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# HOLISTIC PLANNED GRAZING CAN IMPROVE VEGETATION ATTRIBUTES OF THE SEMI- ARID COMMUNAL RANGELANDS OF THE LOWVELD IN THE EASTERN CAPE, SOUTH AFRICA

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**Abstract–** Most South African rangelands face widespread degradation due to poor grazing management practices. Development agents are encouraging communal livestock farmers to adopt holistic planned grazing (HPG) management as an alternative to conventional grazing. Holistic grazing is considered to enhance rangeland vegetation, secure forage for livestock and wildlife and conserve environment. Therefore, a study was conducted to examine the effects of grazing management on botanical composition, species diversity and biomass yield in the semi-arid rangelands in the lowveld region of the Eastern Cape province, South Africa. We sampled three communal-HPG (CHPG), communal-continuous (CC) grazing camps, and two adjacent commercial-rotational (CR) farms. Twenty-three herbaceous species were identified in all study sites. *Eragrostis chloromelas* and *Aristida congesta* dominated all grazing systems with more productive species such as *Themeda triandra* and *Digitaria eriantha* being more abundant at CCHPG thanCC grazing. Mean value for biomass yield in the dry season was higher in CR than CCHPG and CC. There were no significant differences (P>0.05) in NAPP, species diversity, richness and evenness. The study showed that CR grazing remains superior in biomass productivity. Nonetheless, if given enough attention, HPG can enhance vegetation conditions in degraded communal lands and improve rangeland productivity for sustainable livestock production.

## INTRODUCTION

In Africa, there is a growing interest to sustainably manage or improve deteriorating rangelands (in particular, the communal grazing lands) to maintain the ecosystems functions, and produce ecosystem goods and services on a sustainable base. In the grassland ecosystems of South Africa, two livestock production-based land use and management are widely recognized, namely commercial-rotational or communal-continuous grazing. The production systems differ in terms of available grazing resources, production objectives, management and use of the rangeland resources (Siyabulela *et al*. 2020). Commercial livestock production in South Africa is well developed, capital-intensive system raising single (Smet and Ward, 2005; Smet and Ward, 2006; Kotze *et al*., 2013) or mixed livestock species primarily for commercial sales of live animals and/or their products (Siyabulela *et al*., 2020) in the local market or for export purpose. Commercial ranches are fenced and divided into paddocks to allow rotational graze and rest periods. This gives adequate time for vegetation utilisation and re-growth as well as soil maintenance after successive grazing (Sandhage-Hoffman *et al*., 2015). Grazing under rotational grazing system involves conservative stocking rates that are altered by the farmer to sustainable forage production and profitable livestock farming. Different grazing practices under commercial rotational system include deferred rotation, rest rotation, high intensity-low frequency, and short duration grazing (Holocheck, 1983). The communal livestock production system is mainly but not entirely sedentary, ranging from small to medium livestock ownership per household (Gwelo *et al*., 2015; Siyabulela *et al*., 2020). Within each community (referred to as village), grazing areas are shared by community members (who own livestock) with equal and open access rights and without temporal as well as spatial restrictions to use of the rangeland resources (Kotze *et al.,* 2013, Siyabulela *et al*., 2020). Depending on the agro-ecology zone, farmers raise mixed livestock species on vast extensive rangelands that have been continuously grazed for the entire year. Continuous grazing gives little opportunity to rest grazing lands for vegetation recovery or to apply grazing land management practices that promote utilization and resting. Continuous grazing has also been reported to induce selective grazing that will eventually cause rangeland deterioration or degradation (Smet and Ward, 2006; Fantubi and Dube, 2008; Tefera, 2013). With no exception in the Eastern Cape province, a substantial portion of the grazing land that has been communally used for raising diverse livestock species has suffered deterioration or degradation.

