Modern Agricultural Science and Technology, ISSN 2375-9402, USA
November 2020, Volume 6, No. 7-12, pp. 5-18
Doi: 10.15341/mast(2375-9402)/02.06.2020/002
Academic Star Publishing Company, 2020
www.academicstar.us

The Effect of Different Rangeland Management Strategies on Rangeland Condition, Available Grazing and Animal Performance in Tarchonanthus Camphoratus Rangeland in the Kudumane District, South Africa

Franci P. Jordaan, and Nkosinathi P. Bareki

1. Pasture Science Division, Department of Agriculture and Rural Development, Potchefstroom, South Africa

2. Animal Science Division, Department of Agriculture and Rural Development, Potchefstroom, South Africa

Abstract: Grazing land ecosystems occupy approximately one third of the earth's land area and many are degrading primarily due to inappropriate land use practices. It is believed that many of the world's rangelands are degraded as a result of excessive stocking rates. According to various authors the solution to the problem of overstocking is rotational grazing and more specific rotational resting. In this paper an evaluation was made of different grazing management strategies for their ability to contribute to improved rangeland condition. The hypothesis was made that long controlled resting periods can contribute in improving rangeland condition under heavily overstocked situations. The results of this study corroborate with the long-standing conclusions that stocking rate accounts for the majority of variability associated with plant and animal production on rangelands and not the grazing system applied.

Key words: Rangeland management systems, stocking rate, continuous grazing, rotational grazing, rotational resting

1. Introduction

Grazing land ecosystems occupy approximately one third of the earth's land surface and many are degrading primarily due to inappropriate land use practices [1-3]. At least 1 billion rural and urban people depend on these ecosystems for their livelihoods, often through livestock production, or for ecosystem services that affect human well-being [1, 4]. Foraging by livestock and wildlife is the primary use of grazing ecosystems – these ecosystems provide many ecosystem services that are essential for rural and urban populations, including the significant influence that management has on watershed and ecosystem function [1, 5]. It is however, believed that many of the world's rangelands are degraded as a result of excessive livestock grazing [6].

Livestock grazing has both individual plant and ecosystem level effects [7]. At the individual plant level, grazing during the growing season immediately removes photosynthetic tissue and may, but not always, place grazed plants at a competitive disadvantage with ungrazed plants [1, 7-10]. Adverse ecosystem effects are typically observed when repeated grazing occurs during the growing season across consecutive years [7]. Perennial grasses have many structural and physiological adaptations that permit them to be grazed on an annual or nearly

Corresponding author: Franci P. Jordaan, Ph.D., Specialist Scientist, research area: rangeland dynamics, rangeland degradation, rangeland restoration. E-mail: fjordaan@nwpg.gov.za.

annual basis. When the frequency, intensity and timing (growing vs. dormant season) of grazing exceeds the plant's ability to recover before the next grazing event, grazing can shift the composition of a plant community towards those species that are selected less often by grazing animals [1, 7].

Poor grazing practices also lead to soil erosion, soil compaction and reduced water infiltration rates, exacerbating the most limiting factor in most grazing ecosystems which is plant-available soil water [1, 11]. Therefore, the probability of shifts in vegetation and other effects depends on the grazing system applied (timing, intensity, duration, etc.), plant community composition, kind and class of grazing animals, site characteristics, and interactions between grazing and other disturbances [7]. It is extremely important that managers adopt grazing management practices/systems that maintain or restore soil and ecosystem function and resilience that are required for sustainable use in the long term [1].

The general goal of grazing systems is to increase production by ensuring that key plant species capture sufficient resources (e.g., light, water, nutrients) to enhance growth and by enabling livestock to harvest available forage more efficiently [12]. The specific objectives by which grazing systems are purported to increase production are to 1) improve species composition or productivity by ensuring that key plant species rest during the growing season, 2) reduce animal selectivity by increasing stock density (i.e., animals per land unit) to overcome small-scale heterogeneity (i.e., patch grazing), and 3) ensure more uniform animal distribution within large heterogeneous management units by improving water distribution and/or cross-fencing [12].

The grazing system that is mostly applied in the communal grazing areas of South Africa is continuous grazing. It is also a known fact that the communal rangelands are normally heavily overstocked [13]. Many authors blame overstocking and continuous grazing for the current state of degradation in the communal areas [14-18]. According to various authors the solution to the problem of overstocking is rotational grazing and more specific rotational resting [19-22].

The aim of this paper is thus to find a solution to continued rangeland degradation in the communal grazing areas of the Northwest Province in South Africa, given the fact that overstocking occurs at levels of 200% above grazing capacity. This was done through evaluating different grazing management strategies for their ability to contribute to improved rangeland condition. The hypothesis that long controlled resting periods can contribute in improving rangeland condition under heavily overstocked situations was tested.

2. Materials and Methods

2.1 Study Area

The study area falls within the Kuruman Thornveld [23] of the Northern Cape Province, South Africa. This vegetation type falls within the Savanna Biome. This Biome is characterized by a grassy ground layer and a distinct upper layer of woody plants [24]. The geology and soils can be described as Campbell Group dolomite and chert and mostly younger, superficial Kalahari Group with red windblown sands (up to 1.2 m deep) [23]. The study area receives summer and autumn rainfall, whilst the winters are very dry. The mean annual precipitation (MAP) is between 350-450 mm [23]. The bulk of the rainfall in the study area is between January and March. The study area is characterized by great seasonal and daily variations in temperature — the summers are very hot, whilst the winters are moderate. Mean monthly maximum and minimum temperatures are 35.9°C and -3.3°C in November and June, respectively [23]. The absolute maximum temperatures range up to 42°C [24], with the absolute minimums ranging between -8.3°C and -9.7°C [25, 26].

As was mentioned, the study area has well developed tree and shrub layers and a grassy ground layer [24]. The tree layer is dominated by *Searsia lancea*, whilst the shrub layer is dominated by *Tarchonanthus camphoratus.* Dominant grass species include species like *Schmidtia pappophoroides*, *Digitaria eriantha*, *Stipagrostis uniplumis*, *Eragrostis lehmanianna* and *Aristida stipitata* [27].

