SIMULATION OF WINTER GRAZING ON TEMPERATE PASTURE

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Summary

A model has been developed for estimating liveweight change and pasture growth during 90 days of winter. Availability of pasture and liveweight of sheep in May were the main input parameters. Since soil moisture and nutrients were regarded as non-limiting, pasture growth was estimated from a function of leaf area, temperature and incoming radiation.

The model gave accurate predictions of experimental results over six years at three stocking rates ($r^2$ values for pasture availability and liveweight on day 90 were 0.87 and 0.83 respectively). Sensitivity analyses indicated that pasture availability at the beginning of winter had a larger influence on liveweight at the end of winter than did either pre-winter liveweight or winter pasture growth rate.

I. INTRODUCTION

Predictions of sheep production from conditions in late autumn would greatly aid decisions concerned with optimal winter management. Late autumn liveweights are closely related to those at a mid-autumn joining and thus reflect the number of lambs conceived (Coop 1962). Losses through pregnancy toxaemia and undernutrition, the amount of pasture available to lactating ewes, and the extent of supplementary feeding could be assessed from estimates of liveweight change and pasture growth during winter. A model covering the 90-day period from May to August was developed to provide such estimates.

On the Southern Tablelands of N.S.W. winter growth of phalaris-subterranean clover pastures which have had a long history of fertilizer and grazing is not likely to be restricted by soil moisture (Slatyer 1960) or soil nutrients. The aspect of particular sites may be important, although this effect may be accounted for by temperature (Williams and Biddiscombe 1965) and radiation intensity. The pasture growth section of the model was thus simplified so that data from grazing experiments could be used to derive the remaining relationships.

Levels of availability and liveweight in May would largely reflect pasture production in response to mid-autumn weather and site conditions, and the effect of stocking rate and grazing management. In this paper, the model will be used to predict the effects of availability ($A_i$) and liveweight ($B_i$) in May, and stocking rate ($SR$) from May to August, on availability ($A_f$) and liveweight ($B_f$) in August. Responses in $A_f$ and $B_f$ to changes in $A_i$, $B_i$, $SR$ and other major parameters will be presented in a sensitivity analysis. The detailed treatment of model development and subsequent production runs will be described by McKINNEY (1972).

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Fig. 1.—Structure of winter model
II. MODEL CONSTRUCTION

The model comprises two main sections (Figure 1), pasture (phalaris-subterranean clover) and animal (sheep).

(a) Pasture

Pasture growth rates were estimated from an experiment at stocking rates of 7.5 to 22.5 sheep/ha (continuous grazing) in 1963, 1964 and 1966. The calculations were based on intakes of pasture by sheep and changes in green pasture availability during 3- or 4-weekly periods. Intakes were estimated by the reverse use of feeding standards and details of the method are given in Section (b) (i).

(i) Temperature-and leaf area effect.

Pasture growth rates (growth minus mortality) were clearly affected by temperature and leaf area. The relationship is described in equation (1) which was fitted by least squares.

\[ G = 72.0 + 8.3T - 0.03T^2 \]  \( \{1\} \)

\( r^2 = 0.89 \), residual standard error (SE) = 4 kg/ha/day.

where \( G \) = pasture growth rate (kg/ha/day),

\( T(1) = 1 - e^{-0.126T} \), where \( T \) = (maximum + minimum screen temperatures) – 3.9°C,

\( f(A) = A/BXL \), where \( A \) = available green dry matter (kg/ha),

\( BXL \) = maximum availability (estimated 1500 kg/ha of pasture at which all leaves are light saturated, and when \( A \geq BXL \), \( f(A) = 1 \).

(ii) Shading effects

The reduction (PL) in growth due to shading was, assumed to be proportional to the extent that \( A \) exceeded \( BXL \) (equation {2}). When \( A - BXL \) was equal to \( XL \) (determined by the level of incoming radiation, \( R \) in \( J/cm^2/h/day \)), no growth occurred.

\[ PL = 1 - (A - BXL)/XL \]  \( \{2\} \)

where \( XL = 0.0048R \), and \( PL \) was constrained to values from 0 to 1.

(b) Animal

(i) Intake

Intakes were estimated by converting liveweight gain and maintenance energy requirements into equivalent amounts of herbage dry matter. The amount of dead matter included in the diet was considered small and the digestibility of eaten material therefore constant at 0.72. The following assumptions were derived from Agricultural Research Council (1965) and Graham (1964).

Proportion of digestible energy metabolizable = 0.82

Energy value of herbage dry matter = 18.4 MJ/kg

Net energy requirement (XM) for maintenance per unit liveweight to the power 0.73 = 0.33 MJ

Energy value of liveweight gain = 20.9 MJ/kg

Efficiency of use of metabolizable energy for maintenance (km) = 0.72

and for liveweight gain (kf) = 0.51

assuming that digestibility (D) = 0.72

The intakes calculated above were related to the availability of green pasture.
in the same years and equation \(3\) was fitted by least squares \((r^2 = 0.77, \text{SE} = 0.29 \text{ kg/head/day}).\)

\[
I = 1.36(1 - e^{-0.00108A}) - 0.03 \tag{3}
\]

where \(I\) = dry matter intake (kg/head/day), with an upper limit of 1.33 kg/head/day. The availability at which 85 per cent of the maximum intake occurred was 1750 kg/ha.

