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Forage–cattle relationships in a communally managed semi-arid savanna in northern Zululand, South Africa

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Development of extensive livestock production in KwaZulu-Natal is constrained by seasonal variability of rangeland production and low forage nutritional quality. A three-year study was implemented to determine the seasonal variation in herbaceous biomass and chemical composition of veld, animal weight, body condition and blood metabolites in a communal area where farmers wished to commercialise. The period of study was not characterised by unusual climatic conditions. Herbaceous biomass increased in wet months and decreased in dry months. Crude protein concentration was higher in wet seasons than dry seasons. Neutral detergent fibre was generally high. Calves gained 0.53–0.63 kg d^{-1} during the wet season and took 15 months to reach weaning weight. The mean weights and body condition scores of cows and bulls increased during wet seasons and decreased during dry seasons. Blood urea nitrogen was low in the dry season while creatinine concentrations increased in the dry season and dropped in the wet season. The results indicated that the quantity and quality of forage were insufficient for the development of commercial beef production. Further research is needed to develop and test strategies for improving the availability of nutrients in situations where communal farmers wish to develop livestock production.

Keywords: biomass, blood metabolites, forage quality, livestock, nguni

Introduction

In South Africa, extensive livestock production on rangeland occurs within two types of land tenure system: commercial and communal. Communal rangelands are state-owned tribal lands where people have historical rights to live and use the land. These areas occur mainly in the former ‘bantustans’ (e.g. KwaZulu and Transkei) and ‘coloured reserves’ created and administered under the colonial and apartheid minority government between 1913 and 1994 (Scogings *et al.* 1999, Vetter *et al.* 2006). In the sense that they are densely populated, they are quite unique when compared to communal rangelands elsewhere in the world (Hoffman *et al.* 1999). Communal areas are being reduced by the increasing need for residential properties, leading to increased grazing pressure per unit land area under a livestock population that is not decreasing. Many of the people who live in these areas depend at least partly on the natural resources for their livelihoods (Scogings *et al.* 1999). Livestock production is an important contributor to these livelihoods in communal areas and half the livestock population of South Africa is found in these communal areas (Scogings *et al.* 1999, Kunene and Fossey 2006). South African communal rangelands thus support millions of livestock and people.

Communal farming systems in South Africa are poorly understood relative to commercial systems (Scogings and Goqwana 1996, Hoffman *et al.* 1999, Scogings *et al.* 1999). The level of research conducted in communal rangelands is largely descriptive and the focus is on communal–commercial comparisons, which is confounded by the extreme socioeconomic differences between the two systems. Comparisons between different communal areas are needed for the development of technology that improves productivity in a sustainable way through communal management (Scogings *et al.* 1999).

Livestock in communal areas are maintained with minimum inputs and are dependent on rangeland resources for much of the year (Simbaya 2002). However, the quantity and quality of rangeland forage varies between wet and dry seasons, being abundant and nutritious in the wet season and scarce and fibrous during the dry season (Willms *et al.* 1996, Shinde *et al.* 1998, Kanneganti *et al.* 1998, Devendra and Sevilla 2002, Omer *et al.* 2006). In the wet season there is usually an increase in animal performance (Hatch and Tainton 1997). In the dry season, available forages are usually characterised by low concentrations of proteins, energy, minerals and vitamins required to maximise ruminal microbial activity (Leng 1990, Simbaya 2002). The forages also have elevated fibre concentrations, which limit intake and digestibility (Jung and Allen 1995). The resulting depressed microbial activity reduces rumen efficiency and reduces the true digestibility and intake of feed, resulting in low reproductive performance and poor growth rates of ruminants (Leng 1990, Pamo *et al.* 2007). Ruminant productivity is thus limited by the dry season (Wilkins 2000, Omer *et al.* 2006).

The main constraint for communal livestock systems in South Africa is the inadequate quantity and quality of rangeland forage at the end of the dry season. It follows that a basic knowledge of the seasonal changes in fodder is fundamental for the efficient management of communal rangelands for livestock production (Omer *et al.* 2006). Improved knowledge of the quantity and quality of rangeland forages, as well as the seasonal changes in these attributes, enables farmers to determine expected animal production, periods of nutritional deficiencies and the best way to match the animal's needs to the forage's ability to provide nutrition throughout the year (de Waal *et al.* 1999). Yet, few studies have quantified these changes for communal rangelands in South Africa (Scogings and Goqwana 1996, Hoffman *et al.* 1999, Scogings *et al.* 1999, Morris 2006). Such information is important for assessing the feasibility of implementing the South African government's policy of promoting commercialisation of agriculture in communal areas (see National Department of Agriculture 2005).

Approximately half of the KwaZulu-Natal province of South Africa is under communal management and perceived to be degraded (Hoffman *et al.* 1999). Yet, the issue of managing communal rangelands in the province have been neglected (Peden 2005). Research was initiated to explore possible constraints on livestock production in a communal area of northern KwaZulu-Natal that could affect the future development of livestock production in the area. Following an initial situation analysis to obtain baseline information on herd dynamics, management practices and rangeland condition, the first objective of the research was to quantify seasonal variations in forage quantity and nutritional quality. In particular, the quantity and quality of forage were expected to decline during the dry season. Another objective was to determine seasonal variations in animal weight and body condition score. It was expected that body weight and condition score would decline substantially in the dry season. Thirdly, blood metabolite concentrations were studied as integrative indexes of the nutrient status of the rangelands relative to nutrient use by livestock. Finally, animal and forage parameters were expected to be correlated. It was anticipated that such basic knowledge would be valuable for assessing the feasibility of developing livestock production in communal areas.

