The influence of stocking rate, range condition and rainfall on seasonal beef production patterns in the semi-arid savanna of KwaZulu-Natal

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Received 13 October 1995; accepted 8 August 1997

Grazing trials were established at two sites in the semi-arid savanna (Lowveld) of KwaZulu-Natal. The sites differed initially in range composition. Llanwarne was dominated by Themeda triandra, Panicum maximum and P. coloratum, and Dordrecht by Urochloa mosambicensis, Sporobolus nitens and S. ioclados. Three treatments at each site were stocked with Brahman-cross cattle to initially represent 'light' (0.17 LSU ha⁻¹) 'intermediate' (0.23 LSU ha⁻¹) and 'heavy' (0.30 LSU ha⁻¹) stocking. Cattle mass data collected over 116 three-week periods were used to develop a step-wise multiple linear regression model where summer mass gain (kg ha⁻¹) was significantly related (p < 0.01) to total seasonal rainfall (mm) (measured 1 July to 30 June) and stocking rate (LSU ha⁻¹). Winter mass loss (kg ha⁻¹) was related to residual herbage mass at the end of summer (kg ha⁻¹) and the length of winter (days). Although range condition did not significantly influence summer mass gain, winter mass loss was inversely related to residual herbage at the end of summer, which suggested that grass species in the Lowveld may differ in production potential rather than in quality.

Weidingsproewe is op twee terreine in die semi-droë savanna (Laeveld) van KwaZulu-Natal uitgeoef. Die terreine het aanvanklik verskillende spesiesamsettings gehad. Llanwarne is gekenmerk deur Themeda triandra, Panicum maximum en P. coloratum, en Dordrecht deur Urochloa mosambicensis, Sporobolus nitens en S. ioclados. Op beide terreine is Brahmanakruis gebruik om drie veelbeddinge te verwy, 'n 'ligte' (0.17 GVE ha⁻¹), 'intermediêre' (0.25 GVE ha⁻¹) en 'hoë' (0.30 GVE ha⁻¹) veelading. Liggaams massa is oor 116 drie-week periodes gemee en gebruik om 'n stapsgewyse, veelvuldige lineêre regressiemodel te ontwikkel. Massatoename in die somer (kg ha⁻¹) was betekenisvol afhanklik van totale seisoenale reënvall (mm) (gemes tussen 1 Julie en 30 Junie) en veelading (GVE ha⁻¹). Massaverlies gedurende die winter (kg ha⁻¹) was afhanklik van residiële plantmateriaal (kg ha⁻¹) aan die einde van die somer en die lengte (dae) van die winter. Alhoewel veldtoestand nie massatoename gedurende die somer beduidend beïnvloed het nie, was massaverlies gedurende die winter deur residuelle plantmateriaal aan die einde van die somer beïnvloed. Dit mag aandui dat grasspesies in die Laeveld in produktsiepotensiaal eerder as in kwaliteit verskil.

Keywords: summer livemass gain, winter livemass loss, modelling

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Introduction

Although stocking rate influences individual animal performance (Mott, 1960; Riewe, 1961; Jones & Sandland, 1974), livestock production in semi-arid systems is strongly influenced by temporal rainfall variability (McDonald, 1982; O'Connor, 1985; Ellis & Swift, 1988; Hatch & Tainton, 1995). This paper examines the relationship between rainfall, range condition, stocking rate and livestock production patterns in the semi-arid savanna, with the aim of developing a model to predict seasonal patterns of livemass change.

Procedure

Grazing trials were established at two adjacent sites in the semi-arid savanna (Lowveld) of KwaZulu-Natal. Data were collected over a seven-year period (1986–1993). The sites differed in range composition. Llanwarne (27°35'S; 31°45'E, 320 m a.s.l.) was dominated by Themeda triandra, Panicum maximum and P. coloratum and considered to be in good condition for cattle production. Dordrecht (27°36'S; 31°46'E, 320 m a.s.l.), was initially dominated by Urochloa mosambicensis, Sporobolus nitens and S. ioclados, and was considered to be in poor condition for cattle production. Soils of the Komatipoort System, predominantly of the Swartland form with Clowley, Hutton, Mispah, Glenrosa and Bonheim forms, occurred at the sites (Soil Classification Working Group, 1991).