Since the last few decades, another land use practice known as Holistic Planned Grazing™ (HPG) has been introduced in communal and commercial farms. However, this approach has received little attention to the management and use of communal grazing lands. The practice uses high stocking density to mimic nature and purports to have positive long-term effects by restoring degraded rangelands and adapting to the changing climate. Thereby having long-term positive effects on rangelands and the animals. Livestock grazing in continuous, rotational, and HPG may show great differences that may result in spatial variations in vegetation composition. Indeed, there are mixed views between farmers and scientists on the benefits of HPG over conventional grazing methods (McIvor, 2013). Some ecologists agree that HPG may be a suitable practice in communal areas because it does not encourage destocking for the poor farmers, yet it can restore degraded rangelands. However, in South Africa changes in the grass layer variables between the HPG and communal-continuous and commercial-rotational management have not been documented. Grass biomass determines grazing capacity and animal feed supply, provides protective cover to the soil, regulates nutrient cycling and soil moisture. More so, the abundance of key grass species or functional groups is another indication of rangeland health that must be quantified because individual species or functional groups may vary in biomass production, grazing values, acceptability and also have contrasting ecological benefits and adaptation

Therefore, the study objectives were to investigate the species composition, diversity and above ground herbaceous yield under HPG and conventional grazing at three landscape positions (upper, middle and lower) in the lowveld regions of the Eastern Cape province, South Africa.

## MATERIALS AND METHODS

### Study Site

The study was conducted in sweetveld grasslands of the Eastern Cape province of South Africa covering Mceula communal lands and two adjacent commercial farms (Blue Boulders and Fordyce) (Figure 1). The study sites are located in Enock Mgijima local municipality characterised by dry inland climate with a mean annual rainfall of 413 mm per year occurring mainly in summer (October to March). Grasses dominate the vegetation with woody plant encroaching some parts of the grazing lands. The dominant grass species are *Themeda triandra, Digitaria eriantha, Microchloa caffra, Eragrostis chloromelas, Aristidaa congesta, Cymbopogon pospischilii* and *Heteropogon contortus*. The woody vegetation is dominated by nitrogen-fixing trees mainly that of *Vachellia* and *Senegalia spp.* The soils are mainly developed from shales and generally shallow, little leached, poorly structured and immature as soil development is limited by low and erratic rainfall.

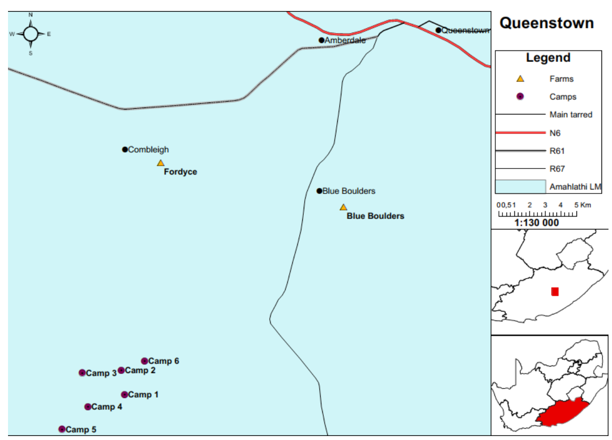


**Fig. 1.** Map showing the study area

Because of a history of absence of prescribed management practices and the resultant overgrazing, vast areas of Mceula communal land are in poor condition with many parts subject to soil erosion. As a result, part of Mceula has been practicing HPG since 2013 through the help of Olive Leaf Foundation and Savory Hub to address degradation problems.

