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Short-Term Effect of Grazing Exclusion and Uncontrolled Grazing on Species Abundance, Dry Matter Yield and Nutritive Value in an Invaded Area by *Euryops floribundus* in the Eastern Cape, South Africa

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Abstract

Grazing exclusion (GE) is the most effective rangeland restoration technique which facilitates species diversity and forage quality. This study aimed at assessing short-term impact of GE and continuously grazed rangeland on relative frequency, dry matter yield and nutritive value of dominant grasses in an area invaded by *Euryops floribundus*. A plot of 2.5 ha was measured and the boundaries demarcated using tape measure and steal pins, the plot was further divided into two subplots of 1ha each which were 5 m apart. One subplot was fenced and protected from grazing livestock, while one subplot was grazed continuously and not fenced. Three parallel belt transects of 100 m × 2 m with 3 m apart were laid out in both subplots. Woody plants occurring within the transects were identified and recorded to determine density. In each subplot, a 0.25 m^2 quadrant measuring was thrown randomly to take detailed records on plant species, relative frequency of species and herbage biomass. Four dominant species at the two sites were harvested to determine the nutritive value. Results indicate that grazing exclusion (GE) facilitates grass species diversity, subsequently sixteen and thirteen grasses species were recorded in the GE and uncontrolled grazed (UG) sites, respectively. *Eragros-*

tis chloromelas (21.7%), and *Themeda triandra* (13.2%) had high relative frequencies in the GE site. Highest biomass production was recorded in the GE site (1400 kg·ha^{-1}) compared to UG site (1102 kg·ha^{-1}). Crude protein content was relatively lower at UG site (5.4% - 5.8%) as compared to GE site (7.2% - 7.8%). It was concluded that, GE showed a positive impact on a relative frequency (%), dry matter yield and crude protein content. UG creates a conducive environment for *Euryops* recruitment. Further studies are required to examine the impact of GE in long-term trial setup.

Keywords

Dry Matter Yield, Crude Protein, Nutritive Value, Relative Frequency

1. Introduction

Grassland biome covers approximately 40% of the earth's surface [1] [2]. Exploitation of grassland resources have become a major concern towards achieving United Nations' Sustainable Development Goals [2]. Gradual deterioration or depletion of grazing resources through overgrazing and spread of undesirable plants were the most reported constraints hindering food security and livelihoods of communal farmers [3] [4]. According to [5], rangeland deterioration is associated with socio-cultural behaviour (anthropogenic activities) environmental factors and ecological processes such as the interaction between species communities and seed dispersal.

Eastern Cape Province in South Africa is not an exception, invasion of *Euryops floribundus* has been reported as a primary threat on the sustainability of livestock production and livelihood of communal farmers [6] [7] [8]. The grazing management system employed and spread of *Euryops floribundus* in the communal areas have changed native forage quality, nutritive value of herbaceous species, the hydrology and soil properties leading to land degradation [6] [8] [9].

[2] indicated that rangeland conservation is vital for sustainable livestock production in harmony with the United Nations' Sustainable Development Goals. For restoration of rangelands, grazing exclusion is one the rangeland management practices which influences species diversity, forage quality and quantity [5]. Grazing systems such as the continuous or rotational grazing have a great impact on vegetation communities influencing forage quality and quantity. Hence, knowledge on the dynamics of forage quality and quantity is critical because native vegetation constitute the main feed consumed by grazing animals in communal areas [10] [11]. The sustainability of rangelands requires a broader understanding on how grazing management systems may influence forage quality and diversity [10] [12].

Inappropriate application of rangeland management practices such as uncontrolled grazing has a profound effect on responses of herbaceous layer in terms of species abundance [10] [12] [13] and nutritive value [10]. Therefore, understanding the nutritional status of native grasses, their dry matter yield and the dynamics of plant species in a community is vital for sustainable livestock production [10]. Changes of weather patterns also create favourable conditions to alien plants, as a result, many grassland ecosystems in Africa are experiencing the introduction and spread of species previously unknown in the grazing communities [14].