Procedure

Study area

The uPhongolo Municipality, on the border between KwaZulu-Natal and Swaziland, is among the most degraded areas of KwaZulu-Natal (Hoffman *et al.* 1999). The area is semi-arid according to the United Nations Convention to Combat Desertification (Hoffman *et al.* 1999). Data were collected from late 2004 to mid 2006 at Emoyeni (27°23′ S; 31°28′ E), which is a communal area c. 20 km west of the town of Pongola. The vegetation at Emoyeni is Northern Zululand Sourveld (Mucina and Rutherford 2006). The altitude is 550–750 m above sea level, although surrounding elevations reach beyond 850 m. The area is therefore rugged with steep slopes. Soils are generally well-drained sandy soils of granitic origin with occasional dolerite dykes crossing the area. Mean annual rainfall is c. 770 mm with most of it falling in summer, while winters are dry (Camp 1997). The mean annual temperature is 20.4 °C with mean summer temperatures of 26 °C and mean winter temperatures of 14 °C (Camp 1997).

Data collection

A situation analysis was conducted in late 2003 and early 2004 to determine herd dynamics, management practices and rangeland condition. Questionnaire and interview surveys were conducted among 15 cattle owners who agreed to participate in the project at Emoyeni (J Clayton and J Binedell, Agricultural Research Council, unpubl. data). Rangeland condition and grazing capacity were estimated according to a method widely promoted for use in KwaZulu-Natal and other provinces of South Africa (Hardy and Hurt 1999, Tainton 1999, Smith 2006). The method results in a veld condition score (VCS) derived from a combination of objectively estimated botanical composition (relative abundance of species) and subjectively estimated 'ecological groupings' (responses to grazing) and 'grazing values' (potential productivity and relative palatability) of species (Heard *et al.* 1986). The VCS is expressed relative to a benchmark that represents the potential condition. Given a grazing capacity for the benchmark, a grazing capacity for the sampled sites can be derived from the VCS.

Herbaceous and woody vegetation were surveyed to estimate relative abundance of grasses and density of woody plants, which can negatively affect grazing capacity. Four veld type units (VTUs) were identified, namely north-facing slopes, south-facing slopes, west-facing slopes and an alluvial flood plain on the Spekboom River. Twelve sample sites were located across the VTUs. A 100 $\times$ 2 m belt transect was surveyed at each site to estimate the abundance of woody plants. The height of each woody plant was measured. At each site, a 100-point survey of grasses was conducted along two, parallel, 100-pace transects, whereby a spike was dropped vertically every two paces and the nearest grass species was identified. Non-grass herbaceous plants were recorded as either forbs or sedges. If no plant was found within 15 cm of the spike, then a bare area was recorded. The resulting data were transformed to an estimate of grazing capacity in relation to that described for the benchmark for commercial livestock production in Bioresource Group (BRG) 20, within which the study area occurs (Camp 1997, Camp and Smith 1998).

On the basis of the situation analysis outlined above, a more intensive programme of monitoring the forage resource and livestock condition was planned, which ran for almost two years from late 2004 to mid 2006. Observations were usually undertaken at intervals of six weeks, as far as was logistically possible. Dry matter (DM) yield of available forage was estimated from quadrats harvested each time to calibrate a disc pasture meter (DPM) for future use in non-destructive estimates of DM yield in the area (Bransby and Tainton 1977). Five circular quadrats (0.16 m^2) were located 40 paces apart along two parallel 100-pace transects 25 m apart on each site. Before clipping each quadrat, the settling height (cm) of the DPM above the quadrat was recorded. The material under the disc was then harvested at 2 cm above ground level and placed in a paper bag.

Harvested samples were oven-dried at 60 °C for 48 h and weighed to determine the DM content (g), after which they were milled through a 1.0 mm screen and analysed for nitrogen (N) according to the Kjeldahl technique and crude protein (CP) was calculated as N × 6.25 (AOAC 1990). Neutral detergent fibre (NDF) analysis was performed by the sequential procedure of Goering and van Soest (1970).

Cattle, including calves, were individually weighed using an electronic scale every six weeks in the morning before they went out to graze. Body condition score (BCS) was visually evaluated concurrently with the weighing of cattle by the same technicians using a five-point scale (ARC 2000), where 1 indicated emaciation, 5 indicated obesity and 3 was the ideal condition. Body-condition scoring is a reliable guide for evaluating the nutritional status of cattle, with lower scores corresponding to poorer nutritional intake and greater metabolic need (Nicholson and Sayers 1987, Corro *et al.* 1999).