**Data Collection**

Eight farms were selected. These are: three communal - continuous (CC) grazing (Camp 4-6); three communal- holistic planned grazing (CHPG) (Camp 1-3) and two commercial ranches-rotational (CR) grazing (Blue Boulders and Fordyce) (Fig. 1). Each site was divided into three major landscape positions (upper, middle and lower). 100 m x 10 m permanent plots were established in each major landscape unit giving a total of 36 plots. In addition, two 1m x1m (1m$^2$) grazing exclosures were fenced in each site for long-term monitoring and biomass estimation. The exclosures were erected before the onset of the growing season in August 2016. The plots were approximately 50 m apart. A step point method was used to estimate the composition of the herbaceous layer from 150-points observation per plot (Mentis, 1981). Point observations one metre apart were made along two straight parallel lines (transects) 5m apart over the length of the plot. Data collection on grass species composition was carried between April-May 2017. Identification for few grass species were made in the field using A Guide to Grasses of South Africa book (Van Oudtshoorn, 1999). All the other grass species were collected with full inflorescences and other vegetative parts and sent to South African National Biodiversity Institute (SANBI) Herbarium in Pretoria for identification. Vegetation diversity was calculated using Shannon's diversity index (Krebs, 1989), while evenness was calculated using the formulae adopted by Teka *et al*. (2013). All herbaceous vegetation within each exclosure was harvested to a stuble height towards end of the growing season for aboveground biomass determination (ANPP). Standing vegetation outside the exclosure was also harvested from ten 0.5 m x 0.5 m (0.25m$^2$) quadrates. The harvested materials were placed in paper bags and dried to constant weight at 75°C for 48 hours and weighed to determine the dry biomass yield. In the first year herbaceous biomass was harvested during the dry season (August) and in the second year, it was harvested towards the end of the growing season (March).

**Experimental design and statistical analysis**

Varied cross-site comparisons were used to assess the relative impacts and benefits of the three grazing management within the grassland biome. The statistical model was generally 3 landscape positions (upper, middle and lower) and three land management systems: continuous-communal or HPG-communal and rotational- commercial using unequal replications non-randomised blocks. Data were analysed using the Mixed Model procedure of SAS (2007) to test the effects of grazing management and landscape position on biomass production, species composition, basal cover, diversity, richness and evenness. Mean separation was conducted using the PDIFF procedure of SAS (2007).

## RESULTS

**Herbaceous layer**

In Table 1, a total of 23 grass species were identified in all study sites of which 3 were annuals, 15 were long-lived perennials and 5 were short-lived perennials. Twenty-two percent of the total grasses were classified as highly palatable species, 30 % as moderately, 22 % as less desirable and 26 % as virtually unpalatable species. A species is referred to as dominant when the average frequency exceeds 12 % at least in one land use system and is considered common when its average frequency falls within >5-12 % (Siyabulela *et al*., 2020). Based on these definitions the following grass species were regarded as common or dominant: *Aristida congesta, Chloris virgata, Cynodon incompletus, Digitaria eriantha, Eragrostis chloromelas, Heteropogon contortus, Microchloa caffra, Panicum stapfianum, Sporobolus stapfianus, Themeda triandra, Tragus koeleriorides, Urochloa panicoides* and Forb spp.

**Composition of common and dominant herbaceous species**

The abundance of some species varied greatly between land management systems or stocking rates within each land use system (Table 2). The abundance of *A. congesta*, was significantly affected by land management (P=0.003) but without significant effect of landscape position and interaction of the two factors. Accordingly, CC land had greatest abundance of *A. congesta* followed by the CHPG (Table 2), whereas with regard to landscape, lower slopes had greater abundance in all land management (mean:28 %) than the middle (15 %) and upper slopes (18 %). Similarly, both land management (*P = 0.05*) and landscape (*P = 0.02*) affected the occurrence of *C. incompletus* being highest in CR land use and in the upper slope (mean: 15 %) compared to the middle (mean: 5 %) and lower slope (7 %). For *D. eriantha*, the general

**Table 1.** Life forms, desirability, ecological grouping and percent herbaceous composition in the sweetveld in the different grazing management practices

