeda triandra*.

4. DISCUSSION

The general findings of this study include the effects of landscape variables (aspect and elevation) and grazing on vegetation condition in a mountainous rangeland. Slope aspect had a significant effect on plant height and percent cover of palatable *Themeda triandra*. Elevation was found to be the only landscape variable that had a significant effect on the plant species richness and plant diversity. However, the interaction of aspect and elevation showed a consistent pattern of vegetation condition across the entire study area. The grazing density had a marginally significant influence on the average plant height. Nevertheless, the presence of low grazing density had an insignificant effect on species richness, plant diversity, and percent cover of both unpalatable *Merxmuellera disticha* and palatable *Themeda triandra.*

4.1 Effects of landscape variables and grazing on plant height

In this study, the slope aspect was identified as the main landscape variable that had a significant effect on plant height, with taller plants on the south-facing slopes of mountainous rangelands in Lesotho. This was inconsistent with the study undertaken by Kutiel & Lavee (1999) on the effects of aspect on soil and vegetation properties which revealed that vegetation on the north-facing slopes was taller than on the south-facing slopes. However, the specific effects of aspect and elevation or the interaction of both on plant height have not been thoroughly investigated.

The action of grazing results in both damage to individual plants and changes in physical appearance of the plant community (Milchunas et al. 1988). This is consistent with the findings of this study which revealed that grazing in mountainous rangelands had a negative effect on plant height. In the Mokhotlong district rangeland plants are shorter in the presence of grazers and taller in absence of grazers. Other studies of similar nature suggest that more intense grazing has been associated with a higher proportion of short plants, leafy plants, small seeds, and medium fecundity. Low levels of grazing have been associated with medium height plants and plants with medium lateral spread (Díaz et al. 2001; Mcintyre & Lavorel 2001).

4.2 Effects of landscape variables and grazing on plant species richness

The results of this study revealed that there was an inverse relationship between plant species richness and elevation. This implies that there was a lower number of plant species in areas of higher elevation. These findings are similar to those found in Hubei Province, China which showed a decline in species richness with increasing elevation from 1000-3105 m.a.s.l (Hua 2004). The results of this study also correspond with a study in the Himalayas, Nepal, where between 1,500 and 2,500 m little change in the number of species was observed, but above this altitude, a decrease in species richness was evident.

However, these results do not correspond with a case study from Los Tuxtlas, Mexico, in which terrestrial plants did not show significant changes with elevation, which might be influenced by the rather narrow elevational interval (Krömer et al. 2013). These results are also inconsistent with the study by Shimono et al. (2010) in Tibet which detected a clear relationship between elevation and species richness, and a weak steadily increasing trend of richness was detected with increasing elevation. This implies that further studies are required to understand the relationship between elevation and species richness, and how this varies from place to place.

4.3 Effects of landscape variables and grazing on plant species diversity

Plant species diversity is partly influenced by a large difference between regions, and is partly due to local and landscape factors. According to the results of this study, elevation was found to have a major effect on species diversity, with lower species diversity attributed to a higher elevation. This implies that species diversity (Shannon diversity index) decreases with increase in elevation. These results are consistent with the findings of a study conducted at a forest in Garhwal, Himalaya, which showed that species diversity was maximum at the lower altitudes, medium at mid-elevation and lowest at the higher elevations (Sharma et al. 2009). However, according to the findings of Boscutti et al. (2018), elevation directly influences plant growth but not plant diversity.

4.4 Effects of landscape variables on *Merxmuellera disticha* and *Themeda triandra* and their response to grazing.

The landscape variables (aspect and elevation) and the interaction of both aspect and elevation had no significant effect on the percent cover of *Merxmuellera disticha* across the entire study area. In addition, there was no significant effect of grazing density on the percent cover of *Merxmuellera disticha*. These findings are not a surprise since this plant species was described as a very tough wiry grass. This grass species easily outcompetes other grasses under current conditions of selective grazing, as it is not eaten by grazers, but its neighbors are; thus, this species can have high abundance in the absence of fire or other disturbances (Sieben et al. 2010).