2.2 Trial Design

The study was done on the farm Wesselsvlei which is approximately 30 kilometers south east of Mothibistad in the Northern Cape Province of South Africa. The trial was executed on a 900 ha expanse of a part the farm. Four (4) different rangeland management strategies were investigated under extensive livestock farming conditions. A total of 99 commercial Bonsmara breeding cows were used in the trial. Cows were randomly allotted to different treatments and based on the official grazing capacity norm for the trial area, different stocking rates were applied. The following four treatments were applied (Fig. 1):

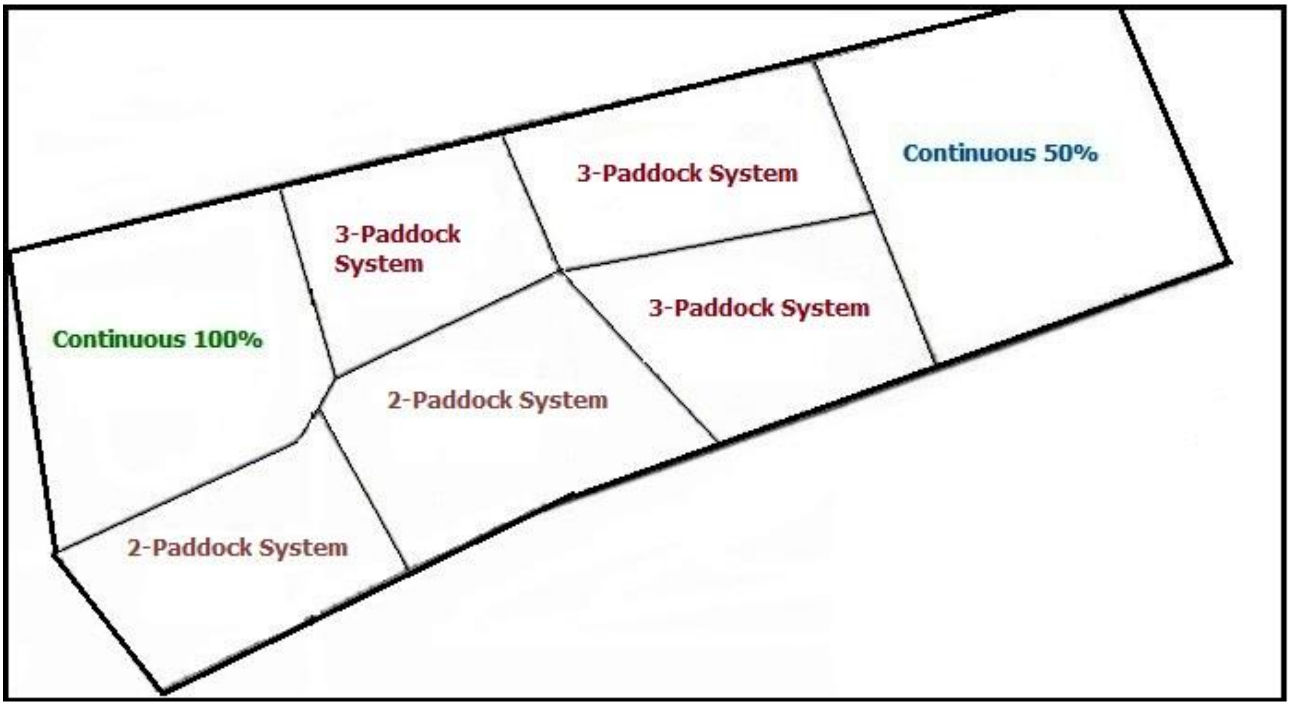

Fig. 1 Trial design on the farm Wesselsvlei.

- Treatment 1: Continuous grazing at 50% overstocking, accommodating 18 breeding females.
- Treatment 2: Continuous grazing at 100% overstocking, accommodating 18 breeding females.
- Treatment 3: A two paddock grazing system accommodating 28 breeding females, at a 100% overstocking, where one of the paddocks was continuously grazed for a year, while the other was rested. Because the 100% overstocking was calculated for the whole area, this implies that for a specific grazing period in one half of the area the actual overstocking was at 200%.
- Treatment 4: A three paddock grazing system accommodating 35 breeding females, at a 100% overstocking, where two of the paddocks were grazed rotationally for a year, while the third paddock was rested for a whole year. Again the 100% overstocking was calculated for the whole area which implies that for a specific paddock for a specific period the overstocking is actually 300%.

The paddocks in the trial area were comparable in terms of the herbaceous species composition as well as the herbaceous production at the beginning of the trial. The animals in the trial were allocated to the treatments in a randomly stratified manner, to ensure comparable initial age and weight distributions. One permanently marked monitoring plot was placed randomly in each paddock of each treatment — these plots were representative of the vegetation of each paddock. A benchmark site of 120 × 30 m was also erected in each paddock of each treatment. The purpose of the benchmark sites was to evaluate the grazed rangeland (outside the benchmark sites where the different grazing systems were applied) with the vegetation inside the benchmarks sites which represented the “ideal” rangeland management system (grazed only during the winter).

2.3 Data Collection and Data Analysis

Herbaceous species composition surveys were done bi-annually on fixed transects in the grazed and benchmark sites. These surveys were done at the end of the rainy (growing) season (May) for this area using the descending point, nearest-plant method [25, 28]. Frequency of occurrence was established with the wheel point apparatus [29]. The frequency and occurrence of the grass species in the grazing areas were determined on five (5) fixed transects of approximately 300 m each. A total of 1500 points were done with every survey. In the benchmark sites the surveys were done at two fixed transects (±200 points). Nearest plant point surveys within a radius of 45 cm of that point were performed. When an annual herbaceous species or a bare patch was pointed out, the nearest perennial species within a radius of 45 cm from the point was also recorded. When the nearest plant was further than 45 cm from the marked wheel point, it was recorded as a bare patch. Bare ground was thus recorded as a “vegetation species”, and equates to the lack of herbaceous cover within that point (radius of 45 cm for this study) [30]. The species composition data was used to calculate the rangeland condition index for each grazing system.

The basal cover of the herbaceous layer was also determined bi-annually by the wheelpoint apparatus [29] as described above. It was noted as a hit when the point of the wheelpoint apparatus landed in the middle of a live and active growing grass tuft. Basal cover surveys were not done in the benchmark sites as the points were too few to determine true basal cover.

Above ground phytomass (production) of the herbaceous layer was determined during spring (November) and in autumn (May) outside the benchmark sites. In the benchmark the surveys were only done during May to determine the total herbaceous biomass production for the growing season. The Dry Weight Rank Method of t’Mannetje and Haydock [31] were used. In the grazing areas 50 × 1 m^2 quadrates were randomly placed and all herbaceous material above 4 cm were cut and placed in paper bags. Inside the benchmark sites 15 × 1 m^2 quadrates were used. The herbaceous material was dried for 48 hours at 70°C after which it was weighed or the calculation of the rangeland condition index the classification of the grasses for this paper was based on the quantitative climax method of Dyksterhuis [32] and adapted according to the ecological information for the arid to semi-arid regions of South Africa [33-40]. Degradation as well as grazing indices have been developed for this area. For this paper a new index was developed for every grass species by averaging the degradation and grazing index for each species. The rangeland condition scores that were calculated thus conveyed multivariate information about the current state of the vegetation as well as the usability in terms of grazing for each grazing system. The herbaceous species were further classified according to the grazing-index and were grouped as (i) desirable species (DE), (ii) less desirable species (LD), (iii) undesirable species (UD) and bare patches (BP). The grouping of the species was based on specialists’ knowledge for the particular survey area.