| Species | Life form | Palatability | Ecological group | Management Practice | | |
|---|---|---|---|---|---|---|
| | | | | CR | CHPG | CC |
| *Aristida congesta* | SP | MA | Inc IIc | C | D | D |
| *Aristida diffusa* | LP | LA | Inc IIc | R | - | - |
| *Chloris virgate* | WP | MA | Inc IIc | Pr | Pr | C |
| *Cynodon incompletus* | LP | HA | Inc IIc | D | R | C |
| *Cymbopogon pospischilii* | LP | PA | Inc I | Pr | R | Pr |
| *Digitaria eriantha* | LP | HA | Dec | D | D | C |
| *Eragrostis barbinodis* | LP | HA | Inc IIc | - | Pr | Pr |
| *Eragrostis curvula* | LP | PA | Inc IIb | Pr | R | Pr |
| *Eragrostis chloromelas* | LP | MA | Inc IIa | D | D | C |
| *Eragrostis gummiflua* | LP | PA | Inc IIc | - | Pr | - |
| *Eragostis obtuse* | SP | LA | Inc IIc | Pr | Pr | R |
| *Eustachys paspaloides* | LP | HA | Dec | Pr | R | R |
| *Forbs* | A | PA | Inc IIc | C | C | C |
| *Heteropogon contortus* | LP | LA | Inc IIa | Pr | C | Pr |
| *Hyparrhenia hirta* | LP | LA | Inc IIa | - | - | Pr |
| *Microchloa caffra* | LP | PA | Inc IIc | Pr | D | D |
| *Panicum stapfianum* | LP | MA | Dec | C | Pr | C |
| *Sporobolus stapfianus* | LP | MA | Inc IIc | D | R | D |
| *Themeda triandra* | LP | HA | Dec | Pr | C | Pr |
| *Trichoneura grandilumis* | SP | PA | Inv | Pr | R | - |
| *Tragus koeleriorides/ T. berteronianus* | A | LA | IncIIc | Pr | R | C |
| *Urochloa panicoides* | A | MA | IncIIc | R | Pr | D |
| *Melinis repens* | SP | MA | IncIIc | - | Pr | Pr |

A= Annual, SP= Short-lived Perennial, LP= Long-lived Perennial, HA= Highly Palatable, MA= Moderately Palatable, LA= Less Palatable, PA= Poorly Palatable, Pr= Present (< 1%), Dec = Decreaser species, Inc = Increaser species, Inv = Invader. RC – commercial-rotational, CC – communal-continuous, CHPG – communal-holistic planned grazing.

**Table 2.** Composition (%) of common grass species, in relation to land management systems

| Grass Species | CR | CC | CHPG | Significance |
|---|---|---|---|---|
| *Aristida congesta* | $8.2^{a}$ ±6.9 | $34.1^{a}$ ±3.6 | $19.4^{b}$ ±3.6 | 0.003 |
| *Chloris virgata* | - | 9.7±2.5 | - | 0.74 |
| *Cynodon incompletus* | $15.2^{a}$ ±3.2 | $7.7^{b}$ ±2.1 | $4.3^{b}$ ±3.1 | 0.05 |
| *Eragrostis chloromelas* | $25^{a}$±3.1 | $10^{b}$±2.8 | $2^{a}$±2.5 | 0.002 |
| *Digitaria eriantha* | $17^{a}$ ±2.7 | $11^{a}$ ±2.3 | $14^{a}$ ±2.2 | 0.28 |
| *Heteropogon contortus* | - | - | 10.8±2.1 | 0.29 |
| *Microchloa caffra* | - | $17^{a}$ ±3.3 | $13.5^{a}$ ±2.0 | 0.57 |
| *Panicum stapfianum* | $7.9^{a}$ ±1.9 | $7.6^{a}$ ±1.6 | - | 0.93 |
| *Sporobolus stapfianus* | $18.1^{a}$ ±3.9 | $14.0^{a}$ ±5.7 | $3.8^{b}$ ±3.7 | 0.04 |
| *Themeda triandra* | - | - | 11.4±1.6 | 0.23 |
| *Tragus koeleriorides/ T. berteronianus* | - | $7.3^{a}$±1.3 | $2.6^{a}$ ±2.0 | 0.16 |
| *Urochloa panicoides* | $3.3^{a}$ ±2.19 | $13.4^{a}$±1.7 | - | 0.01 |
| Forbs | $8^{a}$ ±1.6 | $8.9^{a}$ ±1.3 | $7^{a}$ ±1.3 | 0.58 |

[a,b,c] Means in the same row with different superscripts are significantly different (*P < 0.05*).
RC – commercial-rotational, CC – communal-continuous, CHPG – communal-holistic planned grazing.

model showed significant difference (*P < 0.05*) between land management systems, and a presence of land management x landscape interaction effect (P = 0.03). The statistical difference between land management was limited only to the lower slope being highest in the CR (mean: 21.5 %)than the CC (mean: 4.2 %) and CCHPG (mean: 8.0 %).