Three treatments at each site were stocked at the start of each season (October) with 250 kg Brahman-cross cattle to represent 'light' (0.17 LSU ha⁻¹), 'intermediate' (0.23 LSU ha⁻¹) and 'heavy' (0.30 LSU ha⁻¹) stocking. [LSU denotes large stock unit as defined by Meissner, et al. (1983).] Seven and eight steers were allocated to the light and intermediate treatments, and eight and nine to the heavy treatments, at Dordrecht and Llanwarne respectively. The area of land allocated to each treatment was varied to provide the required range in stocking rates. Game, primarily impala (Aepyceros melampus), nyala (Tragelaphus angasii), kudu (Tragelaphus strepsiceros) and warthog (Phacochoerus aethiopicus), occurred at both sites. The actual cattle stocking rates applied in each season were calculated for the summer and winter using the animal unit equivalents approach of Alderman & Barber (1973). A two-paddock rotational grazing system for each stocking rate treatment gave a total of six paddocks per site. Paddocks received alternate spring and autumn rests. The period of stay depended on the season and was therefore variable. Cattle were weighed at three-weekly intervals (from November 1986 to June 1993) after being starved overnight. Herbage mass was estimated at each recording date as the mean of 50 readings, recorded with a pasture disc-meter.
(Bransby & Tainton, 1977), on a fixed diagonal transect in each camp. Mean disc-meter heights for each camp were converted to an estimate of herbage mass (kg.ha⁻¹) using the generalised calibration equation developed for the two sites by Turner (1990), where herbage mass (kg.ha⁻¹) = 882 + 271* (mean disc height in cm). Patterns in herbage mass consequently followed mean disc-meter heights.

Range condition was assessed in 1986, 1988, 1989, 1990, 1993 and 1994 using the nearest-plant method (Foran et al., 1978) to collect 150 points at 3-m intervals on each of two fixed transects, from which proportional species composition was calculated for each paddock following the nomenclature of Gibbs Russell, et al. (1990). Range condition was indexed as the sum of the proportions of three key forage species, T. triandra, P. maximum and P. coloratum (Table 1). Daily rainfall (mm) records were kept for each site and total seasonal rainfall was calculated from 1 July to 30 June.

A step-wise multiple linear regression approach (Steel & Torrie, 1981) was used to reflect the influence of stocking treatment (LSU.ha⁻¹), range condition and total seasonal rainfall (mm) (recorded from 1 July to 30 June) on summer mass gain (kg.ha⁻¹). A winter loss model examined the influence of residual summer herbage mass (kg.ha⁻¹) and the length of the winter period (days) (defined as the number of days between the last rainfall event of >15 mm in summer and the first rainfall event of an equivalent amount in the following spring) on winter livemass loss (kg.ha⁻¹). The period over which herbage accumulation continued after the last date in summer on which >15 mm of rain was recorded, and the delay before recorded herbage accumulation occurred after the date on which >15 mm of rain was recorded in spring, were therefore assumed to be equal.

Table 1 The sum of proportions of three key forage species (T. triandra, P. maximum and P. coloratum) in each of the light (L), intermediate (M) and heavily (H) stocked paddocks during the 1986, 1988, 1989, 1993 and 1994 surveys at Llanwarne and Dordrecht

<table>
<thead>
<tr>
<th>Llanwarne</th>
<th>Dordrecht</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Survey</strong></td>
<td><strong>L1</strong></td>
</tr>
<tr>
<td>1986</td>
<td>52</td>
</tr>
<tr>
<td>1988</td>
<td>54</td>
</tr>
<tr>
<td>1990</td>
<td>56</td>
</tr>
<tr>
<td>1993</td>
<td>45</td>
</tr>
<tr>
<td>1994</td>
<td>56</td>
</tr>
</tbody>
</table>

Results and discussion

Total seasonal rainfall patterns reflected considerable spatial and temporal variability (Figure 1), where the mean for the seven-year period was 569 mm and 612 mm at Llanwarne and Dordrecht respectively. Rainfall was slightly below the long-term mean of 518 mm at each site during the 1986/87 season, consistently higher for the 1987/88 to 1990/91 seasons and considerably below the mean during the 1991/92 season (Figure 1). Rainfall patterns within seasons are presented in detail by Hatch & Tainton (1995).