The percentage basal cover for each survey site was calculated by dividing the number of hits of each survey by the total number of points for that specific survey and then multiplied it by 100.

As was already mentioned the herbaceous production data was analyzed according to the Dry Weight Rank Method [31].

Animal growth performance data originated from records collected between 2004 and 2006 calendar years, from a population of 264 animals. A total of 151 animals were commercial Bonsmara cattle participating in the trial. The remaining 113 stud (registered) Bonsmara cattle were managed under industry standard rotational grazing and therefore used as a benchmark herd on animal growth performance.

A complete animal record consisted of its identity; pedigree information; dates of birth and weaning; dates at the age of 12 and 18 months; sex; weights recorded at birth, weaning, 12 months and at 18 months of age.

The number of growth performance records available after editing and the general descriptive statistics for the traits analyzed are presented in Table 1 for both commercial and stud herds.

Growth traits are often described by performance of an animal at various stages of the growth curve [46]. As a result, animal performance data used were collected in accordance to the South African National Beef Cattle Improvement Scheme's growth trajectory

Table 1 Descriptive statistics for the traits analyzed with data from the registered herd (benchmark) above diagonal and data from the commercial herds (trial) below diagonal within row.

Trait	*n*	Mean ± SE	SD	Min	Max
BWT	111	36 ± 0.44	4.60	25	50
	148	34 ± 0.38	4.62	20	50
WWT	106	258 ± 3.27	33.70	140	345
	121	200 ± 3.44	37.80	85	300
YWT	84	274 ± 3.66	33.56	135	380
	98	227 ± 4.09	40.52	120	330
EWT	65	398 ± 3.97	32.00	335	475
	73	349 ± 5.30	45.30	250	465

BWT = Birth weight, WWT = Weaning weight, YWT = Yearling weight, EWT = Eighteen months' weight, SE = Standard Error, SD = Standard deviation, Min = Minimum and Max = maximum

cut-off ages. Weight measurement of an animal recorded at any given time represented an observation of its phenotype. Growth traits are however often affected by the adaptability of the animal to the production environment [47, 48]. The latter is mainly because expression of these traits is dependent on both the animal's inherent growth ability and on the production environment [49, 50]. It is for the latter reason that growth traits (animal weights) were used in this trial to study animal performance as influenced by different stocking rates.

All weights used were actual weights and were not adjusted for any biological effects, i.e., sex, age at wean, dam age, etc. This was done because for grazing trials, adjusted weights are likely to condense the environmental influence of the trial on animal performance.

As a general management protocol, all animals from both herds were weighed every 28 days. For improved accuracy of the weights, all non-suckling animals were weighed in a fasted state (fasted from feed for ±16 hours) to limit variation in gut fill. All weighing processes of both herds were done with 24 hours of each herd. The weights of calves at birth were recorded within 72 hours postpartum. The same routine animal management protocol for activities such as daily wellbeing and mineral lick supply inspections, parasite control and vaccinations were correspondingly followed for all treatments. During the annual selection process at weaning, on average 15% of the worst females and 60% of the worst male calves were culled and sold to adapt the animal numbers and herd replacement rate to the desired pasture capacity [51].

All quantitative animal performance data of the response variables were analyzed using the IBM SPSS® Statistical package (2015). The separation of means was computed using Tukey's post-hoc test for multiple comparisons. All computed means were considered significant at $P < 0.05$.

3. Results

3.1 Rainfall

The results of the rainfall data for 1998/99 to 2005/06 are shown in Fig. 2. This particular study was conducted from the 2002/03 season to the 2005/06 season. The mean average rainfall for the four year study period was approximately 387 mm which is slightly less than the long term average for the area which is 400 mm. From this figure it is clear that the rainfall in this area is extremely erratic. Three of the four years preceding the trial period were extremely dry (1998/99-2000/01). The rainfall during this period varied between 122 mm and 270 mm. The rainfall figure for the 2001/02 season (the year before the trial started) was slightly higher than the long term average, namely 433 mm. The rainfall figures for two of the years during the trial period (2002/03-2005/06) were below the long term rainfall average (221 mm and 371 mm), whilst the last two years of the trial received above average rainfall (483 mm and 472 mm) (Fig. 2). The bulk of the rainfall was received from December to April (active growing season), with January receiving the most rainfall on average, namely approximately 92 mm.

3.2 Rangeland condition score/indexes

The rangeland condition scores/indexes for the grazed areas as well as the benchmark sites are shown in Figs. 3 and 4.

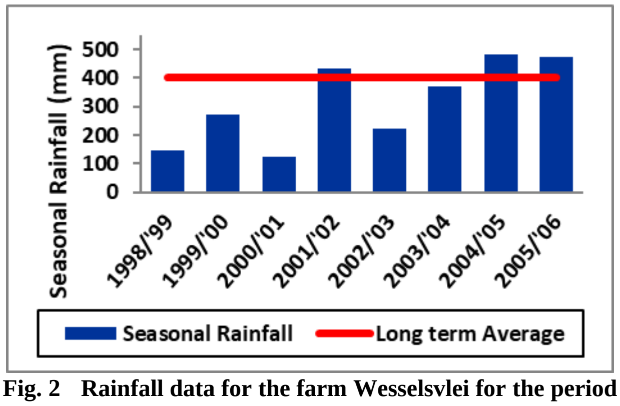

Fig. 2 Rainfall data for the farm Wesselsvlei for the period from 1998/99 to 2005/06.

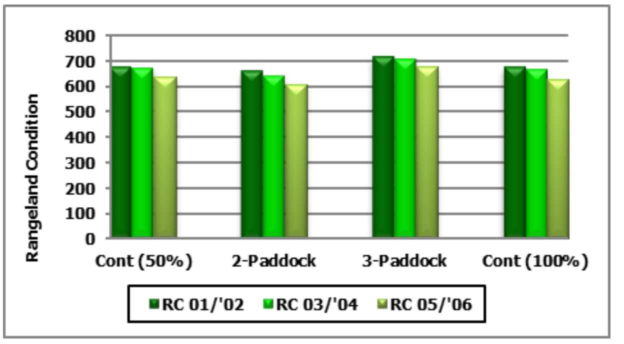

Fig. 3 Rangeland condition scores for the grazed areas for the different grazing systems.