The nutritional and metabolic status of animals is reflected in blood metabolite concentrations, which represent an integrated index of the adequacy of nutrient supply in relation to nutrient utilisation independent of physiological state (Pambu-Gollah *et al.* 2000, Caldeira *et al.* 2007). Blood samples were collected from heifers in the morning every six weeks depending on the availability of the animals by venipuncture of the *vena caudalis mediana* (tail vein) using 4 ml Becton Dickinson Vacutainer® blood collection tubes containing heparin anticoagulant (green top). The samples were placed on ice in insulated containers to keep them at normal refrigerator temperature (4 °C) while transported directly to Empangeni Veterinary Hospital. The samples were analysed for cholesterol, blood urea-nitrogen (BUN) and creatinine on the same day using a Reflovet® Clinical Analyzer (Roche, Germany), which is a dry chemistry system that uses reflectance photometry. Samples of heparinised whole blood were applied directly to reagent strips and did not require special preparation (e.g. centrifugation) before being inserted into the analyser. Blood urea-nitrogen concentration is a useful indicator of the protein status of animals and has been positively correlated with dietary nitrogen in sheep and cattle (Pitts *et al.* 1992, Huntington *et al*. 2001, Kohn *et al.* 2005). Creatinine concentration increases during periods of food restriction, but declines with increased food availability (Sakkinen *et al.* 2001). Cholesterol, however, is positively associated with animal weight (Gades *et al.* 2000).

Data analysis

The DPM height and DM data were used to calibrate the DPM for future use in non-destructive surveys of the study area and similar areas. Calibration was done by fitting simple linear regression models to the data for both the dry (May to September) and wet (October to April) seasons (Danckwerts and Trollope 1980). Three sites were rockier than others and were excluded from the calibration models. Estimates of the average available biomass for the study area were based on the DM data from the samples clipped to calibrate the DPM. Both forage and animal data were tested for all assumptions of parametric tests and analysed using SPSS version 13 (SPSS 2006). Repeated-measures analysis of variance was used to model monthly changes in forage availability, but was not used for other variables because of unequal sample sizes. Differences between wet season and dry season means of forage CP and NDF, body weights and condition scores of cows, oxen and bulls, and cholesterol, BUN and creatinine of heifers were tested with *t*-tests adjusted for unequal sample sizes. Pearson's correlation analysis was performed on the monthly estimates of animal parameters (dependent variables) and forage parameters (independent variables).

Results

Situation analysis

The questionnaire and interview surveys in 2003 showed that the group of farmers originally owned a total of 123 cattle, comprising 87 (70%) adults (18 bulls, nine oxen, 60 cows >2 years old) and 36 sub-adults (21 steers and 15 heifers ≤2 years old). Some animals were >10 years old. The male:female ratio was 2:3. Most of the animals (84%) were regarded as Nguni, while the rest were other breeds and mixed breeds. As far as could be established by talking to the farmers, the grazing area covered c. 270 ha. Cattle were allowed to graze free-ranging during the day and were kraaled at night. According to the farmers, intercalving intervals for productive cows was two years for cows ≤8 years old and three years for cows >8 years of age on average. One-third of the cows had never produced a calf. The farmers indicated that 40% of the animals belonged to only two of the farmers, while the remaining 13 farmers owned 5.5 animals (range 2–9 animals) on average. Most of the animals (96%) were held as a form of savings (to sell whenever substantial cash is needed), 3% were kept for milk and 1% was kept for slaughter. Individual farmers managed their own animals separately. Therefore, practices such as dipping, castration and dehorning were not implemented uniformly across the herd.

The vegetation surveys in 2004 indicated that bush density was very high, ranging from c. 16 000 woody plants ha^{-1} on north-facing and south-facing slopes, to c. 23 000 woody plants ha^{-1} on west-facing slopes and c. 33 000 woody plants ha^{-1} on the alluvial plain. Woody phytomass, expressed in terms of 'tree equivalents' (TE = total height of plants/1.5 m) (Teague *et al.* 1981), was moderate to very high, ranging from c. 4 500 TE ha^{-1} on north-facing and south-facing slopes, to c. 9 500 TE ha^{-1} on west-facing slopes and c. 10 300 TE ha^{-1} on the alluvial plain. Compared to the benchmark for BRG 20, the veld was dominated by grasses that increase through long-term overgrazing (Camp 1997, Camp and Smith 1998). Average grazing capacity was estimated to be c. 22% of the benchmark. Assuming an ideal stocking rate of 4 ha AU^{-1} for BRG 20 (Camp 1997, Hoffman *et al.* 1999), the recommended average stocking rate was therefore 18.2 ha AU^{-1}, where 1 AU is an animal of 450 kg that consumes 10 kg DM d^{-1} (Camp and Smith 1998, Smith 2006). Assuming that adult Nguni cattle are 0.84 AU each (T Dugmore, KwaZulu-Natal Department of Agriculture and Environment Affairs, pers. comm.), the recommended average number of cattle for the 270 ha grazing area was 18 compared to the c. 135 cattle that the farmers kept.