Livemass gain per individual animal (kg.LSU⁻¹) tended to decrease and gain per unit area (kg.ha⁻¹) increase as stocking rates increased across treatments. Livemass gain was influenced by rainfall patterns (Hatch & Tainton, 1995) and decreased summer gains were evident for drier seasons (1986/87, 1991/92) (Table 2). Patterns of winter mass loss

![Figure 1 Variation in total seasonal rainfall (mm) about the long-term mean of 518 mm at Llanwarne and Dordrecht](image)

Table 2 Summer livemass gain and winter mass loss per individual animal (kg.LSU⁻¹) and per hectare (kg.ha⁻¹) for ‘light’ (L) (0.17 LSU.ha⁻¹), ‘intermediate’ (M) (0.23 LSU.ha⁻¹) and ‘heavy’ (H) (0.30 LSU.ha⁻¹) stocking at Llanwarne and Dordrecht

<table>
<thead>
<tr>
<th>Season</th>
<th>Llanwarne</th>
<th>Dordrecht</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Summer</td>
<td>Winter</td>
</tr>
<tr>
<td></td>
<td>LSU /ha</td>
<td>LSU /ha</td>
</tr>
<tr>
<td>1986/87</td>
<td>L 174</td>
<td>29.6</td>
</tr>
<tr>
<td></td>
<td>M 161</td>
<td>40.3</td>
</tr>
<tr>
<td></td>
<td>H 158</td>
<td>47.4</td>
</tr>
<tr>
<td>1987/88</td>
<td>L 231</td>
<td>34.7</td>
</tr>
<tr>
<td></td>
<td>M 233</td>
<td>53.6</td>
</tr>
<tr>
<td></td>
<td>H 246</td>
<td>78.8</td>
</tr>
<tr>
<td>1988/89</td>
<td>L 224</td>
<td>33.6</td>
</tr>
<tr>
<td></td>
<td>M 207</td>
<td>43.5</td>
</tr>
<tr>
<td></td>
<td>H 199</td>
<td>55.7</td>
</tr>
<tr>
<td>1989/90</td>
<td>L 182</td>
<td>27.3</td>
</tr>
<tr>
<td></td>
<td>M 176</td>
<td>38.7</td>
</tr>
<tr>
<td></td>
<td>H 153</td>
<td>39.8</td>
</tr>
<tr>
<td>1990/91</td>
<td>L 226</td>
<td>33.9</td>
</tr>
<tr>
<td></td>
<td>M 221</td>
<td>48.6</td>
</tr>
<tr>
<td></td>
<td>H 220</td>
<td>61.6</td>
</tr>
<tr>
<td>1991/92</td>
<td>L 154</td>
<td>23.1</td>
</tr>
<tr>
<td></td>
<td>M 136</td>
<td>28.6</td>
</tr>
<tr>
<td></td>
<td>H 147</td>
<td>42.6</td>
</tr>
<tr>
<td>1992/93</td>
<td>L 215</td>
<td>30.1</td>
</tr>
<tr>
<td></td>
<td>M 224</td>
<td>49.3</td>
</tr>
<tr>
<td></td>
<td>H 202</td>
<td>54.5</td>
</tr>
</tbody>
</table>
(kg.LSU⁻¹) reflect little difference between stocking treat-
ments and sites, with the exception of the 1991/92 season
where losses were substantial. Losses invariably increased
as stocking rates were increased at both sites. Supplementary
feeding (sugar-cane tops at 20 kg.LSU⁻¹.d⁻¹ for all stocking
treatments during the winter of 1992 and for the intermediate
and heavy stocking treatments at Dordrecht during the winter
of 1993, restricted mass loss at these times.

The length of the period (days) over which cattle gained
mass tended to be longer at Llanwarne (302 ± 65) than at
Dordrecht (269 ± 33) (Table 3), so that the length of the
period of mass loss was shorter at Llanwarne (51 ± 44) than at
Dordrecht (86 ± 32). Average daily gains (ADG) were conse-
quently lower at Llanwarne than at Dordrecht given similar
mass gain for the summer, but cattle continued to gain mass
for a longer period in each season at Llanwarne.