The proportion of *E. chloromelas* was significantly lowest (*P < 0.05*) in the CC and in the upper slope of all management system (mean: 12 %) compared to the other landscape positions (mean: 21 %). Both *Microchloa caffra* and *Tragus koeleriorides* were recorded only in the communal grazing systems, whereas *H. contortus* and *Themeda triandra* were recorded only in the CHPG. The abundance of *S. stapfianus* was significantly greatest (*P <0.05*) in the CHPG and highest (*P < 0.05*) in the upper slope of the CC and CR grazing land use. The occurrence of *U. panicoides* varied between land management systems (P = 0.01) and these significant variations were limited to the lower and middle slopes of the CC and CR grazing systems.

**Life form, palatability and ecological groups**

The proportion of annual and short-lived perennial grasses was significantly lowest (P < 0.01) in CHPG land use. In all land use, the abundance of short-lived perennial grasses was significantly (P = 0.05) greatest in the upper slopes (mean: 24 %) and lowest (mean: 16 %) in the lower slopes. Long-lived perennial grasses had lowest (P < 0.0001) abundance in the continuous grazing land use system. Highly and virtually unpalatable species were more abundant (P < 0.05) in the CHPG than continuous grazing camps, whereas moderately (P = 0.01) and less palatable (P = 0.06) species were more copious in the continuous grazing camps. As for ecological groups, Increaser I, IIa and invader species were recorded only in CHPG camps. Increaser IIb and IIc species occurred more abundantly in the continuous grazing camps than CHPG camps.

In Table 3, the proportion of annual and short-lived perennial grasses was significantly lowest (*P < 0.01*) in the CHPG land use. In all land use, the abundance of short-lived perennial grasses was significantly (*P = 0.05*) greatest in the upper slopes (mean: 24 %) and lowest (mean: 16 %) in the lower slopes. Long-lived perennial grasses had lowest (*P < 0.0001*) abundant in the CC land use system. Highly and virtually unpalatable species were more abundant (*P < 0.05*) in the CCHPG than the CC or CR farms, whereas moderately (*P = 0.01*) and less palatable (*P = 0.06*) species were more copious in the CC farms. As for ecological groups, Increaser I, IIa and invader species were recorded only in the CHPG farm. Increaser IIb and IIc species occurred more abundantly in the CR or CC farms, respectively than CHPG farm.

**Species richness, diversity and evenness**

Shannon's diversity index, species richness and evenness were not affected (*P > 0.05*) by grazing

**Table 3.** Mean relative abundance (%) of life forms, desirability and ecological groups in the three land management systems