The presence of a low density of grazers in the study area had no significant effect on the percent cover of *Themeda triandra* (Fig. 9). However, slope aspect had a significant effect on percent cover of *Themeda triandra*. The larger proportion of this grass species occurs mainly on the north-facing slopes. *Themeda triandra* is a perennial grass commonly found in Africa, Australia, and Asia. Within these regions, it occurs across a widespread variety of microclimates, landscape formations, and ecosystems (Marshall & Bredon 1967). Because it is prevalent across these zones, it has great economic and ecological value, as it is a palatable species across most of its range (Dunning et al. 2017).

Themeda triandra is fundamental in supporting local livestock of both native and introduced grazers, and is thus vital to wildlife and livestock production, and consequently improves rural livelihoods. It is an important climax species that is well adapted to fire, a common element of many areas in the grazing lands of Lesotho. Poor grazing management plans, however, can result in a decline of *Themeda*, as it is not well adapted to an uninterrupted, selective grazing system or high-intensity grazing (Snyman et al. 2013). A decrease in percent cover of *Themeda* in grassland biomes is usually a direct indicator of a low grazing value, species richness, plant diversity and ecosystem function (Snyman et al. 2013).

5. CONCLUSION

The landscape features (aspect and elevation) and grazing have a significant effect on the overall condition of rangeland plants in the Mokhotlong district. The south-facing slopes support slightly taller plants than the north-facing slopes, and this pattern was consistent across elevations. The presence of grazing density suppresses the plant growth (shorter plants) in the rangeland ecosystem and the increase in grazing from low, medium, and high is likely to result in loss of vegetation.

The main landscape variable that had a significant effect on plant species richness and diversity was elevation. Both plant species richness and diversity were higher between 2275-2900 m a.s.l (low elevation) and lower between 2901-3090 m a.s.l (higher elevation). The low grazing density, and interaction of aspect and elevation had no consequence on the plant species richness and diversity.

The absence of grazers contributed to the proliferation of herbaceous plants, both palatable (e.g. *Themeda triandra*) and unpalatable (e.g. *Merxmuellera disticha*). The low grazing density had no significant effect on the percent cover of palatable plants. The presence of a higher density of grazers may eliminate competition from herbs, which directly enhance the growth of undesirable woody plants. Therefore, future grazing management should carefully keep livestock grazing pressure at a low level to maintain the ecological functions of rangeland ecosystems while still supporting the livelihood of farmers.

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APPENDICES

A detailed protocol for data collection

Assessing the effects of landscape features and grazing on grazing lands of Mokhotlong district, Lesotho – Protocol for data collection

Mokitjima James Tsilane

Background of the project and aims of the study

The livelihoods of farmers in the highlands of Lesotho depend on optimizing animal productivity, and healthy soils and plants in highly variable environments. It is of great importance that land managers and farmers have the fundamental knowledge and understanding of their terrestrial systems. This provides a premise to strategically manage grazing and achieve desired goals of the farming community without degrading the land. To this end, studies have inferred that herbivory is the main cause of change in rangeland vegetation. Other investigators have understood the variability of climatic factors as the key agent of change (Fuhlendorf et al. 2001).

However, for the purposes of this study, the focus is on the variable landscape in mountainous rangelands of Lesotho as a primary change agent in the productivity of plant communities. This study aimed to investigate the effects of varying landscape features and the relative contribution of herbivory on rangeland vegetation. These entailed exploring patterns of relationships between rangeland plants, landscape features, and grazing livestock with an emphasis on plant type, plant form, species composition, forage production, species richness, response to grazing, and total cover (Liao & Clark 2018).

Sampling design

The project site of Phapong, Figure 1, in the Mokhotlong district of Lesotho is mountainous grazing land that covers a total land mass of 1048 ha. Elevation in the project site ranges between 2775 m and 3090 m above sea level (a.s.l). The main variability in environmental conditions occurs from north-facing slopes to south-facing slopes. For the purposes of the study design, the area will be divided into areas at low elevation (between 2775 and 2900 m a.s.l.) and high elevation (over 2901 m a.s.l.), on different aspects, north (N) and south (S). Thus, four main strata will be defined: low elevation area on N-facing slopes (LEN), low elevation area on S-facing slopes (LES), high elevation areas on N-facing slopes (HEN), and high elevation areas on S-facing slopes (HES).

The management unit describes a portion of land in the project site that is likely to experience the same grazing pressure under the current management system and location of cattle post huts, as shown in Figure 1 below. Each management unit comprises all four strata of LEN/S and HEN/S. Within each landscape stratum, 2 randomized sampling points will be generated in each stratum using the sampling design tool in ArcGIS 10.5. This makes a total of 8 sampling points located at least 100 m apart in each management unit. Data will be collected for 5 days within the month of June on a total of 24 sampling points in the project site.