The presence of such woody invasive species, most of which undesired by grazing animals is posing a danger to the sustainability of livestock production since their presence is negatively affecting the growth and existence of desired herbaceous species [14]. In the current circumstance, there is the need to understand the effect of the grazing management system employed and the presence of invasive woody species on relative frequency, dry matter yield and nutritive value of the herbaceous layer in grassland communities in the Eastern Cape Province. The objective of this study therefore is to evaluate the short-term impact of grazing exclusion and continuously grazed rangeland on nutritive value, relative frequency and biomass production of selected grass species in the invaded grassland communities.

2. Methods and Materials

2.1. Site Description

The study was conducted at Mxe communal rangelands in Cala, Sakhisizwe local municipality under the Chris Hani District of the Eastern Cape Province. The area lies at 31˚32'39.17"S, 27˚37'22.73"E, with an elevation of 4017 m (**Figure 1**).

The mean annual rainfall ranges between 430 mm - 790 mm, while the mean annual temperature varies from 14.7˚C to 37˚C [15]. Tsomo grassland is the vegetation type, which is characterised by gently-sloping lowland plains intersected by mountains [15]. The herbaceous layer is dominated by white grasses which are often grazed short or replaced by *Euryops floribundus*. Soils were derived from two parent material namely mudstone and shale [15]. Grazing capacity for the areas ranged from 4 - 8 hectare per large stock unit [16].

2.2. Research Layout

Research site was chosen based on vegetation uniformity and land use type being grazing [17]. In November 2018, a plot of 2.5 hectares was measured and boundaries demarcated using a tape measure and metal pegs. The plot was further divided into two subplots, each measuring 1ha with the two subplots separated by 5 m. One subplot was fenced and protected from grazing livestock (*i.e.* enclosure subplot), while the other one was not fenced and left open for continuous grazing. The fenced subplot remained enclosed and not grazed for an entire year (November 2018-November 2019), for vegetation recovery. The fenced camp was identified as a grazing exclusion (GE) whereas the second subplot was unfenced and identified as an uncontrolled grazing (UG).

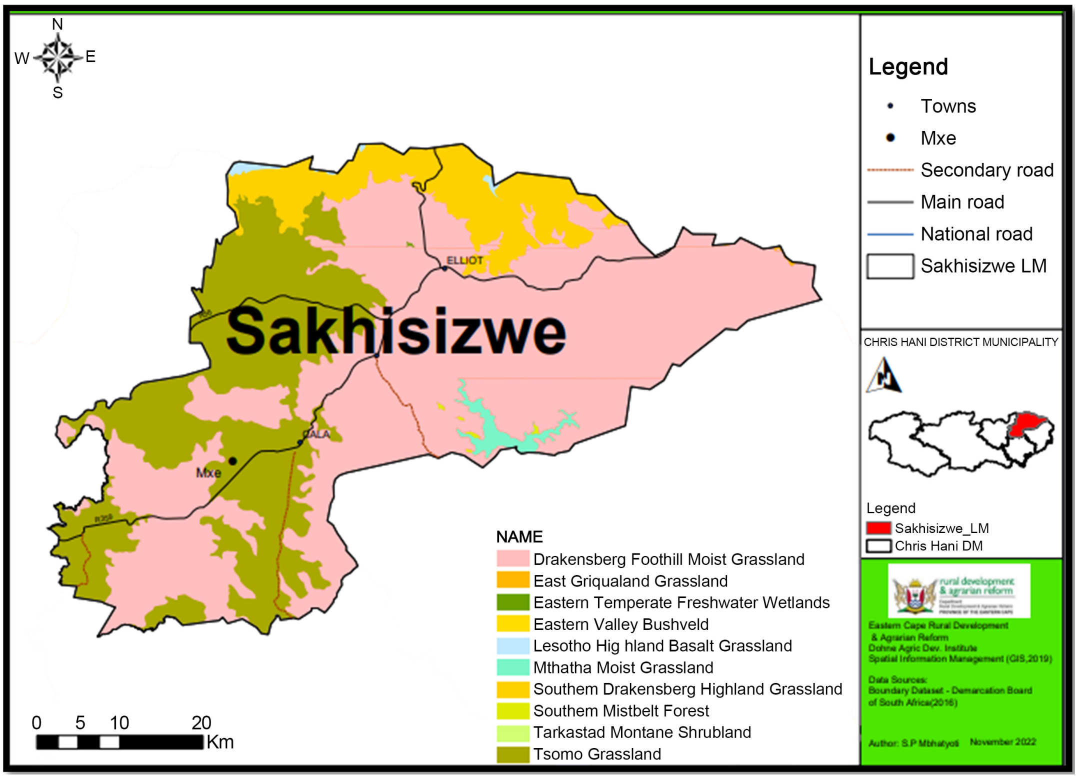

Figure 1. Study sites at Mxe communal rangeland in Sakhisizwe local municipality.