| | Management Practice | | | |
|---|---|---|---|---|
| | CR | CHPG | CC | Significance |
| Lifeforms | | | | |
| Annual | $22.6^{ab}$±2.4 | $17.5^{b}$±1.8 | $25.4^{a}$±1.8 | 0.01 |
| Short-lived perennials | $21^{a}$±2.1 | $13.6^{b}$±1.5 | $25.1^{a}$±1.5 | <.0001 |
| Long-lived perennials | $64.8^{a}$±3.0 | $69.8^{a}$±2.5 | $50.7^{a}$±2.5 | <.0001 |
| Palatability | | | | |
| Highly palatable | $23.0^{ab}$±1.8 | $28.3^{a}$±1.8 | $22.9^{b}$±1.5 | 0.03 |
| Moderately palatable | $43.4^{ab}$±3.2 | $32.6^{b}$±2.6 | $42.6^{a}$±2.6 | 0.01 |
| Less palatable | $17.1^{ab}$±1.7 | $15.4^{b}$±1.2 | $19.8^{a}$±1.3 | 0.06 |
| Virtually unpalatable | $21.7^{ab}$±2.5 | $25.6^{a}$±2.1 | $18.8^{b}$±2.1 | 0.08 |
| Ecological groupings | | | | |
| Ecological groups | | | | |
| Decreasers | $23.4^{a}$±2.5 | $24.0^{a}$±2.0 | $21.6^{a}$±2.0 | 0.70 |
| Increaser I | - | 9.9±0.8 | - | 0.63 |
| Increaser IIa | - | 10.6±0.7 | - | 0.57 |
| Increaser IIb | $20.2^{a}$±1.4 | $15.2^{b}$±1.2 | $17.8^{ab}$±1.3 | 0.03 |
| Increaser IIc | $46.6^{b}$±3.2 | $45.9^{b}$±2.6 | $66.7^{a}$±2.6 | 0.0004 |
| Increaser III | - | - | - | - |
| Invader | - | 10.1±7.4 | - | 0.41 |

$^{a,b,c}$ Means in the same row with different superscripts are significantly different (*P < 0.05*).

RC – commercial-rotational, CC – communal-continuous, CHPG – communal-holistic planned grazing.

management systems, but a slightly greater species richness value was recorded in CHPG (9.8) than the CR (8.8) and CC (8.9) grazing systems. Landscape positions showed a significant effect on diversity, being greater in the middle than the lower and upper slope positions of all farms (Table 4). Landscape position also showed a significant effect on species richness ($P < 0.01$), but this interacted significantly with land management systems showing greatest value in the middle or upper slopes than the lower slopes only in the CHPG and CR farms. Management x slope interaction affected ($P < 0.05$) species richness.

### Herbaceous biomass yield

The mean values for available grass dry matter (DM) yield showed a significant ($P < 0.0001$) order of: CR (910 kgha$^{-1}$) > CCHPG (261 kgha$^{-1}$) > CC (109 kgha$^{-1}$) (Fig 2). Net above ground primary production (NAPP) was within the range of 809 kgha$^{-1}$ – 890 kgha$^{-1}$(Fig 2). Landscape position significantly interact with land management to influence the available DM yield. Middle slope recorded the highest available grass DM yield in both CR and CHPG whereas in the CC, both middle and upper slopes had higher DM yield than lower slope. Annual net primary production of grass was not significantly affected by land management and landscape position although lower and middle slopeshad slightly greater yield than upper slopes (Fig. 3).