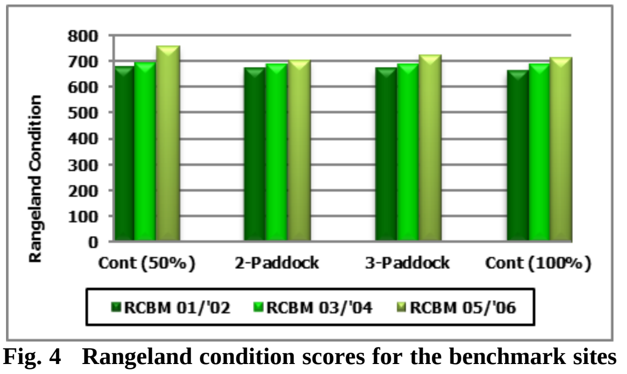

Fig. 4 Rangeland condition scores for the benchmark sites within the different grazing systems.

From Fig. 3 it is clear that the 3-paddock system started off with the highest rangeland condition score (712), whilst the scores for the other grazing systems varied between 657 (2-paddock system); 673 (continuous grazing 100%) and 675 (continuous grazing 50%). It is further evident from this figure that there is a constant decrease in the rangeland condition of all the grazing systems irrespective of the higher rainfall that was received in the last two years of the trial. At the end of the trial the 3-paddock system still had the highest rangeland condition score, namely 677, whilst the lowest score was in the 2-paddock system, namely 607. The fact that the changes in the rangeland condition of the grazed areas were not significant is an indication that the herbaceous species composition did not change much during the trial period for the different grazing systems.

If the rangeland condition scores of the benchmark sites are studied the opposite tendency occur as was found in the grazed areas (Fig. 4). The rangeland condition scores showed an increase from the onset to the end of the trial. All the benchmark sites were grazed clean only during the winter and were not subjected to a specific grazing system. The rangeland condition score in the benchmark sites reacted thus positively to the higher rainfall that was received at the end of the trial. It is further evident from this figure that the rangeland condition scores varied between 633 and 674 at the beginning of the trial and varied between 701 and 756 at the end of the trial period.

It is thus clear from Fig. 3 that none of the grazing systems had a beneficial influence on the rangeland condition scores of the grazed areas as all the rangeland condition scores showed a decreasing tendency. The higher rainfall at the end of the trial period also did not have a positive influence on the scores of the grazed areas as it was the case in the benchmark sites (Fig. 4).

3.3 Basal Cover

As was mentioned, the basal cover was only determined in the grazing areas for the different grazing systems and not in the benchmark sites. This is due to the fact that the benchmark sites are too small that enough point surveys for a true reflection of the percentage basal cover could be obtained. The percentage basal cover for the different grazing systems is indicated in Fig. 5.

From Fig. 5 it is clear that all the grazing systems started off with almost the same basal cover — 5.5% for both the 2- and 3-paddock systems; 5.6% for the 100% continuous grazing and 5.8% for the 50%

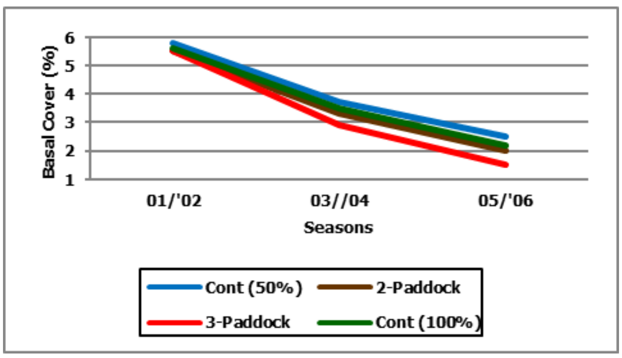

Fig. 5 Percentage basal cover for the grazed areas for the different grazing systems.

continuous grazing. From the start to the end of the trial the different grazing systems showed the same decreasing tendency for the basal cover. This is once again an indication that the grazing system *per sé* didn't have an influence on the basal cover. It is however, clear from this figure that the stocking rate had a definite influence on the basal cover. The 3-paddock system (300% overstocked) had the lowest basal cover at the end of the trial, namely 1.5%. This was followed by the 2-paddock system (200% overstocked) with a figure of 2%. The basal cover for the 100% continuous grazing system was 2.2%, whilst that of the 50% continuous grazing system was 2.5%. It is thus clear that the areas with the highest percentage overstocking had the lowest percentage basal cover and *vice versa*.

3.4 Herbaceous Production, Grazing Capacity and Utilization Percentage

The herbaceous production of the grazed areas as well as the benchmark sites is shown in Figs. 6 and 7.

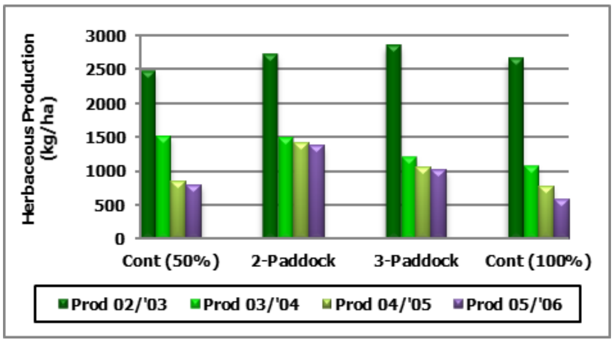

Fig. 6 Herbaceous production for the grazed areas for the different grazing systems.

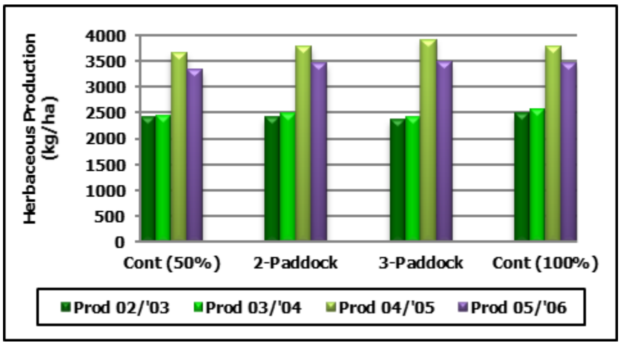

Fig. 7 Herbaceous production for the benchmark sites within the different grazing systems

From Fig. 6 it is clear that the initial herbaceous production of all the grazing systems was comparable to each other — the production varied between approximately 2500 kg/ha to 2800 kg/ha. Although the trial started in a relative dry year, the trial area was rested for a year before the onset of the trial. At the onset of the trial the 3-paddock system had the highest production (2849 kg/ha), whilst the lowest production was in the continuous grazing (50% overstocked), namely 2469 kg/ha. From this figure it is further evident that there is a significant decrease in the herbaceous production from the 2002/03 season to the 2003/04 season. This decrease can be ascribed to both the low rainfall that was received during the 2003/04 season as well as the fact that animals grazed an area that was rested for a year. As was mentioned the overstocking in the grazing systems varied between 50% and 300%. It is further evident from this figure that there is a steady decrease in the herbaceous production from the 2003/04 season to the 2005/06 season in all the grazing systems.