Seasonal variations

During the phase of more intensive data collection (2004–2006), the mean dry matter forage yield differed across months ($F_{9,54} = 6.68$, $P < 0.001$) (Figure 1). There was an increase in the DM yield in the wet months and a decrease in the DM yield in the dry months. The bulk of the DM yield was produced in the wet months where most of the rainfall occurred. The DM yield ranged from a high of 1 298.6 ± 237.46 kg ha^{-1} in March 2005 to a low DM yield of 229.2 ± 65.10 kg ha^{-1} in September 2005. Regression models were developed to calibrate the disk pasture meter for the wet season ($y = 2.46x - 0.29$, $r^2 = 0.56$) and for the dry season ($y = 3.58x - 3.42$, $r^2 = 0.50$) where y is the dry mass (g) and x is the disk height (cm) (Figure 2). The high variation in the models was probably due to the terrain of the area, veld type and veld condition among other factors (Bransby and Tainton 1977).

The CP content of the forage followed a similar trend to that of DM yield (Table 1). There was a significant difference in the CP content of the veld between the 2004/05 wet season and the 2005 dry season ($t = 3.82$, df = 34, $P = 0.001$), the 2005 dry season and the 2005/06 wet season ($t = -4.79$, df = 40.68, $P < 0.001$) and the 2005/06 wet season and 2006 dry season ($t = 2.39$, df = 36.81, $P = 0.022$). There was an increase in CP in the wet season and a decrease in CP in the dry season. The NDF values for Emoyeni differed between the 2004/05 wet season and the 2005 dry season ($t = -3.16$, df = 34, $P = 0.003$), the 2005 dry season and the 2005/06 wet season ($t = 2.22$, df = 39.89, $P = 0.032$) and the 2005/06 wet season and the 2006 dry season ($t = 1.99$, df = 39.02, $P = 0.053$). An increase in NDF was observed in the 2005 dry season and lower values of NDF were observed in the wet seasons (Table 1).

Accurate data on herd structure and dynamics in 2004–2006 were difficult to obtain because of the communal nature of the system. The number of animals brought for weighing varied according to each individual farmer's circumstances, such as whether or not anyone was available to herd the animals. However, during the study period, from November 2004, the herd comprised a total of c. 135 animals consisting of c. 85 (62.5%) cows, c. 10 (7.5%) oxen, c. 20 (15%) bulls, 10 (7.5%) female calves and 10 (7.5%) castrated calves. Calving rate was c. 24%. From November 2004 to April 2005, calves gained 0.53 kg d^{-1} on average, after which they stopped gaining until at least September 2005, when they were no longer weighed as calves (Figure 3). Calves in February 2006 were c. 60 kg, gained c. 35 kg to reach c. 95 kg in March (six weeks later) and then gained only 15 kg in the next three months as the dry season began. Calving occurred at almost any time of the year in the study area and tended to peak in the middle of the wet season. Assuming the calves that were weighed in November 2004 (average weight of 100 kg) were born in January 2004 and weighed c. 25 kg at birth (Smith 2006), and most of their weight

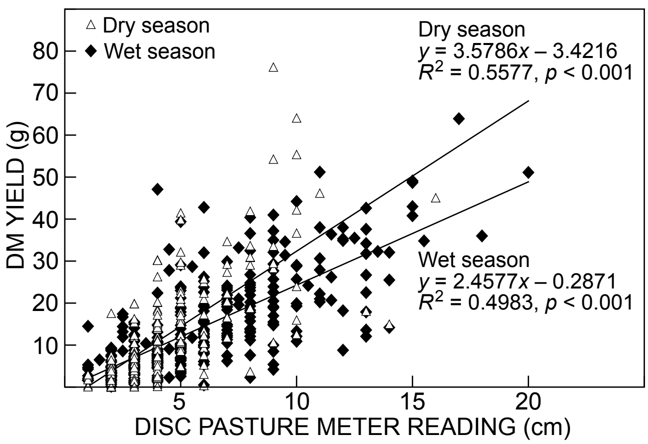

Figure 2: Calibration of the disc pasture meter in the dry season (May to September 2005) and the 2004/05 and 2005/06 wet seasons (October to April) at Emoyeni. DM = dry matter