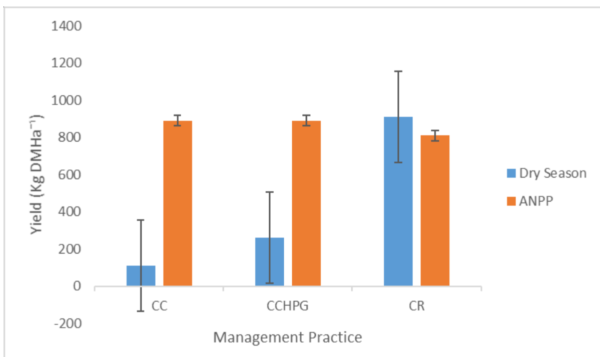


**Fig. 2.** Mean herbaceous biomass yield (± standard error) recorded under the three management systems

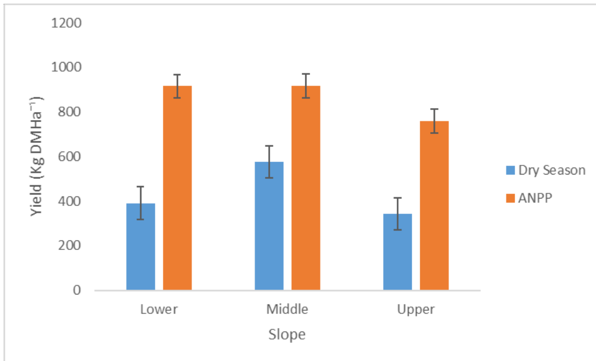


**Fig. 3.** Mean herbaceous biomass yield (± standard error) recorded under the three main landscape positions

## DISCUSSION

### Herbaceous species composition

The grass species identified in the study partially corresponds with those reported in earlier studies (Maziko, 2017; Siyabulela *et al.*, 2020) in similar ecologies. The significantly higher proportion of increaser II species in the communal rangeland including *A. congesta,C. dactylon, C. virgata, E. chloromerasT. berteronianus*, and *U. panicoides* suggests rangeland with poor veld condition which is overgrazed and is degrading (Smet and Ward, 2005; Kgosikoma *et al.*, 2015) justifying the introduction of HPG as a restoration measure to part of the rangeland. *A congesta* and *T. berteronianus* have been shown to increase under heavy grazing (Abule *et al.*, 2005). *Aristida* and *Chloris* spp. are grass species known to have poor forage value (Van Oudtshoorn, 1999), good self-seeding ability, drought tolerance and spreading capacity (Jawuoro *et al.*, 2017) hence their abundance.The occurrence of annuals was greater in CC grazing land than the other land-use systems could be an indication that palatable perennial grasses were replaced with annual grasses on the communal grazing land which was subjected to higher grazing pressure than the other two land-use sites. The study indicates high proportions of highly palatable and productive grasses in HPG

**Table 4.** Mean species richness (S), diversity (H) and evenness (E) in the upper, middle and lower landscape positions

| Landscape position | S | H | E |
|---|---|---|---|
| Upper | 9.0±0.35$^{a}$ | 1.6±0.08$^{a}$ | 0.8±0.02$^{a}$ |
| Middle | 10.3±0.35$^{b}$ | 1.9±0.08$^{b}$ | 0.8±0.02$^{a}$ |
| Lower | 8.3±0.35$^{a}$ | 1.6±0.08$^{a}$ | 0.8±0.02$^{a}$ |

Means with different superscripts differ significantly ($P < 0.05$) in each study site land-use, an observation also made by Peel and Stalmans (2018) in their study in Zimbabwe. Forbs were prevalent in CC farms where continuous grazing occurred. Similar observations were made by Jawuoro *et al*., (2017); this may be ascribed to heavy grazing where forbs and annual grasses replace palatable perennial grasses. The high occurrence of *D. eriantha* in all grazing systems including those with heavy stocking rates was unexpected. The frequency of *T. triandra* was relatively high in all grazing systems. Some report of numerous studies in the arid and semi-arid environments where highly palatable species are prevalent in grazing lands subject to light grazing pressure (Tefera *et al*., 2010, 2013). Greater abundance of increasers in CC grazing is expected suggesting that prolonged overgrazing may have taken place to cause significant changes in the species. *Cynodon species* was dominant in CR grazing. This agrees with the observation that in the Grassland Biome of South Africa, it is the key species in rangeland that is severely overgrazed. *Heteropogon contortus,* a desirable species was common in the CHPG land use on patches of rocky soils.

**Species richness, diversity and evenness**

There were no significant statistical differences among management systems in species diversity, richness and evenness. This is consistent with the predictions of resilience to influence grazing on diversity of systems which have long histories of grazing, especially in the arid and semi-arid ecosystems (Mertzger *et al*., 2005). Though the diversity of grass species among grazing management systems was approximately uniform, some slight differences existed. CHPG had higher species richness than CC, which shows a positive outcome of holistic planned grazing implementation. Given that the HPG has been in place for a few years the results are striking. The relatively rapid response suggests that this communal rangeland is fairly resilient and can quickly recover when subjected to appropriate grazing management practices. A similar observation was made by Odadi *et al*. (2017) in Kenya. Moreover, these improvements were evident despite higher stocking rates in CHPG land use, suggesting that the benefits of planned grazing can outweigh any undesirable effects of increased stocking rate. This is significant because increased stocking would normally be expected to have negative effects on vegetation (Fynn and O'Connor, 2000). Higher plant diversity in areas under CHPG land use could be partly attributed to more even distribution of grazing pressure and reduced forage selectivity by concentrated livestock herds.