Table 3 The length of the period (days) of summer
mass gain and winter loss at Llanwarne and
Dordrecht (November 1996 to June 1993)

<table>
<thead>
<tr>
<th>Season</th>
<th>Llanwarne</th>
<th>Dordrecht</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain (kg)</td>
<td>Loss (d)</td>
<td>Gain (kg)</td>
</tr>
<tr>
<td>1986/87</td>
<td>189</td>
<td>85</td>
</tr>
<tr>
<td>1987/88</td>
<td>357</td>
<td>21</td>
</tr>
<tr>
<td>1988/89</td>
<td>357</td>
<td>0</td>
</tr>
<tr>
<td>1989/90</td>
<td>294</td>
<td>63</td>
</tr>
<tr>
<td>1990/91</td>
<td>348</td>
<td>42</td>
</tr>
<tr>
<td>1991/92</td>
<td>231</td>
<td>126</td>
</tr>
<tr>
<td>1992/93</td>
<td>336</td>
<td>126⁴</td>
</tr>
</tbody>
</table>

⁴ Period of winter mass loss in 1993 ends outside of study period
   (November 1996 to June 1993)

Development of a summer mass gain model
Summer livemass gain per hectare (kg.ha⁻¹) was significantly
related (p < 0.01) to rainfall (mm) and stocking rate (LSU.
ha⁻¹) (Table 3), but was not significantly related to range
composition.

Predicting summer livemass gain
Summer livemass gain per hectare (kg.ha⁻¹) was related (p <
0.01) to rainfall (mm) and stocking rate (LSU.ha⁻¹) (Table 4),
but was not related to range composition (p>0.05). This sug-
gested that a change from a Themeda-Panicum dominated to
a Urochloa-Sporobolus dominated state may not be associ-
ated with reduced summer livemass gain, provided the
amount of herbage does not become limiting. Importantly, the
amount of residual summer herbage (kg.ha⁻¹) was directly
related to the proportion of T. triandra, P. maximum and P.
coloratum (Hatch & Tainton, 1995). Grass species in the
semi-arid savanna may therefore differ in terms of production
potential rather than quality. Changes in range composition
may consequently influence patterns of winter mass loss
rather than summer mass gain, provided intake is not
restricted during the summer.

The quadratic relationship between livemass gain per hec-
tare and rainfall in this study implied that livemass gain
would increase at a decreasing rate as rainfall increased,
attain a maximum (at 700 mm) and then decline. This may be
the consequence of an increased growth rate and hence
increased stemminess of T. triandra and P. maximum during
higher rainfall seasons. This would have acted to reduce the
quality of intake and hence animal performance. In practice,
range managers may increase stocking pressure to compen-
sate for increased herbage production during wetter seasons
by reducing the area grazed. This would reduce the extent of
stem accumulation and allow utilisation of younger stem
material. Accumulated herbage in ungrazed paddocks may
then provide a drought reserve or be burnt to restrict bush
thickening.

Despite considerable evidence to suggest that the relation-
ship between stocking rate and livemass gain per unit area is
quadratic (Mott, 1960; Cowlishaw, 1969; Conway, 1974;
Jones & Sandland, 1974), at least until maximum gain is
attained (Heitschmidt & Taylor, 1991), this tendency was not
evident in this study. This was related to the restriction of
stocking treatments to a range of likely economic stocking
rates in this study (Hatch, 1994) which did not result in summer
forage limitations. The stocking rate at which maximum
gain per hectare would be reached was therefore calculated from
the slope (a) and intercept (b) coefficients of the linear
relationship between stocking rate and individual animal per-
formance (Edwards, 1981) (Table 4).

The stocking rate at which maximum summer livemass
gain per hectare would be attained (Gmax) would be consider-
ably higher at Dordrecht than at Llanwarne (Table 5). This dif-
fERENCE may be attributed to the dominance of S. iocladius
and S. nitens at the former, where the intake on less productive
(and less stemmy) species may be higher during the summer
than for more productive (and more stemmy) species such as
T. triandra and P. maximum. Greater summer individual ani-
mal performance during drier seasons (1991/92) at Dordrecht
than at Llanwarne (Table 2) may be the consequence of greater
accessibility to higher quality forage at Dordrecht while cattle at
Llanwarne were forced to select lower quality stem material.
Importantly, despite higher summer production, even during
drier seasons, little forage is likely to remain at the end of summer on range dominated pioneer species
(Hatch & Tainton, 1995). This may account for the longer
periods of winter mass loss at Dordrecht, which will influence
the period over which supplementary feeding may be
required to maintain animal condition.