The decrease in the herbaceous production was also more distinct between the different seasons in the continuous grazing systems that in the rotational systems. This phenomenon might be ascribed to the fact that the rotational systems had different forms and lengths of rest periods included in the systems, whilst this was not the case in the continuous grazing systems (Fig. 6).

From Fig. 7 it is clear that the herbaceous production in the benchmark sites within the different grazing systems was only influenced by the rainfall as the production figures followed the rainfall patterns. The first two seasons of the trial could be described as relatively dry and therefore the lower herbaceous production of approximately 2500 kg/ha in all the benchmarks sites within the grazing systems. The 2004/05 season received the highest rainfall (483 mm) – from Fig. 7 it is clear that the highest herbaceous production was also recorded during this season in all the benchmark sites within the grazing systems. The rainfall of the last season of the trial was slightly lower than that of 2004/05 and this is also reflected in a decrease in the herbaceous production.

When Figs. 6 and 7 are compared it is clear that the potential of the rangeland for the last two seasons (relatively wet years) was between 3900 kg/ha to 3300 kg/ha for the different grazing systems. In the grazed areas the herbaceous production figures varied between 1400 kg/ha and 580 kg/ha. The production potential for the rangeland was thus more than three times higher than what was achieved with the different grazing systems.

The grazing capacity figures for the grazed areas and the benchmark sites are shown in Figs. 8 and 9.

In these two figures the Y-axis was kept constant to indicate the true effect that was obtained with the grazing capacity figures. From Fig. 8 it is clear that there is an increase in the grazing capacity figures from the onset of the trial to the end of the trial in all the grazing systems. This figure correlates with Fig. 6 —as the herbaceous production decreases, the number

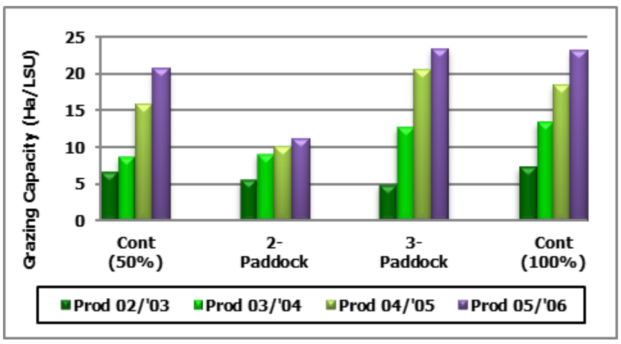

Fig. 8 Grazing capacity figures for the grazed areas for the different grazing systems.

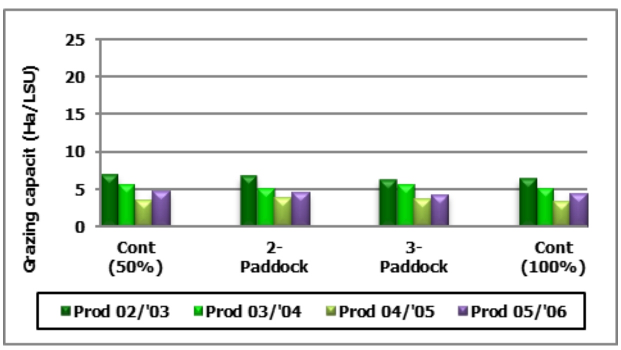

Fig. 9 Grazing capacity figures for the benchmark sites within the different grazing systems.

of hectares to sustain one livestock unit (LSU) will increase. When the grazing systems are compared it seems as if the 2-paddock system had the least negative effect on the grazing capacity figure. In this system the allotted area is divided in two paddocks of which one half is grazed whilst the other half rests for the whole year.

Fig. 9 follows the same pattern as Fig. 7 — as rainfall increased the herbaceous production of the benchmark sites, the grazing capacity figures decreased accordingly. The best grazing capacity figures were obtained during the 2004/05 season when the herbaceous production was the highest in the benchmark sites. When Figures 8 and 9 are compared (constant Y-axis) it is clear that the grazing capacity potential of the rangeland in the benchmark sites was much higher than that of the grazed areas within the different grazing systems. The grazing capacity potential of the rangeland during the last two seasons of the trial in the benchmark sites was between 3.4 ha/LSU and 4.7 ha/LSU (Fig. 9). The grazing capacity figures obtained in the grazed areas during the last two seasons of the trial varied between 10.1 ha/LSU and 23.3 ha/LSU. These figures are thus once again three to five times higher than what the potential of the rangeland is.

The utilization percentages for the different grazing systems are indicated in Fig. 10.

From this figure it is clear that the lowest utilization percentage was found with the 50% overstocked continuous grazing system, whilst the highest percentage utilization was found in the 3-paddock system. Although the 3-paddock system was a rotational system with rest periods included in the system, the area that was grazed was 300% overstocked. It was interesting that the percentage utilization in the 100% overstocked continuous grazing systems was higher than that of the 2-paddock system that was 200% overstocked. This might be ascribed to the fact that in the continuous grazed system the animals might have grazed the grass species twice or even more which decreased the vigor of the plants as no rest periods occurred where the plants could recover. In the 2-paddock system at least half of the allocated area is rested for a whole year.

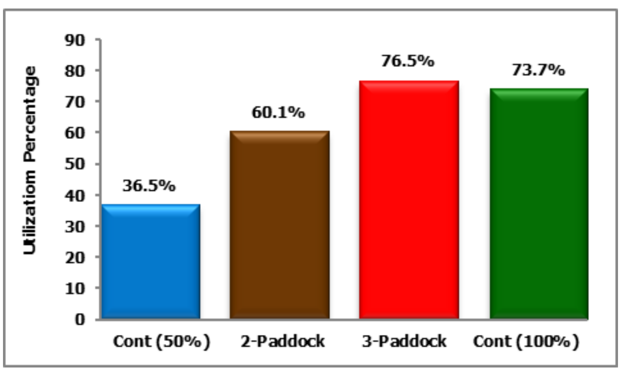

Fig. 10 Utilization percentage of the different grazing systems.