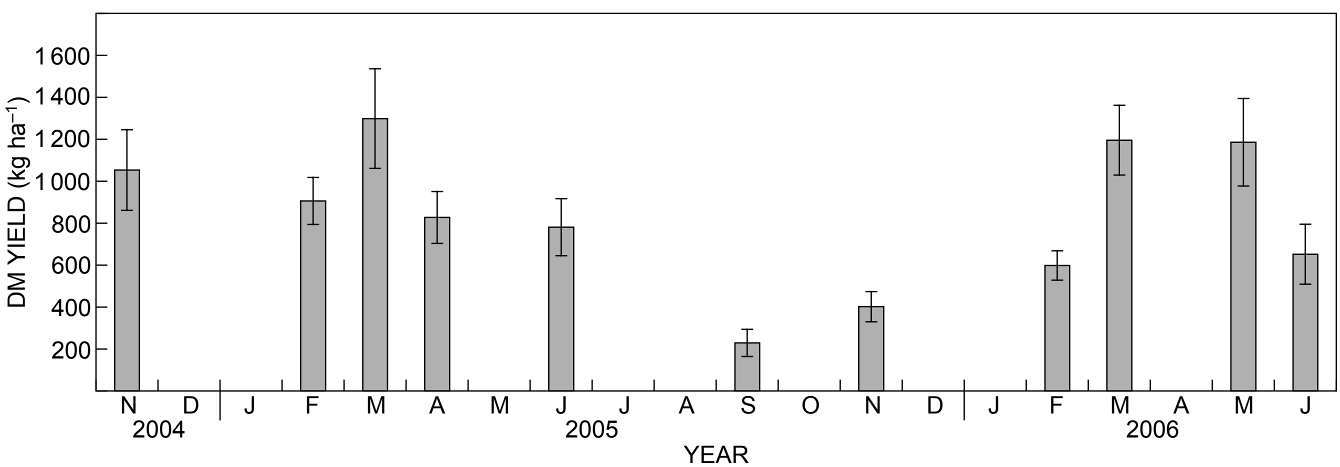

Figure 1: The estimated mean ± SE dry matter (DM) forage yield (kg ha^{-1}) for 12 sample sites at Emoyeni from November 2004 to June 2006

gain of c. 75 kg was gained before May 2004, then it can be estimated that they grew at c. 0.63 kg d^{-1} in the first few months after birth, stopped growing for the 2004 dry season and then gained c. 0.53 kg d^{-1} for the 2004/05 wet season. They were thus c. 15 months old when their mean weight was 141–182 kg.

Oxen mean weights fluctuated the most (220–450 kg), while bull mean weights were 290–420 kg and cow mean weights were 280–330 kg. Mean weights of cows and bulls tended to increase during the wet season and decrease during the dry season (Table 2). Mean weights of bulls varied significantly between the 2005 dry season and the 2005/06 wet season ($t = -2.46$, df = 24.52, $P = 0.021$). Oxen showed an unexpected increase in weight in the 2005 dry season and a decrease in weight in the 2005/06 wet season. From November 2004 cows, oxen and bulls attained high condition scores in the wet season and low condition scores in the dry season (Table 3). The mean body condition scores of cows, oxen and bulls in the wet season were close to the ideal score of 3. The body condition scores of cows was significantly different between the 2004/05 wet season and the 2005 dry season ($t = 8.96$, df = 277.53, $P < 0.001$) and the 2005 dry season and the 2005/06 wet season ($t = -9.94$, df = 171.30, $P < 0.001$).Oxen showed significant differences in body condition scores between the 2004/05 wet season and the 2005 dry season ($t = 6.15$, df = 48.25, $P < 0.001$) and the 2005 dry season and the 2005/06 wet season ($t = -9.99$, df = 22.00, $P < 0.001$). The body condition scores of bulls was also significantly different between the 2004/05 wet season and the 2005 dry season ($t = 8.16$, df = 59.21, $P < 0.001$) and the 2005 dry season and the 2005/06 wet season ($t = -3.15$, df = 15.02, $P = 0.001$).

Preliminary data collected in August 2003 and March 2004 indicated that cholesterol (c. 3.2 mmol l^{-1}) and BUN (c. 5.3 mmol l^{-1}) were consistently normal. From November 2004, cholesterol did not show substantial seasonal differences, but BUN tended to be lower in the dry season, while creatinine tended to be lower in the wet season. Cholesterol was higher in the 2005 dry season than the 2005/06 wet season ($t = 2.99$, df = 24.37, $P = 0.006$) (Table 4). Nevertheless, cholesterol was consistently within the normal range of 1.3–3.8 mmol l^{-1} (Blood and Henderson 1960). BUN concentrations were lower in the 2005 dry season than the 2005/06 wet season ($t = -5.03$, df = 19.64, $P < 0.001$) (Table 4). Monthly BUN values ranged from 3.3 ± 0.20 mmol l^{-1} to 4.9 ± 0.25 mmol l^{-1}, which were within the normal range of 3.1–4.7 mmol l^{-1} (Blood and Henderson 1960). Creatinine levels varied significantly between the 2005 dry season and the 2005/06 wet season ($t = 5.73$, df = 37.72, $P < 0.001$), being lower in the wet season (Table 4), but remained within the normal range of 80–133 μmol l^{-1} (Blood and Henderson 1960).

Table 1: Trends in mean ± SE crude protein (% dry matter) and neutral detergent fibre (% dry matter) of rangeland forage at Emoyeni

Season	Nutrient	
	Crude protein	Neutral detergent fibre
Wet season 2004/05 ($n = 18$)	6.0 ± 0.29	81.5 ± 1.18
Dry season 2005 ($n = 18$)	4.5 ± 0.25*	86.0 ± 0.76*
Wet season 2005/06 ($n = 33$)	6.1 ± 0.22*	83.7 ± 0.66*
Dry season 2006 ($n = 18$)	5.2 ± 0.28*	81.7 ± 0.78*

* Mean is significantly different to the previous season's mean according to *t*-test ($P < 0.05$)

Correlations

Forage DM and CP were not correlated with the weights of oxen and bulls, but DM and body condition were positively correlated ($P = 0.011$) (Table 5). A significant correlation was also observed between CP and the weight of cows ($P = 0.035$). NDF and the weights of cows, oxen and bulls and NDF and body condition were not correlated. A strong negative correlation was observed between CP and creatinine ($P = 0.025$). BUN was not correlated with forage DM, CP and NDF.