Predicting winter livemass loss
Winter mass loss (kg.ha⁻¹) was negatively related (p < 0.01)
to residual summer herbage mass (kg.ha⁻¹) and positively
Table 5 Calculation of the stocking rate (LSU.ha⁻¹) at which maximum gain per hectare (Gmax) would be attained at Llanwarne and Dordrecht (based on the slope (a) and intercept (b) coefficients of significant (p < 0.01) linear relationships between stocking rate and average daily gain)

<table>
<thead>
<tr>
<th>Season</th>
<th>Llanwarne</th>
<th>Dordrecht</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>1987</td>
<td>−0.84</td>
<td>1.13</td>
</tr>
<tr>
<td>1988</td>
<td>−1.18</td>
<td>1.04</td>
</tr>
<tr>
<td>1989</td>
<td>−0.80</td>
<td>1.02</td>
</tr>
<tr>
<td>1990</td>
<td>−0.67</td>
<td>0.13</td>
</tr>
<tr>
<td>1991</td>
<td>−0.59</td>
<td>0.59</td>
</tr>
<tr>
<td>1993</td>
<td>−2.21</td>
<td>2.35</td>
</tr>
<tr>
<td>Mean</td>
<td>0.37</td>
<td></td>
</tr>
</tbody>
</table>

* No negative relationship between stocking rate and average daily gain detected – data excluded.

Table 6 A step-wise multiple linear regression model relating residual summer herbage mass (kg.ha⁻¹) and the length of the winter (days) (from the last date in summer to the first date in the subsequent spring on which >15 mm of rain was recorded) to winter mass loss (kg.ha⁻¹)

<table>
<thead>
<tr>
<th>Variables in model</th>
<th>Coefficient</th>
<th>t-value</th>
<th>r²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>8.209615</td>
<td>2.29</td>
<td>0.51**</td>
</tr>
<tr>
<td>Winter length</td>
<td>0.037206</td>
<td>4.03**</td>
<td></td>
</tr>
<tr>
<td>Residual summer herbage mass</td>
<td>−0.002806</td>
<td>−2.43**</td>
<td></td>
</tr>
</tbody>
</table>

** p<0.01

related (p < 0.01) to winter length (days) (Table 6). Cumulative winter grazing days (LSU.gd.ha⁻¹) did not influence the extent of mass loss. This may be the consequence of rainfall and hence some growth during winter, supplementation during periods of forage deficit and the ability of the cattle to browse during adverse conditions. Residual herbage mass and the length of the winter would be unaffected by these factors.

As residual herbage mass was a function of cumulative summer grazing days (LSU.gd.ha⁻¹), rainfall (mm) and range condition (indexed as the sum of the proportions of T. triandra, P. maximum and P. coloratum) (Hatch & Tainton, 1995), it can be implied that winter mass loss would be related to each of these factors. Although summer mass gain was not significantly related to range composition, the extent of winter mass loss may be strongly influenced by range condition through its effect on residual summer herbage mass (Figure 2).

Conclusions

Although winter mass loss was related to residual summer herbage and winter length, the relationship was confounded by winter rainfall, supplementation during drier seasons and the ability of the cattle to browse during adverse conditions. Although the winter model provides an indication of the factors which influence winter mass loss, it may be limited in its application. Addition of the amount of available browse during periods of forage deficit and estimates of browse intake in relation to stocking rate may consequently be important additions to allow the refinement of a winter mass loss model. The summer mass gain model, based on the relationship between rainfall and stocking rate and summer mass gain, may provide a useful tool to assess the influence of various stocking strategies on production risk through the incorporation of stochastic rainfall effects. Integration of the beef production model outlined in this study into an economic model may provide an indication of the influence of various stocking strategies on the probability of obtaining given levels of income and hence the risk associated with each strategy (e.g. Hatch et al., 1995).

Acknowledgements

Research funding provided by the Department of Agricultural Development, and the Range and Forage Institute; and the generous hospitality and assistance of Jannie and Rita Bender at Llanwarne Estates, Magudu is gratefully appreciated. Prof. J. van Ryssen, Department of Animal Science, University of Natal translated the abstract into Afrikaans.

References


EDWARDS, P.J., 1981. Grazing management. In: Veld and pasture
management in South Africa. (Ed.) Tainton, N.M. Shuter & Shooter, Pietermaritzburg.