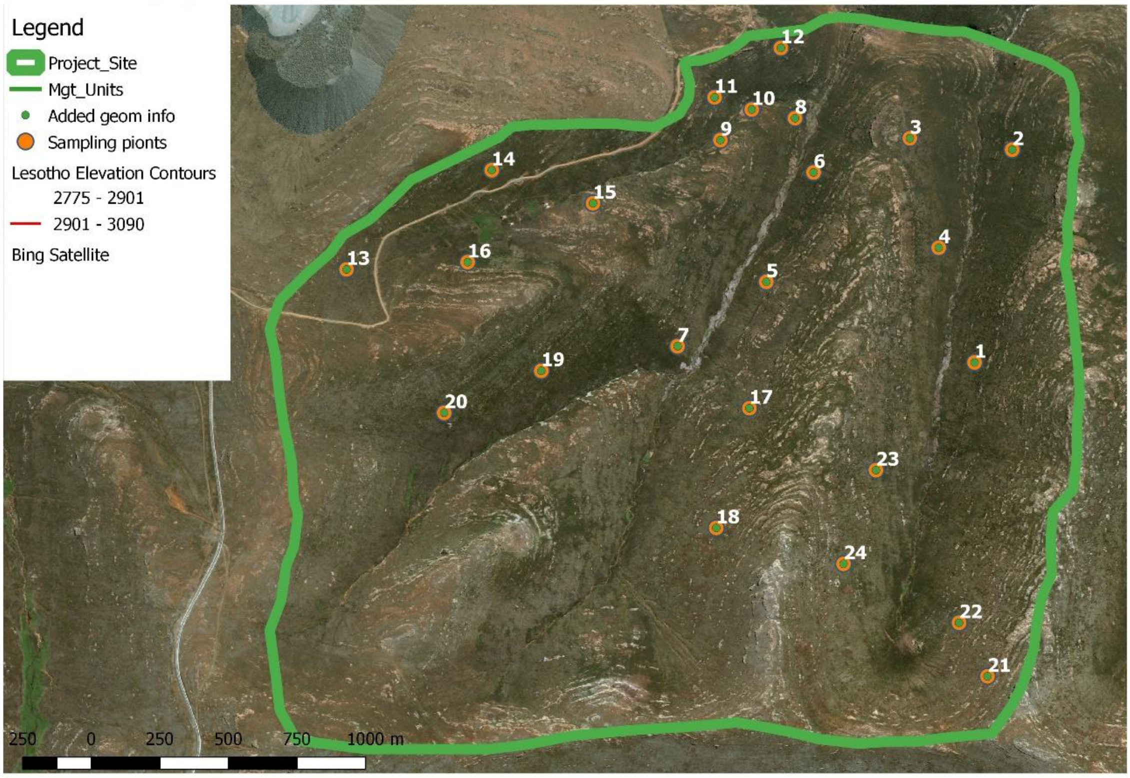

Figure 1. The project site of Phapong in the Mokhotlong district of Lesotho.

Data collection

At each sampling point, a 10 m transect line will be established perpendicular to the orientation of slope, as shown in Figure 2. Along the transect, the measurements are taken in four quadrats (0.1 m^2) placed sequentially at a 3 m interval (Schmutz et al. 1982). The data on percent cover of each plant species is visually estimated based on the proportion of the quadrat occupied and is recorded on the data form provided. The count of sheep and/or goats pellets will be recorded as none (0), low (< 20), medium (20-40), high (>50) to estimate herbivory density.

SAMPLING POINT:

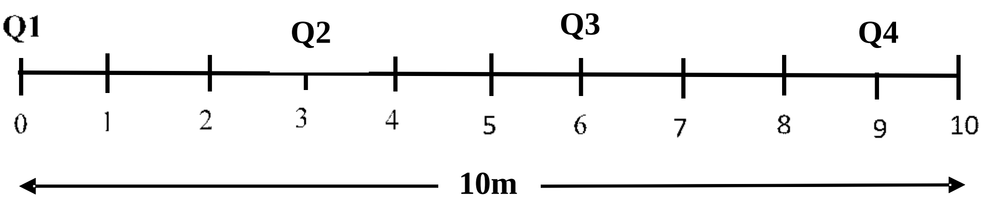

Figure 2. 1-10m tape measure at each sampling point.