3.5 Animal Performance

Weight trends that describe animal growth performance for all four analyzed growth traits are shown in Fig. 11. In these results, animal growth performance from the stud herd is used as a benchmark reference point given that this herd was managed under industry standard rotational grazing system.

In general, birth weight (BWT) trends showed no difference between treatments means (Fig. 11). Similarly, no statistical difference ($P \geq 0.615$) between treatments means could be found for BWT (Table 2) as opposed to other growth traits. This result suggest as expected, that the inherent herd phenotypic expression of BWT was not affected by the different grazing systems or stocking rates between treatments.

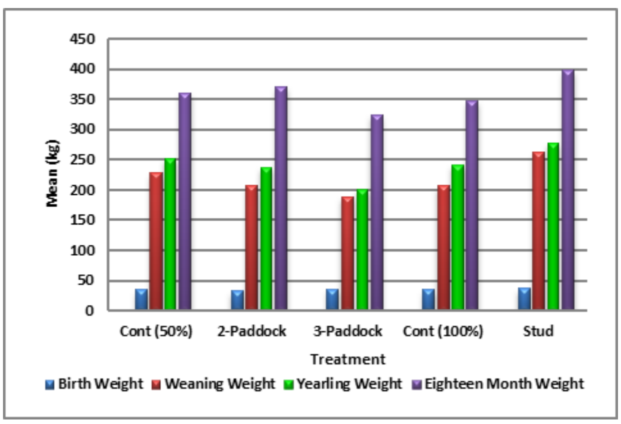

Fig. 11 Weight trends for all four analyzed growth traits with in the different grazing systems.

As can be observed from Fig. 11, different grazing systems presented differences in growth traits. Weaning weights for all treatments differed (P = 0.001) from the benchmark (stud) herd, suggesting that all forms of overstocking affected the phenotypic expression of this trait in this study. It is further evident from Table 2 that there were no statistical differences in WWT means between the 2-paddock, 3-paddock and the 100% overstocking system. The 3-paddock system yielded however the least WWT's that were 10 kg and 12 kg less than that of the 2-paddock and the 100% overstocking system respectively. Given that the sale price of an animal in a beef-value-chain is based primarily on its weight, this difference is of economic importance to note.

Between treatments, only the 50% overstocking on continuous grazing system yielded WWT that were closer, although significantly different (P = 0.001) to WWT of the standard rotational grazing system. Similarly for both YWT and EWT, all treatments yielded lighter weights than that of the benchmark (stud) herd. These trends give emphasis to the suggestion that overstocking has a negative effect on growth performance of grazing animals.

From Table 2, the animal performance by treatment ranking for WWT and YWT (best to worst basis) will follow this order: i) Cont. (50%), ii) Cont. (100%), iii) 2-paddock and iv) 3-paddock. In comparison to the benchmark herd, all treatments performed poorly with the largest difference of 58 kg observed on WWT (Table 1).

Table 2 Mean of Birth Weight, Weaning Weight, Yearling Weight, and Eighteen Month's Weight by treatment, with the benchmark herd in italics.

Trait	BWT	WWT	YWT	EWT
Treatment				
Cont. (50%)	34.20^{ab}	223.11^{b}	249.58^{b}	360.24^{b}
2-Paddock	32.84^{a}	196.24^{a}	228.57^{ab}	371.20^{b}
3-Paddock	33.91^{ab}	186.21^{a}	205.13^{a}	324.52^{a}
Cont. (100%)	34.29^{ab}	198.15^{a}	233.41^{b}	347.19^{ab}
Stud	*35.87^{b}*	*258.51^{c}*	*273.93^{c}*	*398.42^{c}*

^{abc} Means with different superscripts within column differed significantly at the 0.05 level.

4. Discussion

According to Manley et al. [19, 41] increased grazing pressure and/or stocking rate will influence the botanical composition. In this trial the change in the herbaceous botanical composition would then ultimately have been reflected in the rangeland condition scores for the different grazing systems. As was shown in the results of the rangeland condition scores (point 3.2) none of the grazing systems studied had a specific influence on this aspect. All the rangeland condition scores in the grazed areas showed a decreasing tendency. The decrease in the rangeland condition scores was 6% and 7% for the continuous grazing systems (50% and 100%) respectively, whilst it was 8% for the 2-paddock system and 5% for the 3-paddock system. The reason why no specific tendency was observed in the rangeland condition scores might be ascribed to the short duration of the trial – only four years when it was ended due to poor BCS of the trial animals. The observed animal BCS for at least more than half of the treatments were below acceptable animal welfare thresholds and thus warranted the termination of the trial.

A marked decrease in basal cover as the stocking rate increased was also observed by Barnes and Denny [42]. The same tendency was observed in this trial. The decline in the percentage basal cover was the highest in the 3-paddock system (300% overstocked), namely 73%. This was followed by the 2-paddock system (200% overstocked), namely 64%, the 100% overstocked continuous grazing system (61%) and the 50% overstocked grazing system (57%). Similarly, animal performance showed corresponding trends where the 3-paddock system animals' performed the worst, followed by the 2-paddock system as shown by the weaning and post-weaning traits. Although the herbaceous species composition thus showed no changes, as discussed in the rangeland condition scores, the sizes of the tufts showed definite changes as it became smaller, therefore the lower percentages basal cover. However, this tendency appeared once again in all the grazing systems and can thus not solely be ascribed to a particular grazing system.

From the herbaceous species production data in this trial (point 3.4) it was clear that there was a definite decline of the above ground production in all the grazing systems. According to Davies et al. [7] and Briske et al. [12] extremely high stocking rates are normally associated with very high forage utilization – the consequence of this high forage utilization is that the herbaceous production is reduced severely. These high rates of utilization do not provide in the end sufficient forage, and animal production will decline. In corroboration, animal performance from all treatments was much lower than that of the benchmark herd. The mean WWT difference of 58 kg between the trial herds and that of the benchmark herd highlights a stocking rate discrepancy effect of huge economic importance. This is particularly so given that WWT represents the first marketable product in cow-calf beef cattle enterprises. Using the current weanling selling price of about R34/kg, the difference of 58 kg on WWT translates to a potential loss of R1972.00 per weaned calf as a consequence of an incorrect stocking rate.

In general, the differences in growth traits between treatments were large enough to warrant economic and animal welfare scrutiny. This was particularly true for both the 3- and 2-paddock stocking rates which had the worst body condition scores (BCS) from an animal husbandry perspective.