2.3. Sampling Procedure

In December 2019, data were collected after 12 months of rest (fallow) and grazing in the GE and the UG sites. Three parallel belt (50 m × 2 m) transects 5 m apart were laid out in each subplot. Woody plants located within the transects were identified, counted and their heights measured. This was to determine tree density and tree class. Within the transects a quadrat measuring 0.5 m × 0.5 m (0.25 m^2) was randomly thrown (*i.e.* three quadrants per transect) and herbaceous vegetation within a quadrat were identified and recorded to determine the type of herbaceous species present, their frequency of occurrence and the biomass yield. Samples were harvested at about 5 cm from the ground level using scissors, three samples per transect were taken (*i.e.* total of 9 samples per subplot). All the 18 biomass samples were oven-dried at 65˚C for 48 hours at Dohne Agricultural Development Institute to determine dry matter yield ($kg \cdot ha^{-1}$). All the identified herbaceous vegetation species were classified into four groups namely high desirability, desirable, less desirable and undesirable by using method of [18].

2.4. Nutritional Value Analysis of Dominant Grasses Species

Three dominant grasses species at both GE and UG sites were selected and harvested to determine the nutritive value. The selection of dominant grass species was based on the relative frequency percentage (those with high relative frequency (%) were selected, three grass species per site as shown in **Table 1**). Six grass tufts per grass species per site were harvested at ground level using scissors. After harvesting, samples of the same species per site were combined to form one sample per grass species. Therefore, three samples per site were store on well labelled paper bags and transported to Dohne Agricultural Development Institute for Laboratory analysis. All samples (six) were oven dried at 65˚C until constant weights were obtained and later milled to pass through 1mm sieve to determine their nutritional value. The selected species were *Aristida congesta*, *Eragrostis chloromelas*, *Eragrostis plana*, *Hyperrhenia hirta* and *Themeda triandra* [12]. Ash content was analysed following the method of AOAC (1990). Nitrogen (N) was determined by the micro-Kjeldahl method [19]. Crude protein (CP) was calculated as nitrogen (N) × 6.2. Acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined using the procedure of [20].

Table 1. Relative frequency (%) of herbaceous species at grazing exclusion and continuously sites.

			Relative frequency (%)	
Species	**Desirability**	**Life form**	**Uncontrolled grazing site**	**Grazing exclusion site**
Panicum maximum	HD	P	0	3
Themeda triandra (Iqunde)	HD	P	0	13.2
Cymbopogon pospischilii (Isiqungu)	LD	P	3.9	5
Hyperrhenia hirta (Igcelwana)	D	P	2.6	12.6
Aristida congesta (Nokawusana)	LD	P	23.9	1.8
Cynodon dactylon (Uqaqaqa)	HD	P	1.5	1.8
Eragrostis capensis	D	P	7.8	4.6
Eragrostis chloromelas	D	P	23.5	21.7
Eragrostis curvula	D	P	0	4
Eragrostis obtusa	D	P	5.9	1.7
Eragrostis plana (Msuka)	LD	P	7.6	5.1
Heteropogon contortus (Umkhonto)	D	P	1.9	9.2
Microchloa caffra	LD	P	3.9	3
Sporobulus africanus (Injinca)	LD	P	5.9	4
Aristida diffusa (Nokawusana)	LD	P	3.9	0.8
Non-grass plants	UI	UI	7.7	8.5

HD = high desirable, D = desirable, LD = Less desirable and UI = Unidentified.

