DEVELOPMENT AND ANALYSIS OF HAY FEEDING REQUIREMENTS

L. P. THATCHER*

Summary

A model was constructed of a sheep-grazing system based on improved pastures. The model was validated against results from a stocking-rate experiment at the Pastoral Research Station, Hamilton. It was used to simulate grazing at ten different stocking rates (2.5 to 25 wethers ha\(^{-1}\)) for the years 1879 to 1967. Two other levels of pasture production were also investigated, namely 80 per cent and 65 per cent of the Research Station level. The amounts of hay fed in accordance with specified feeding rules were determined for all the stocking rate - pasture production regimes over the 89 year period. Probabilities of feeding various sizes of hay reserve were then calculated from these results. The probabilities were analysed in an inventory model to determine the cost-minimizing reserve for each stocking rate-pasture production regime.

I. INTRODUCTION

In a study of drought-feeding requirements (Thatcher 1971), drought was defined as any period of supplementary feeding. A model of the grazing system was used to derive drought probabilities for the Hamilton region of Victoria. The grazing model allowed the recognition of two components of “feed” drought which are difficult to isolate from climatic records, namely; (i) the length of drought and (ii) the severity of a drought, as indicated by the quantity of supplementary feed required.

Most previous analyses have neglected the gradual incidence of “full” drought and consider drought requirements to be full feeding throughout its duration. This may cause over-estimation of the cost-minimizing (or profit-maximizing) fodder reserve, because although it is true that a severe drought is normally long, it does not follow that a long drought is normally severe.

II. THE GRAZING MODEL

A grazing model was constructed to represent fine-woolled crossbred or comeback wethers grazing on improved pastures of perennial ryegrass and subterranean clover at the Pastoral Research Station, Hamilton. The model was used to generate the amount of hay required by sheep grazing at the ten stocking rates (2.5 to 25 wethers ha\(^{-1}\)) on such pastures during a period of 89 years. Since the research station pastures were considered to be more productive than many

*Division of Animal Industry, Victorian Department of Agriculture, Melbourne, Victoria, 3002.
pastures in the district, hay feeding requirements were also generated for pastures with levels of production of 80 per cent and 65 per cent of Research Station pastures.

(a) Sub-model for pasture production

In the Hamilton region of Victoria there is a twin-peaked pattern in growth rates over a year — one peak in autumn and a higher peak in spring. In modelling, the pasture available at any time was more important than growth rates per se. A schematic representation of pasture production was assumed where straight lines were used to represent segments of the curve of pasture growth rate.

The two main inputs required to derive pasture production were the date of the autumn break and the June and October rainfall. The date of autumn break was determined from a soil-moisture budget in which daily rainfall less evapotranspiration was added to residual soil moisture. The break was defined as the first of at least fourteen days of a positive soil-moisture budget. False breaks occurred when spells of zero available soil moisture followed a break. The date of autumn break determined the origin of a linear growth rate curve which reached a peak at which a phase linearly decreasing growth rate was encountered until the constant winter growth rate of 16.8 kg ha⁻¹day⁻¹.

Spring growth was represented by a triangular growth curve where the base of the triangle was fixed, and by varying the position of the vertex, different amounts of spring growth could be represented. The results from a hay-cutting experiment at Penshurst were used to derive a quadratic relationship between the maximum spring growth rate and June to October rainfall.

The rate of decay of pasture dry matter (percentage/day⁻¹) for a given year was related to peak availability of pasture in spring. Daily decay was the product of the pasture available at the beginning of the day and the decay rate. Until the pasture matured the digestibility of pasture was assumed to be a quadratic function of time. Following maturity a constant rate of decline of 0.9 per cent per day was assumed until summer, when digestibility was a constant 45 per cent.

(b) Sub-models for animal production

Ideally, the relationships required for the sub-models of animal production should be obtained from the same site for the same breed of sheep under the same climatic conditions. This was not possible and the model was necessarily shaped by the availability of information. Several relationships were not available for comeback wethers and those from other breeds were used — sometimes in a subjectively modified form.

There were four sub-models governing different phases of sheep intake; one for eating pasture grown after the autumn break; one for feeding hay alone; one for feeding hay plus pasture from the previous year which remained after the autumn break. The last sub-model also handled any hay feeding necessary in that part of the year.

Sheep intake was determined by pasture availability and digestibility. When the availability was less than 1,568 kg ha⁻¹ dry matter, a quadratic function related intake to the availability of pasture. When the availability was greater than 1,568 kg ha⁻¹, intake was related to digestibility in an equation which imposed an upper limit on intake of 1.8 kg/day⁻¹ dry matter per wether.
Maintenance requirements were related to metabolic liveweight using a relationship derived by Young and Corbett (1968). Digestible organic matter intake less the calculated maintenance requirements was converted to liveweight gain or loss. The efficiency of conversion was related to liveweight using the relationship \( E = 0.055 \left( 1.27 W - 25.8 \right) \), where \( E \) is efficiency (intake of digestible organic matter per kg liveweight change) and \( W \) is liveweight (kg).

(c) Hay feeding rules

The only strategy allowed to ameliorate the effects of drought was feeding hay according to predetermined rules. This was the only strategy investigated because the grazing model was being used to provide information about hay requirements on each of the stocking-pasture regimes investigated, for subsequent analysis in an inventory model. The hay feeding rules were designed primarily to keep the sheep alive and were dependent on liveweight and pasture availability. The decision rules were developed during discussions with research workers and management consultants. Whilst they are similar to district practice, they are not optimal feeding rules.