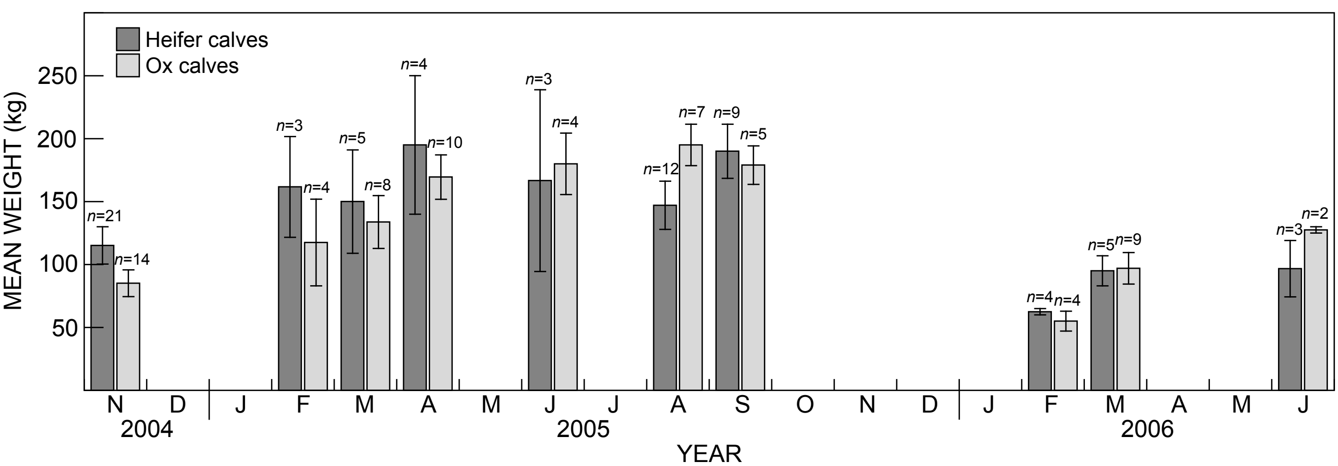

Figure 3: Mean weights of heifer calves and ox calves at Emoyeni from November 2004 to June 2006. Error bars indicate the SE

Table 2: Trends in mean ± SE weights (kg) of cows, oxen and bulls at Emoyeni

Season	Cattle		
	Cows	Oxen	Bulls
Wet season 2004/05	300.2 ± 5.40 (n = 166)	279.0 ± 21.07 (n = 50)	335.7 ± 12.32 (n = 55)
Dry season 2005	287.0 ± 6.68 (n = 136)	294.4 ± 31.22 (n = 23)	317.2 ± 15.46 (n = 30)
Wet season 2005/06	299.7 ± 9.14 (n = 68)	251.5 ± 40.18 (n = 10)	379.6 ± 20.16* (n = 12)

* Mean is significantly different to the previous season's mean according to t-test ($P < 0.05$)

Table 3: Trends in mean ± SE body condition scores of cattle at Emoyeni

Season	Cattle		
	Cows	Oxen	Bulls
Wet season 2004/05	2.5 ± 0.05 (n = 166)	2.7 ± 0.10 (n = 50)	2.8 ± 0.08 (n = 55)
Dry season 2005	1.8 ± 0.06* (n = 136)	1.7 ± 0.14* (n = 23)	1.7 ± 0.11* (n = 30)
Wet season 2005/06	2.6 ± 0.06* (n = 68)	3.0 ± 0.20* (n = 10)	2.6 ± 0.26* (n = 12)

* Mean is significantly different to the previous season's mean according to t-test ($P < 0.05$)

Table 4: Trends in mean ± SE concentrations of cholesterol, blood urea-N and creatinine in heifers at Emoyeni

Season	Blood metabolites		
	Blood urea-N	Cholesterol	Creatinine
Wet season 2004/05	3.6 ± 0.14 (n = 33)	3.1 ± 0.07 (n = 33)	
Dry season 2005	3.5 ± 0.08 (n = 26)	3.1 ± 0.04 (n = 26)	128.4 ± 5.29 (n = 26)
Wet season 2005/06	4.7 ± 0.22* (n = 16)	2.9 ± 0.06* (n = 16)	93.2 ± 3.10* (n = 16)

* Mean is significantly different to the previous season's mean according to t-test ($P < 0.05$)

Discussion

While communal areas may be more degraded than commercial ones and, on average, have double the stocking rates recommended for commercial livestock production, communal stocking rates can be as much as five-fold higher than commercial recommendations (Goqwana 1998, Hoffman *et al.* 1999). The stocking rate recommended for BRG 20 is 3–5 ha AU^{-1} (Camp 1997, Hoffman *et al.* 1999). During 2004–2006, the study area was overstocked by a factor of c. 7.5 compared to commercial standards, which reflects observations elsewhere in semi-arid communal areas. Vetter and Goqwana (2000) found a seven-fold difference between grazing capacity derived from commercial standards (11–16 ha AU^{-1}) and observed stocking rates (2 ha AU^{-1}) on a communal rangeland in the Eastern Cape. There may be various reasons for this, but the most obvious one is that communal livestock owners have different objectives than commercial farmers and therefore determining stocking rates for communal areas on the basis of models designed for commercial production may not be appropriate (Hoffman *et al.* 1999, Scogings *et al.* 1999). As far as we know, no such models exist for communal areas.