The introduction of HPG as a restoration measure could have achieved this and also the results suggest that high species diversity of herbaceous plants can be achieved by using HPG in degraded rangelands. Middle and upper slopes had higher species richness and diversity. This corroborates with Baldock and Smith (2009) who reported higher species richness and diversity upslope.

**Herbaceous biomass production**

Drought is common in the sweetveld (lowveld). Therefore, the relatively low yields observed could be attributed to low amount of rainfall received per annum and its distribution. The significant differences in the biomass yield among the management systems differ from the findings by Briske *et al.* (2008), Carter *et al*. (2014) and Peel and Stalmans, (2018). They state that HPG, rotational grazing and continuous grazing have comparable plant production. The authors also concur with Yayneshet and Tredyte (2015) in their meta-analysis of studies done in sub-Saharan Africa rangelands. They observed that herbaceous biomass in the livestock ranches and game reserve was similar to the communal grazing areas. Rotational grazing and CHPG camps had higher grass dry season DM yield than CC camps. This may be attributed to that rotational and HPG land use allow vegetation longer recovery period which results in high biomass accumulation in contrast to continuous grazing (Teague and Downhower, 2003) and rotational grazing also reduces selectivity on forage species and is expected to benefit them (Kirkman and Moore, 1995; Teague and Dowhower, 2003). Selectivity by grazing herbivores can affect the composition and structure of a plant community through altering competitive interactions. In CC, heavy grazing reduces the occurrence of palatable species, which can cause long-term reduction in vegetation capacity to recover particularly after drought (Gamoun, 2014). In addition, grazing animals have unrestricted access to the whole range and this exposes plants to more frequent defoliation, which can be harmful to productivity, especially during the growing season. The animals continue to graze until forage becomes inadequate to sustain them. The combination of continuous grazing, higher stocking rates, and grazing intensities put pressure on the grazing lands, resulting in the reduced production capacity of forages and their consequential contribution to the low total dry matter yield. The heavy grazing by goats and sheep in the CC land use also maintains rangeland vegetation at low levels and can also limit primary productivity. These effects translate into a reduction in total vegetation cover and species diversity, promoted by selective grazing (Gamoun *et al*., 2012)

The deterioration of the communal grazing land was evident in the low herbaceous biomass production and also the presence of *Vachellia karoo.* Forage yield is strongly affected by management (Oomen *et al*., 2016). However, biomass production is considered an unreliable indicator of rangeland deterioration as it can recover in a relatively short period (Kgosikoma *et al*., 2015). The recorded low dry season biomass yield in CC could also negatively impacts oil physical and chemical properties. Once the soils are affected, it leads to a reduction in herbage productivity hence ANPP. Due to low biomass production, there will be low soil organic matter content and low soil fertility resulting in fragile soils. Generally, the soils in the swerved are less developed, shallow and hold little amounts of water which reduces herbage productivity in such areas. Hence, the little biomass produced would be overused due to high grazing pressure as observed in the continuously grazed land.

The greater dry season biomass yields observed in the middle and upper slopes than lower slopes may be attributed to animals aggregating on the lower lying areas close to watering points and also that low lying areas usually have better forage due to higher soil moisture and nutrient content (Alemayehu *et al.,* 2013; Zhao *et al.,* 2019).

## CONCLUSION

Grazing management systems have great ecological importance as they affect the productivity of rangelands. CR grazing remained superior in biomass productivity. Nonetheless, the study demonstrated that, if given enough attention, HPG can enhance vegetation conditions in degraded communal lands and improve rangeland productivity for sustainable livestock production. Therefore, measures aimed at restoration and sustainable utilisation of rangelands should therefore consider livestock as an integral part of rangeland ecosystems, and therefore their exclusion as an ecological imbalance. This implies that flexibility to allow livestock movement is an indispensable component of sustainable range management in the drylands. Any management which would foster the presence of more highly palatable species would also be advantageous.

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