2.5. Data Analysis

The recorded data were captured in an Excel spreadsheet for descriptive statistics. However, Analysis of Variance (ANOVA) was performed for the forage yield and quality parameters (Ash, CP, ADF, NDF and biomass). The T-test of [21] was used to compare mean differences between GE and UG subplots.

3. Results and Discussion

3.1. Effect of Exclusion and Continuous Grazing on Herbaceous Vegetation

The results showed that grazing exclusion facilitated grass species diversity, subsequently, thirteen and sixteen grass species were identified at the UG and GE sites, respectively (**Table 1**). *Aristida congesta* (23.9%), *Eragrostis chloromelas* (23.5%) and *Eragrostis capensis* (7.8%) had high relative frequencies at the UG site. The abundance of increaser species at UG site showed that grazing without resting may have a detrimental impact on the decreaser species. [22] demonstrated that continuous grazing may lead to the local extension of desirable forage species such as *Panicum maximum* and *Themeda triandra*. *Eragrostis chloromelas* had high frequency (21.7%) followed by *Themeda triandra* (13.2%) and *Hyperrhenia hirta* (12.6%) species in the enclosure site (**Table 1**). The results showed that GE had a positive impact on grasses and non-grass species. This finding is in line with the results reported by [5] and [23].

Grasses were dominant over non-grasses species in the GE. The GE site had 94% grasses and 6% non-grass species while the UG site had 92% grasses and 8% non-grass species (**Table 1**). Among the grasses recorded, the GE site had 19% highly desirable species, 38% desirable and 38% less desirable species. On the other hand, the UG site had 7% highly desirable species, 38% desirable and 46% less desirable species (**Table 1**). Grazing exclusion has shown great potential for improving rangeland productivity for sustainable livestock production. The absence of decreaser species at continuously grazed site confirmed that grasses were selectively and heavily grazed. [22] reported that fire and herbivory are considered as a key retrogressive factors driving rangeland dynamics at both grassland and savanna biomes. The complex ownership of grazing lands and unmonitored stocking rates (due to lack of knowledge on basic principles of rangeland management practices) are major factors leading to continuous grazing and loss of rangeland productivity. In communal areas, rangelands are shared and used by all farmers in a community, with no deliberate rangeland management interventions [4] [22]. Difference in abundance of grasses between GE area and UG site indicates that the use of GE for grass species recovery can be used to rehabilitate degraded rangelands [5] [24]. Moreover, the presence of decreaser species such as *Panicum maximum* (3%) and *Themeda triandra* (13.2%) after exclusion period showed that rangeland can be easily rehabilitated without reseeding. This trend confirmed that short-term grazing exclusion had a positive impact on the relative frequency (%) compared to UG area. This finding is consistent with the results of livestock exclusion research conducted in Ethiopia [5]. In semi-arid regions, long-term exclusion of both grazing and burning may promote the recruitment of woody plants at the expense of highly palatable perennial grasses [17].

3.2. Effect of Grazing Exclusion and Uncontrolled Grazing on Dry Matter Yield

The results showed significant (P < 0.05) variation in terms of dry matter yield between GE and UG sites (**Figure 2**). The highest dry matter yield was recorded at the GE (1400 kg·ha^{-1}) compared to the UG site (1102 kg·ha^{-1}) (**Figure 2**). This finding is in agreement with previous work by [25]. The effect of GE on dry matter herbaceous layer dry matter production of herbaceous species indicated an increasing trend compared to the UG. This finding was expected because the site was spared the effect of grazing and any other disturbance from herbivores. In the absence of grazing, herbaceous species were allowed to reach the maturity phase and complete their life cycle.

Table 2. Chemical composition of herbaceous species at grazing exclusion and uncontrolled grazing.