In terms of the quantity and quality of forage available, our results concurred with evidence from other areas, especially in the Eastern Cape province of South Africa, where herbaceous biomass in communally managed rangelands is 1 000–2 500 kg ha^{-1} at the end of the wet season (de Bruyn 1998, Goqwana 1998, PFS unpubl. data). Such areas typically have stocking rates that are 2–5 times higher than levels recommended for commercial ranchers. In less heavily grazed areas, herbaceous biomass is 2 700–7 500 kg ha^{-1} at the end of the wet season (Owen-Smith and Danckwerts 1997, de Bruyn 1998, Tainton 1999). Therefore, herbaceous biomass in heavily grazed communal rangelands is commonly <40% that of less heavily grazed commercial rangelands, providing far less forage than what is ideal for commercial levels of livestock production (Owen-Smith and Danckwerts 1997, Scogings *et al.* 1999).

Seasonal fluctuations in the quality and quantity of forages tend to follow the seasonal variation in rainfall distribution (Meissner 1997, de Waal *et al.* 1999). As expected, forage availability at Emoyeni peaked in the wet season

Table 5: Pearson's correlation coefficients between forage parameters (dry matter, crude protein and neutral detergent fibre) and animal parameters (weight [W], body condition and blood metabolites) at Emoyeni

Parameter	W_{cows} (n = 10)	W_{bulls} (n = 10)	W_{oxen} (n = 10)	Body condition (n = 10)	Cholesterol (n = 7)	Urea N (n = 7)	Creatinine (n = 4)
Dry matter	–0.03	–0.16	0.04	0.83*	0.27	0.22	0.10
Crude protein	–0.74*	–0.49	–0.44	–0.16	–0.14	0.41	–0.99*
Neutral detergent fibre	0.52	0.13	0.62	0.60	–0.32	0.01	0.66

* Correlation is significant where $P < 0.05$

relative to the dry season. Omer *et al.* (2006) also observed seasonal differences in pasture biomass, with higher biomass in summer because of increased moisture availability. The average forage availability in the wet season at Emoyeni would have been insufficient for maximum intake (NRC 2000). Furthermore, the average forage availability in the dry season was so low that intake would have been severely constrained. The scarcity of forage during the dry season was not only caused by direct effects of seasonal changes, but was also caused by indiscriminate wild fires that affected parts of the grazing area.

Grass hay quality is classified into three categories: high quality (>10% CP), medium quality (8–10% CP) and low quality (<8% CP) (NRC 2000). The rangeland forages at Emoyeni should therefore be considered as poor quality, especially in the dry season. The quality of the forage tended to follow a similar seasonal trend to the DM yield. Crude protein concentration declined to submaintenance levels during the dry season compared to the wet season, which supported observations of Pamo *et al*. (2007) who observed high CP levels for grasses in the rainy season and low CP levels in the dry season.

It has been postulated that heavy grazing improves forage quality (McNaughton 1979, Owen-Smith and Danckwerts 1997), but our study suggests otherwise. Elevated productivity of nutritious forage in heavily grazed systems is expected when soils are nutrient-rich (Belsky *et al.* 1993, Rosenthal and Kotanen 1994, Archibald *et al.* 2005). We postulate that overall forage quality did not improve with heavy grazing because the soils were derived from granites and therefore plant available nutrients were limited. Generally, sustained heavy grazing in such systems leads to reduced overall quality because of poor soils (O'Connor and Bredenkamp 1997, Tainton 1999).

The changes in body weight and condition score of the cattle at Emoyeni were typical of the trend expected from livestock grazing in communal areas. Celaya *et al*. (2007) observed that cattle lost weight considerably in winter because of the decrease in vegetation during winter. Similar trends have been observed elsewhere (Masama *et al*. 2006). Our results showed that the mean weights and condition scores of cows and bulls decreased during the dry season and increased during the wet season, but there was a lag effect. Towards the end of the wet season and early dry season the cattle were still increasing in weight when the quality of the forage started to decline, while at the start of the wet season there was an improvement in CP concentration but no significant increase in the weight of the cattle. Although the animals were fed some hay supplement during the dry season, which was not quantified, this was apparently not enough to offset the decrease in weight.

Consistent with expectations, BUN concentrations of cattle showed significant seasonal variation, with higher concentrations in the wet season and lower concentrations in the dry season, which tracked the variations in CP concentration of the rangeland forages. Plasma urea concentrations are sensitive to seasonal variations in nutrient intake because elevated nutrient intake from new growth in the wet season leads to elevated BUN (Pambu-Gollah *et al*. 2000, Huntington *et al.* 2001). Our results showed seasonal changes in creatinine such that levels were higher in the dry season than the wet season and that creatinine concentration was negatively correlated with CP concentration of the forages. Creatinine concentration has been found to be negatively related to nitrogen intake with the result that creatinine concentrations are higher in the dry season than in the wet season (Sakkinen *et al.* 2001, Davies *et al*. 2007). Low protein intake increases creatinine concentration by decreasing glomerular filtration rate (Sakkinen *et al.* 2001). Therefore, our results suggest that nitrogen intake was restricted in the dry season. Cholesterol levels were not sensitive to the seasonal changes in forage quality, probably due to the poor quality of the forage (Caldeira *et al*. 2007).