The decline in the above ground herbaceous production may be attributed to the following, as explained by Briske et al. [12]: Chronic, intensive grazing is detrimental to plants because it removes leaf area that is necessary to absorb photosynthetically active radiation and convert it to chemical energy. This reduction in energy harvest is manifest in all aspects of plant growth and function because photosynthesis provides the total energy and carbon source for growth. A chronic, intensive reduction in photosynthetic leaf area negatively impacts root systems by reducing energy available to support existing root biomass and new root production. Root mass, branch number, vertical and horizontal root distribution, and root longevity all may be reduced by chronic, intensive defoliation. This reduces the ability of severely grazed plants to effectively access soil water and nutrients that often limit plant growth on rangelands. The decrease in above ground production in this trial was the biggest in the two continuous grazing systems where the plants had no rest and no time to recover (78% decline in production in the 100% continuous grazing system and a 68% decline in the 50% continuous grazing system). In the 2-paddock system the decline in production was 49% and in the 3-paddock system it was 64%. Although these two systems were 200% and 300% overstocked respectively, certain areas/paddocks in both systems got a yearlong rest on a rotational basis during the trial.

5. Conclusions

The results of this study corroborate with the long-standing conclusions that stocking rate accounts for the majority of variability associated with plant and animal production on rangelands and not the grazing system applied [1, 7, 12, 19, 20, 41-45, 52]. Management commitment and ability are thus the most pivotal components of grazing system effectiveness. Grazing systems do not possess unique properties that enable them to compensate for ineffective management (i.e., grazing systems do not provide a “silver bullet” to ensure attainment of desired goals) [12].

Finally the hypothesis that long controlled resting periods can contribute to improvement of rangeland condition under heavy overstocking conditions was thus proved to be wrong with this study. This conclusion is further supported by the observed overall poor growth performance of the trial animals when compared to those of the standard rotational grazing system.

References

[1] R. Teague, Managing grazing to restore soil health and farm livelihoods, in: *Forages and Pastures Symposium: Cover Crops in Livestock Production: Whole-system Approach — 2017 ASAS-CSAS Annual Meeting*, Baltimore, Maryland, July 11, 2017.

[2] MEA (Millennium Ecosystem Assessment), *Ecosystems and Human Well-being: Synthesis*, Island Press, Washington, DC., 2005.

[3] J. A. Delgado, P. M. Groffman, M. A. Nearing, T. Goddard, D. Reicosky, R. Lal, N. R. Kitchen, C. W. Rice, D. Towery and P. Salon, Conservation practices to mitigate and adapt to climate change, *Journal of Soil and Water Conservation* 66 (2011) (4) 118A-129A.

[4] R. Ragab and C. Prudhomme, Soil and Water: climate change and water resources management in arid and semi-arid regions: prospective and challenges for the 21st century, *Biosystems Engineering* 81 (2002) (1) 3-34.

[5] W. H. Schlesinger, J. F. Reynolds, G. L. Cunningham, L. F. Huenneke, W. M. Jarrell, A. Virginia and G. Whitford, Biological feedbacks in global desertification, *Science* 247 (1990) (4946) 1043-1048.

[6] M. Gamouna, B. Pattonb and B. Hanchi, Assessment of vegetation response to grazing management in arid rangelands of southern Tunisia, *International Journal of Biodiversity Science, Ecosystem Services & Management* 1 (2015) (2) 106-113, doi: doi.org/10.1080/21513732.2014.998284.

[7] K. W. Davies, M. Vavra, B. Schultz and N. Rimbey, Implications of longer term rest from grazing in the sagebrush steppe, *Journal of Rangeland Applications* 1 (2014) 14-34.

[8] M. M. Caldwell, *Plant Requirements for Prudent Grazing*, National Research Council, & National Academy of Sciences, Developing strategies for rangeland management. Boulder, CO, USA: Westview Press, 1984, pp. 117-152.

[9] M. M. Caldwell, J. H. Richards, J. H. Manwaring and D. M. Eissenstat, Rapid shifts in phosphate acquisition show direct competition between neighboring plants, Nature 327 (1987) (6123) 615-616, doi: 10.1038/327615a0.

[10] D. C. Hartnett, Density-and growth stage-dependent responses to defoliation in two rhizomatous grasses, Oecologia 80 (1989) (3) 414-420, doi: 10.1007/BF00379045.

[11] T. Thurow, Hydrology and erosion, in: Heitschmidt R. K., Stuth J. W. (Eds.), *Grazing Management: An Ecological Perspective*, Timberland Press, Portland, Oregon, 1991, pp. 141-159.

[12] D. D. Briske, J. D. Derner, J. R. Brown, S. D. Fuhlendorf, R. Teague, K. M. Havstad, R. L. Gillen, A. J. Ash and W. D. Willms, Rotational grazing on Rangelands: Reconciliation of perception and experimental evidence, *Rangeland Egology and Management* 61 (2008) (1) 3-17, doi: doi.org/10.2111/06-159R.1.

[13] A. C. Dahlberg, Vegetation diversity and change in relation to land use, soil and rainfall — A case study from North-East District, Botswana, *Journal of Arid Environments* 44910 (2000) 19-40, doi: doi.org/10.1006/jare.1999.0566.

[14] F. F. Kanthack, The alleged desiccation of South Africa, *The Geographical Journal* 76 (2003) 516-521, doi: doi.org/10.1111/1475-4959.00036.

[15] J. Phillips, South Africa's wasting heritage, *South African Geographical Journal* (14) 19-25.

[16] Food and Agricultural Organization of the United Nations, Land degradation by main type of rural land use in dryland areas, Food and Agricultural Organization of the United Nations, accessed 14 February 2019, available online at: http://www.fao.org/docrep/x5308e/x5308e04.htm#3.4%20land%20degradation%20and%20rangeland%20management.

[17] I. S. Selemani, Communal rangelands management and challenges underpinning pastoral mobility in Tanzania: A review, *Livestock Research for Rural Development* 26 (2014) (5).

[18] A. Andrew, A. Ainslie and C. Shackleton, *Evaluating Land and Agrarian Reform in South Africa: Land Use and Livelihoods, Program for Land and Agrarian Studie*s, University of Western Cape, South Africa, 2003.

[19] W. Manley, R. Hart, M. Samuel, M. Smith, J. Waggoner, and J. Manley, Vegetation, cattle, and economic responses to grazing strategies and pressures, *Journal of Range Management* 50 (1997) 638-646, doi: 10.2307/4003460.

[20] M. D. Pitt and H. F. Heady, The effects of grazing intensity on annual vegetation, *Journal of Range Management* 32 (1979) (2) 109-114.

[21] R. Banister, Eight principals of range management, *Rangelands* 13 (1991) (2) 85-86.