Parameters	Species	Uncontrolled grazing site	Species	Grazing exclusion site
Ash		**10.0 - 12.5**		**13.5 - 13.7**
	A. congesta	(10.0)^b	*E. chloromelas*	(13.7)^a
	E. chloromelas	(12.5)^a	*T. triandra*	(13.5)^a
	E. plana	(12.5)^a	*H. hirta*	(13.6)^a
CP		**5.4 - 5.8**		**7.2 - 7.8**
	A. congesta	(5.5)^a	*E. chloromelas*	(7.2)^a
	E. chloromelas	(5.4)^a	*T. triandra*	(7.6)^a
	E. plana	(5.8)^a	*H. hirta*	(7.8)^a
NDF		**75.3 - 78.9**		**69.0 - 77.0**
	A. congesta	(76.9)^a	*E. chloromelas*	(77.0)^a
	E. chloromelas	(75.3)^a	*T. triandra*	(72.4)^a
	E. plana	(78.9)^a	*H. hirta*	(69.0)^a
ADF		**48.7 - 52.2**		**44.1 - 47.3**
	A. congesta	(48.7)^a	*E. chloromelas*	(47.3)^a
	E. chloromelas	(52.2)^a	*T. triandra*	(44.1)^a
	E. plana	(50.3)^a	*H. hirta*	(46.0)^a

Means within a column followed by the same letter were not significant (P > 0.05). CP = crude protein, NDF = neutral detergent fiber, ADF = Acid detergent fiber, DM = dry matter and DSP = dominant species.

Maturity is a crucial phase in the lifecycle of any plant. Plant maturity leads to storage reserve deposition, dormancy induction, seed coat formation, biomass yield and synthesis of protective compounds. According to [26], repeated defoliation on herbaceous layer under continuous grazing conditions potentially leads to loss of biomass yield and grass vigour. The results clearly showed that GE facilitated species abundance, plant cover and accumulation of biomass compared to UG site. This finding is in agreement with results reported in different areas of Ethiopia [5] [27], in Kenya [28] and in Tanzania [29]. This finding disagrees with the results reported by [10] who stated that the age of enclosures had no effect on grass biomass production. Another possible explanation to the variation in terms of biomass yield among sites may be due to intensity of grazing. According to [22] prolonged grazing is associated with low forage production, uprooting of grasses species and nutrient reserve depletion.

3.3. Effect of Grazing Exclusion and Uncontrolled Grazing on Nutritive Value of Herbage

Grazing management is an essential practice for the conservation of healthy plant cover and the productivity of grazing lands with the aim of improving animal performance. The ash content of *Aristida congesta* (10.0%) was significantly lower compared to *Eragrostis chloromelas* (12.5%) and *Eragrostis plana* (12.5%) at the UG site (**Table 2**). Overall, the GE site had high ash contents (13.5 % - 13.7%) compared to UG site (10.0% - 12.5%) (**Table 2**). Higher ash content in the GE site may be attributable to higher organic matter in the soil since soil was not exposed to erosion. High ash contents may be due to high concentration of soil exchangeable bases, organic matter and soil acidity [30]. Crude protein content of individual grass species showed no significant difference between the two sites (**Table 2**). In terms of crude protein contents amongst individual grasses species, *Hyperrhenia hirta* had high crude protein (7.8%) followed by *Themeda triandra* (7.6%) *and Eragrostis chloromelas* (7.2%) at the GE site. Whereas in the UG site, *Eragrostis plana* had the highest crude protein content (5.8%) followed by *Aristida congesta* (5.5%) and *Eragrostis chloromelas* (5.4%) as shown in **Table 2**. Although not significantly different, crude protein content was relatively lower in the UG site (5.4% - 5.8%) than in the GE site (7.2% - 7.8%) (**Table 2**). The results indicated that crude protein content at UG was less than recommended range (6% - 8%) for maintenance of wild and domestic herbivores [31]. Those in the GE site fell within the recommended range. This trend was expected because young grass leaves with high crude protein were more likely to be affected by selective grazing. Furthermore, young leaves are less resistant to the repeated defoliation. This finding contradicts with that of [10] who reported high crude protein content in an open-grazed rangeland [10] argued that high crude protein at open-grazed areas was influenced by the continuous removal of old forage by grazers, leading to the rejuvenation of new growth. In addition, the deposition of urine and manure from grazers might improve soil fertility and subsequently improve plant growth. Nonetheless this

Figure 2. Dry matter yield (kg·ha^{-1}) at grazing exclusion and continuously grazed sites. Different lowercase letters within bar plots indicate differences with a significant level (P < 0.05) between the two sites.

trend may change under long-term trial because grazing exclusion promote moribund yield and as grasses gets mature crude protein content declines. This finding is in harmony with [31], who reported that grass crude protein declines as maturity from main rain season towards the cool dry season. According to [32] and [33] crude protein content declines with the increasing age of plant and increasing plant structural components such as acid detergent fiber and neutral detergent fiber. As plants age, the proportion of senescent leaves and structural components with low nitrogen content outstrip that of young leaves with higher nitrogen content [33], this cause an overall decline in the plants' crude protein content. Animal trampling, uncontrolled grazing, soil properties and climate related factors may influence the crude fiber content [34].