South African government policy is promoting commercialisation of agriculture in areas under communal tenure, but the feasibility of commercialising agriculture in communal areas is unknown. Since 2002, livestock owners at Emoyeni have been considering a change from communal production to commercial production. The results of this study provide some basis for assessing the feasibility of such a change. The overall forage availability was insufficient to maintain commercial levels of cattle production throughout the year without supplementation for most of the year. Minimum CP in diets of livestock ranges from 7% for mature beef cows to 19% for high-producing dairy cows (Buxton 1996, Meissner *et al.* 1999, NRC 2000). The rangeland forages at Emoyeni were therefore far below the required level of quality for commercial beef production, especially during the dry season. The maximum NDF concentration that does not restrict intake and animal production is 70–75% dry matter for mature beef cows and 15–20% for finishing ruminants (Buxton 1996). The levels of NDF at Emoyeni were higher than this, indicating that commercial animal production would be restricted by both intake and protein. That the conditions would constrain attempts to develop commercial production was shown by calf performance. Calving occurred at any time of the year, but peaked in the middle of the wet season unlike commercial systems in which calving occurs at the end of the dry season. From our rough approximation of calf performance, calves were c. 15 months old at normal weaning weight for commercial beef (150 kg; Smith 2006), which means their weaning age was double that of commercial beef (7–8 months; Smith 2006).

In commercial rangelands, it is well established that range condition is closely related to fodder quality, animal condition and economic returns (Dean and Macdonald 1994, Hoffman *et al.* 1999). In contrast, the relationship is thought to be insignificant for communal rangelands, which provide a wider range of benefits than commercial ones (Cousins 1998, Hoffman *et al.* 1999). The absence of such a relationship may explain why animal numbers in many communal areas have not declined substantially despite decades of high stocking rates (Hoffman *et al.* 1999). Our results, however, suggested that overall animal performance was indeed related to forage quantity and forage quality, which was limiting throughout the year. We hypothesise that during the wet season there was enough forage to offset the potential negative effects of low quality. In the dry season, the negative effect of low quality forage was exacerbated by the decline in forage quantity. Even if animals wanted to eat more they could not find enough fodder to meet their requirements. The resulting weight and condition loss in the dry season would probably have compromised livestock productivity through reduced reproduction and reduced disease resistance (Daka 2002, Omer *et al.* 2006).

The provision of key resources in the dry season has long been identified by South African commercial farmers as a key to sustaining animal production (Scogings *et al.* 1999). As such, planted pastures, crop residues and concentrate feeds have traditionally been used to overcome the shortfall in fodder flow towards the end of the dry season. Neither the technology developed for commercial systems, nor the understanding of communal systems in other parts of the world, however, can be directly transferred to communal systems in South Africa (Hoffman *et al.* 1999, Scogings *et al.* 1999). Management systems must fit the environmental conditions, the objectives of livestock owners and overcome constraints on livestock production. Examples of possible strategies to sustain animal production in communal areas include stock reduction and feed supplementation, but the former is socially unacceptable and the latter is really only an option for subhumid areas, because in semi-arid areas high stocking rates can lead to further degradation (Scogings *et al.* 1999, Peden 2005, Vetter *et al.* 2006).

For semi-arid communal areas, increasing the diversity of livestock by reintroducing locally developed livestock breeds (e.g. Nguni) or game species has been proposed as an option for sustaining animal production, but other options include adjustment of stocking rates in response to conditions, veld burning, rotational grazing and rotational resting (Scogings *et al.* 1999, Vetter and Goqwana 2000, Peden 2005, Vetter *et al.* 2006). As opposed to rotational grazing, which has as its objective the uniform utilisation of veld, rotational resting aims to provide a fodder reserve for the dry season and also allows grass to replenish its stored carbon resources and to set seed. Stock reduction is an inevitable outcome of implementing a successful rotational resting system, because not all the veld can be used. Rotational resting has been found to be an acceptable and beneficial system in some communal areas, but it is usually difficult to manage such systems in communal areas (Goqwana 1998, Vetter and Bond 1999). Therefore, it is unlikely that livestock production in communal areas can be truly commercialised.

Conclusions

The stocking rate at Emoyeni far exceeded the recommended rate for commercial farmers during the period of our research. The low availability of forage, the poor quality of forage and the poor nutrient use by animals restricted livestock performance compared to commercial standards. This was manifested in the loss of weight and body condition of adults during the dry season and the increased time needed for calves to attain weaning weight. Additional research is needed to develop and test strategies for improving the availability and utilisation of nutrients for livestock in semi-arid communal areas. Finally, if livestock owners in communal areas wish to commercialise, then a novel model of ‘semi-commercial’ livestock production may need to be defined.

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