When pasture availability was less than 1,568 kg ha\(^{-1}\) of dry matter, hay feeding increased as liveweight decreased. The sheep were fed a maintenance ration of hay when availability reached 672 kg ha\(^{-1}\) or liveweight fell to 38.5 kg. On April 1, even if the availability was greater than 1,568 kg ha\(^{-1}\) dry matter, hay feeding was initiated if liveweight had fallen to the prescribed level.

(d) Validation of the grazing model

The model was validated by comparing the pasture availability and sheep liveweight data derived from the grazing model with those measured in a stock rate experiment at the Pastoral Research Station for four stocking rates (10, 15, 20 and 25 wethers ha\(^{-1}\)) over three years (1965 to 1967). The validation procedure was to compare graphically the simulated results for pasture availability and sheep liveweight with the experimental results. Such a procedure quickly indicated any malfunction, and new relationships were inserted to improve the model’s performance. Figure 1 presents typical graphical results after the validation procedure had been completed. The amount of hay fed was similar to that fed on the low hay-feeding treatment (1.5 per cent of area closed per sheep) in the experiment.

Of the three years used in validation, 1966 was an extremely productive year and 1967 was a drought year.

After the model had been validated, rainfall records from 1879 to 1967 were analysed to find the dates of autumn break and the June to October rainfalls. These variables were used as data in the grazing model, and the hay feeding requirements were determined for all the pasture-stocking regimes over this period of 89 years. From this information the probability distributions of feeding different levels of hay for each pasture-stocking regime were derived. By way of example, Table 1 shows probabilities of feeding different amounts of hay for some stocking rates on the pastures equivalent to those on the Research Station.

III. INVENTORY ANALYSIS

The probabilities of feeding different levels of reserve hay were analysed in an inventory model designed to determine the reserve which minimized expected costs for each pasture-stocking regime.
TABLE 1

Probabilities of requiring reserves at four stocking rates

<table>
<thead>
<tr>
<th>Size of reserve (kg wether⁻¹)</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>.61</td>
<td>.44</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>.45-11.22</td>
<td>.52</td>
<td>.34</td>
<td>.18</td>
<td>.00</td>
</tr>
<tr>
<td>11.26-22.50</td>
<td>.05</td>
<td>.15</td>
<td>.27</td>
<td>.18</td>
</tr>
<tr>
<td>22.51-33.75</td>
<td>.01</td>
<td>.05</td>
<td>.31</td>
<td>.26</td>
</tr>
<tr>
<td>33.76-45.00</td>
<td>.01</td>
<td>.01</td>
<td>.20</td>
<td>.15</td>
</tr>
<tr>
<td>45.01-56.25</td>
<td>.01</td>
<td>.02</td>
<td>.20</td>
<td>.15</td>
</tr>
<tr>
<td>56.26-67.50</td>
<td>.02</td>
<td>.16</td>
<td>.20</td>
<td>.02</td>
</tr>
<tr>
<td>67.51-78.75</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>78.76-90.00</td>
<td></td>
<td></td>
<td></td>
<td>.05</td>
</tr>
</tbody>
</table>

Fig. 1. — Validation of simulation model for 1967 with twenty sheep ha⁻¹.  
○○○○, Hamilton data; ————, predicted values.
The essential features of the inventory model were: (i) the probabilities of various levels of feed shortage; (ii) the costs of acquiring a fodder reserve and the opportunity cost of the capital needed to acquire the reserve; (iii) the penalty costs of purchasing hay at drought prices if the reserve is inadequate to meet demand; (iv) the salvage revenue of any reserve held in excess of the demand. The sensitivities of the cost-minimizing reserve to changes in the acquisition costs, interest rates, penalty costs and salvage revenues were examined.

A sub-model to accomplish a simple financial analysis could have readily been included in the grazing model. A gross margin for each year could have been determined and an average gross margin and its standard deviation calculated. However, any conclusions and their usefulness are dependent on the costs and prices and on these being representative of a particular situation. To find the minimum cost level of hay reserve would have necessitated a run for each level of reserve for every stocking-pasture regime at all combinations of costs and price investigated—in short, a large task. Therefore, the probabilities of each level of reserve being required were ascertained from the grazing model and used in an inventory analysis, which is the appropriate technique for optimising fodder reserves.

IV. CONCLUSION

The grazing model was validated against the results from the Hamilton experiment, and sheep liveweights and pasture availabilities for all stocking rates showed good agreement, and the amounts of hay fed were similar to those on the low feeding treatment. Thus this simple representation of the grazing complex appeared to be an adequate representation of the real world from which to analyze hay-feeding requirements in the Hamilton region.

Alternative drought policies were not examined in this study and the hay-feeding rules were not varied to determine an optimal feeding policy. However, other aspects of drought policy could also be studied in relation to the grazing model.

V. ACKNOWLEDGMENTS

The assistance given by Professor A. G. Lloyd is gratefully acknowledged. Thanks are also due to several other members of the Faculty of Agriculture in the University of Melbourne and Officers of the Victorian Department of Agriculture at the Pastoral Research Station, Hamilton. This project was financed by the Australian Wool Board.

VI. REFERENCES