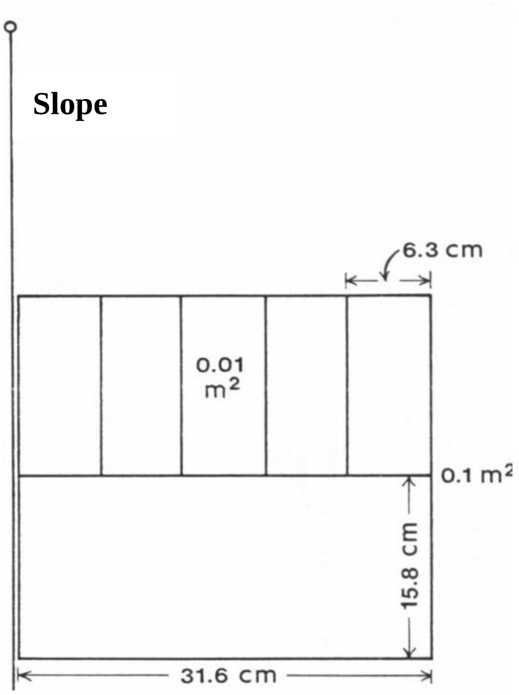

Figure 3. Quadrat placed perpendicular to the slope.

DPM

Figure 4. DPM for estimating biomass.

A disc pasture meter (DPM) will be used to estimate forage production data of each sampling point, Figure 4. 100 DPM readings will be recorded along the same transects used for recording the botanical composition and basal cover of the vegetation (i.e. every 10 cm). The measurements can be taken consistently to one or the other side of the transect line. Readings will record the height of the grass sward in cm, and a conversion factor will be used to estimate herbaceous biomass production (Zambatis et al. 2006).

Materials

- DPM – for assessing foliar biomass of plant community
- Field sheets, pencil, and eraser for labeling bags indicating site, date, plant species and collector name, to record data from sampling points
- m^2 quadrat for assessing species composition and cover
- Permanent marker – for labeling bags indicating site and date
- Tape measure 25 m long for establishing transect line
- Camera – to take pictures of the site at different landscape features
- GPS devise for recording coordinates of sampling points and elevation
- Clinometer for measuring the slope

Table 1. Percent cover of plant species and other surfaces in the study area. The dot (.) means the standard error (StdErr) could not be calculated because of only one sample *of Merxmuellera drakensbergensis.*

Species	Mean	StdErr
Merxmuellera disticha	25.2	1.8
Merxmuellera drakensbergensis	40.0	.
Festuca caprina	25.1	2.4
Ficinia filfomis	7.5	1.4
Pennesetum thubergii	29.5	5.1
Themeda traindra	46.2	3.3
Crassula pellucida	6.0	1.4
Gymnopentzia bifurcata	32.9	6.4
Helychrisium trilineatum	19.3	3.2
Chrysocoma ciliata	15.9	2.0
Eumorphia sericea	30.0	18.0
Pentachistis oreodoxa	10.9	2.0
Helichrysum montanum	15.0	3.6
Passerina montana	23.3	3.8
Helichrysum sessiloides	12.0	4.5
Oxalis obliquifolia	22.5	6.0
Cyprus marginatus	7.3	1.6
berkheya sedifolia	1.3	1.3
Bare	17.1	1.7
Litter	10.9	1.3
Rock	11.8	1.6

Table 2. Sampling points and their co-ordinates

Point id	Longitude_E	Latitude_S
1	28.8893	-29.0278
2	28.8907	-29.0199
3	28.8869	-29.0194
4	28.8879	-29.0235
5	28.8815	-29.0248
6	28.8833	-29.0207
7	28.8782	-29.0272
8	28.8826	-29.0187
9	28.8798	-29.0195
10	28.8809	-29.0184
11	28.8796	-29.0179
12	28.8820	-29.0161
13	28.8658	-29.0244
14	28.8712	-29.0206
15	28.8750	-29.0219
16	28.8703	-29.0241
17	28.8809	-29.0295
18	28.8796	-29.0340
19	28.8731	-29.0281
20	28.8694	-29.0297
21	28.8898	-29.0396
22	28.8887	-29.0376
23	28.8856	-29.0319
24	28.8844	-29.0354