Grasses in the UG site had neutral detergent fiber content (75.3% - 78.9%) compared to 69.0% - 7.0% for the GE site (**Table 2**). In terms of individual plant species *Eragrostis plana* had highest neutral detergent fiber content (NDF) followed by *Aristida congesta* (76.9%) and *Eragrostis chloromelas* at UG site (**Table 2**). While *Eragrostis chloromelas* (77.0%) and *Themeda triandra* (72.0%) had high detergent fiber (NDF) contents at grazing exclusion site (**Table 2**). The UG site had acid detergent fiber content ranging from 48.7% - 52.2% compared to 44.1% - 47.3% in the GE site (**Table 2**). The neutral detergent fiber and acid detergent fiber among the individual grass species displayed no significance at both UG and GE (**Table 2**). [31] argued that neutral detergent fiber and acid detergent fibre of grasses increases with age of plants. Moreover, [5] stated that low of crude protein and high fibers contents are key indicators of low forage quality.

3.4. *Euryops floribundus* Density and Abundance (%) in Terms of Age Class

The results revealed that UG site had high plant density (2100 plants·ha^{-1}) compared to GE site (1971 plants·ha^{-1}). The UG site had 31% mature trees and 69%

Table 3. Woody density of *Euryops floribundus* and tree class (%) at grazing exclusion and uncontrolled grazing sites.

		Age class (%)	
Sites	**Density (Trees·ha^{-1})**	1 m & above (matured)	Less than 1 m (saplings)
Grazing exclusion site	(1971)^{a}	57%	43%
Continuously grazed	(2100)^{a}	31%	69%

Different superscripts (column) denote significant differences (P < 0.05) between grazing exclusion and continuously grazed site.

tree saplings (**Table 3**). High sapling percent indicated that continuous grazing system created favourable conditions for *Euryops floribundus* recruitment or expansion, which also facilitate the replacement of perennial grass species. Conducive microhabitat conditions together with heavy grazing pressure facilitate the replacement of perennial and palatable grasses species with undesirable woody plants [8] [35] [36] [37]. [8] and [34] reported that high grazing pressure promotes woody plant invasion because it creates opens space for woody plant colonisation allowing net recruitment into the grazing land.

Approximately 57% matured and 43% saplings were recorded at the GE site. Sapling percentage of less than 50% indicates a slow rate of *Euryops* recruitment [6]. However, the existing 50% of mature tress has a great potential of outcompeting grasses for water and soil nutrients [17] [37]. This finding was consistent with other authors [6] [8] [9]. The current study showed that GE improves soil cover, which protects soils from undesirable seed to get contact with soil. UG site is more proven to the recruitment of undesirable plants due to poor soil cover caused by uncontrolled grazing. The most effective method of improving degraded rangeland condition is to restore natural vegetation by excluding grazers.

4. Conclusion and Recommendations

In conclusion, GE was found to have a positive impact on the relative frequency (%) biomass production (kg·ha^{-1}) and crude protein content compared to UG sites. Decline of species diversity, forage production and high density of *Euryops floribundus* is associated with continuous grazing. Continuously grazed rangeland creates a conducive condition for *Euryops floribundus* recruitment. This study showed that grazing exclusion has a potential to restore strong perennial grasses and improve rangeland productivity which is key for sustainable livestock production. Regardless of challenges faced by communal farmers, the results can be used as guide to track vegetation changes caused by grazing management system used. In addition, these findings provide a baseline information on potential effects of grazing management might cause on nutritional quality, species diversity and forage production. Long-term research is needed to examine grazing exclusion as potential restoration technique at different conditions (*i.e.* season, rainfall and slope).

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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