The assimilation of digestible energy intake was calculated from the above feeding standards.

(ii) **Supplementary feeding**

The feeding of wheat was simulated when liveweights fell below 32 kg, but only in the amounts required to make up the deficit in energy intake after maintenance was subtracted from intake. A zero substitution effect was assumed.

(c) **Computer languages**

The model was written in FORTRAN IV (for development and production runs), and CSMP (an interactive display version on Control Data 3600; Mackenzie 1971) for the sensitivity analyses. All runs used step intervals of one day.

III. RESULTS

(a) **Model validation**

The model was tested against data from different experiments conducted in 1967, 1969, and 1970 (stocking rates from 7.5 to 29.5 sheep/ha) in the same

![Graph](image-url)
area as those above. Given initial conditions of $A_i$ and $B_i$ in May, predicted liveweights ($B_f$) and pasture availability ($A_f$) in August (after 90 days) were compared with results in both the test and original field experiments (Figure 2). The relationships between actual and predicted results were linear

$\text{(Af)}: r^2 = 0.87, \ SE = 200 \text{ kg/ha}; \ B_f: r^2 = 0.83, \ SE = 3.0 \text{ kg}$.

The regression coefficients were close to unity, and the intercepts, close to zero, indicating little bias.

(b) Production runs

Predicted effects of $A_i$, $B_i$ and $SR$ using climatic data from 1963 were illustrative of curves obtained over a number of years. $B_f$ was very sensitive to $A_i$, $B_i$ and $SR$, at low values of $A_i$, but less so as $A_i$ increased. The intercept on the $A_i$ axis at $B_f = 36$ kg indicates the minimum $A_i$ for safe conditions at lambing (initial liveweights for the survival of pregnant Merino ewes found by Morley, Bennett, and McKinney, unpublished data). At $B_i = 32$ kg these values of $A_i$ (in kg/ha) were 310, 562 and 894 at 7.5, 12.5 and 27.5 sheep/ha respectively.

<table>
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<tr>
<th>Parameter</th>
<th>Basal value</th>
<th>% Change</th>
<th>Final liveweight ($B_f$)</th>
<th>% Change</th>
<th>Final availability ($A_f$)</th>
<th>% Change</th>
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<td>-26</td>
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<td></td>
<td>34.9</td>
<td>-8</td>
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<td>-25</td>
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TABLE 1

Sensitivity tests with CSMP version
The predicted effect of stocking rate on the amounts of supplementary feeding required for survival gave the expected sigmoid curve. This curve is produced by an initial exponential increase with SR. At high SR, the amounts approach those which would be needed if no feed were derived from the pasture.

(c) Sensitivity analyses

The CSMP version was used to test the sensitivity of Bf and Af to variations in the major parameters (Table 1). Variations of 20 per cent in Ai, BXL and G caused more than 20 per cent deviation in Af, but not in Bf. The value of Ai used in the sensitivity analysis was an average figure. With Ai at 1500 kg/ha the response in Bf and Af was reduced to 2 per cent and 3 per cent respectively. D, XM, Bi and Ai had larger effects than SR, G or BXL on Bf. Since D was assumed constant in the derivation of this model, the predicted responses to changes in D would not be realistic. XL had no effect in this analysis since availability rarely reached BXL. This was also true of most of the production runs. BXL will vary with pasture structure, but was assumed constant in order to fit equation (1). XM was maintained constant in the pasture growth and intake calculations of equations (1) and (3).

Ai, Bi and G had important effects on the values of Bf and Af. In the field experiments at 12.5 sheep/ha, the coefficients of variation (between years) of Ai, Bi and G were 0.93, 0.12, 0.39 respectively. Since Ai had effects on Af and Bf similar to those of G, this parameter seemed to be the most important of the three.

IV. DISCUSSION

The accuracy of the model confirmed the adequacy of the various functions, especially those in the pasture growth and intake estimations. Although the effects of soil nutrients and moisture were not assessed in the above experiments, they appear (in view of the precision of the model) to have been unimportant in the years selected. The more variable predictions of sheep liveweight may have resulted from (i) the effects of cold stress, (ii) variability in the energy cost of grazing, (iii) some data including pregnant ewes, (iv) variable energy values of liveweight gain (Searle and Graham 1970), (v) internal parasites and (vi) variations in pasture structure and the proportion of dead matter included in the diet.

The sensitivity analysis showed that, on average, Bf was far more responsive to Ai than to G or Bi, demonstrating the greater importance of saving pasture than liveweight in late autumn. Thus, after mating, the model suggests that sheep should be restricted to a portion of the area to allow as much pasture growth as possible, even at the expense of liveweight. Once growth becomes severely reduced by temperature, there may be little point in continuing this feed rationing. However, restricted grazing would be of little benefit when availability of pasture exceeds 1500 kg/ha in mid- to late autumn.

At high stocking rates on Canberra pastures, it is unlikely that large amounts of feed will be available as winter approaches (Morley, Bennett and McKinney 1969), especially if full use is made of the pasture at joining. Since Bf and Af are highly sensitive, the model could be used to predict production levels from late autumn, and to allocate stock to paddocks in such a way as to minimise supplementary feeding and losses during critical periods.
V. ACKNOWLEDGMENTS

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VI. REFERENCES