[22] M. Gamoun, B. Patton and B. Hanchi, Assessment of vegetation response to grazing management in arid rangelands of southern Tunisia, *International Journal of Biodiversity Science, Ecosystem Services & Management* 11 (2015) (2) 106-113, doi: 10.1080/21513732.2014.998284.

[23] L. Mucina and M. C. Rutherford (Eds.), *The Vegetation of South Africa, Lesotho and Swaziland*, South African National Biodiversity Institute, Pretoria, 2006.

[24] A. B. Low and T. Rebelo, *Vegetation of South Africa, Leshoto, and Swaziland*, Department of Environmental Affairs and Tourism, Pretoria, 1998.

[25] M. Coetzee, Best land-use strategies towards sustainable biodiversity and land degradation management in semi-arid western rangelands in Southern Africa, with special reference to ants as bio-indicators, Ph.D. thesis, North West University, Potchefstroom Campus, 2006, p. 573.

[26] S. Mangold, M. Kalule-Sabiti and J. Walmsley (Eds.), *State of the Environment Report*, North West Department of Agriculture, Conservation and Environment, 2002.

[27] J. P. H. Acocks, Veld types of South Africa, *Memoirs of the Botanical survey of South Africa*, 1988, p. 57.

[28] P. W. Roux, The descending point method of vegetation survey. A point sampling method for the measurement of semi-open grasslands and Karoo vegetation in South Africa, *South African Journal of Agricultural Science* 5 (1963) 273-288.

[29] C. E. M. Tidmarsh and C. M. Havenga, The wheelpoint method of survey and measurement of semi-open grasslands and Karoo vegetation in South Africa, Memoirs of the Botanical Survey of South Africa No. 29, Pretoria: Government Printer, 1955.

[30] K. Leggertt, J. Fennessy and S. Schneider, Does land use matter in an arid Environment? A case study from the Hoanib River catchment, north-western Namibia, *Journal of Arid Environments* 53 (2003) 529-543.

[31] L. 't Mannetje and K. P. Haydock, The dry-weight rank method for the botanical analysis of pasture, *Journal of the British Grassland Society* 18 (1963) 268-275.

[32] E. J. Dyksterhuis, Condition and management of rangeland based on quantitative ecology, *Journal of Range Management* 2 (1949) 104-115.

[33] B. D. Foran, N. M. Tainton and P. de V. Booysen, The development of a method for assessing veld condition in three grassveld types in Natal, *Proceedings of the Grassland Society of southern Africa* 13 (1978) 27-33, doi: doi.org/10.1080/00725560.1978.9648829.

[34] N. M. Tainton, P. J. Edwards and M. T. Mentis, A revised method for assessing veld condition, *Proceedings of the Grassland Society of southern Africa* 15 (1980) 37-42, available online at: https://www.tandfonline.com/doi/abs/10.1080/00725560.1980.9648882.

[35] M. Vorster, The development of the ecological index method for assessing veld condition in the Karoo, *Proceedings of the Grassland Society of Southern Africa* 17 (1982) 84-89, doi: doi.org/10.1080/00725560.1982.9648962.

[36] J. H. Fourie and P. F. Du Toit, Weidingstudies in die Vrystaatstreek: Die bepaling van veldtoestand, *Glen Agric.* 12 (1) 5-9.

[37] J. H. Fourie, and H. J. Fouché, Die bepaling van weidingkapasiteit vanaf veldtoestand, *Glen Agric.* 14 (1+2) 12-13.

[38] J. H. Fourie and A. F. J. Visagie, Weidingswaarde en ekologiese status van grasse en Karoobossies in die Vrystaatstreek, *Glen Agric.* 14 (1985) 14-18.

[39] G. E. Gibbs Russell, L. Watson, M. Koekemoer, L. Smook, N. P. Barker, H. M. Anderson and M. J. Dallwitz, *Grasses of southern Africa: Memoirs of the Botanical Survey of South Africa No. 58*, Pretoria: Government Printer, 1990, p. 437.

[40] F. P. Van Oudtshoorn, *Guide to the Grasses of Southern Africa*, Briza Publications, 2002.

[41] R. H. Campbell, S. Clapp and P. S. Test, Grazing strategies, stocking rates, and frequency and intensity of grazing on western wheatgrass and blue grama, *Journal of Range Management* 46 (1993) 122-126.

[42] D. L. Barnes and R. P. Denny, A comparison of continuous and rotational grazing on veld at two stocking rates, *Journal of the Grassland Society of Southern Africa* 8 (1991) (4) 168-173, doi: 10.1080/02566702.1991.9648285.

[43] A. G. Campbell, Grazing interval, stocking rate, and pasture production, *New Zealand Journal of Agricultural Research* 12 (1969) (1) 67-74, doi: 10.1080/00288233.1969.10427078

[44] J. H. Fourie, D. P. J. Opperman and B. R. Roberts, Influence of stocking rate and grazing systems on available grazing in the Northern cape, *Journal of the Grassland Society of Southern Africa* 2 (1985) (3) 24-26, doi: 10.1080/02566702.1985.9648008.

[45] R. K. Heitschmidt, S. L. Dowhower and J. W. Walker, Some effects of a rotational grazing treatment on quantity and quality of available forage and amount of ground litter, *Journal of Range Management* 40 (1987) (4) 318-321.

[46] S. Newman and S. G. Coffey, *Genetic Aspects of Cattle Adaptation in theTropics*, CAB Publications, 1999.

[47] J. B. Gaughan, T. L. Mader, S. M. Holt, M. J. Josey and K. Rowan, Heat tolerance of Boran and Tuli crossbred steers, *Journal of Animal Science* 77 (1999) 2398-2405.

[48] H. M. Burrow, Variances and covariances between productive and adaptive traits and temperament in a composite breed of tropical beef cattle, *Livestock Production Science* 70 (2001) 213-233.

[49] M. J. Mackinnon, K. Meyer and D. J. S. Hetzel, Genetic variation and covariance for growth, parasite resistance and heat tolerance in tropical cattle, *Livestock Production Science* 2 (1991) 105-122.

[50] G. P. Davis, Genetic parameters for tropical beef cattle in Northern Australia: A review, *Australian Journal of Agricultural Research* 44 (1993) 179-198.

[51] A. A. Boligon, R. Carvalheiro and L. G. Albuquerque, Evaluation of mature cow weight: Genetic correlations with traits used in selection indices, correlated responses,

and genetic trends in Nellore Cattle., *Journal of Animal Science* 91 (2013) 20-28.

[52] H. H. Meissner, M. M. Scholtz and A. R. Palmer, Sustainability of the South African Livestock Sector towards 2050 Part 1: Worth and impact of the sector, *South African Journal of Animal Science*, 43 (2013) 282-297.