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OPTIMIZATION OF A GRAZING MANAGEMENT SYSTEM

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Summary

An optimization procedure was used to explore a model of a grazing system for circumstances which might enable a sheep meat producer to benefit from rotational grazing procedures. Ewe liveweights were calculated over the first 100 days of a year with different initial amounts of dry food and various rainfall patterns. The relative values of alternative management practices were expressed numerically by an objective function which took account of the effect of weight changes of ewes on the value of subsequent lambs, the probability of requiring supplementary food and the cost of moving sheep in a rotational system.

I. INTRODUCTION

Models of systems may be constructed at different levels of complexity depending on the purpose for which they are required. At the first level is the representation of a system in terms of parameters and relationships in order to gain an understanding of the factors involved and their interactions.

However, to base management studies on the output from the model requires an understanding of the response surface created by the inputs. Because of the multiplicity of factors and complexity of interactions one cannot study all possible situations, and it is necessary to move to a higher level in model development in which an optimization procedure effects the most desirable output for any given set of circumstances. This procedure directs the representational model which is contained within it.

This paper presents a preliminary report of an attempt to apply an optimization procedure to a model of a grazing system in order to select the best system of grazing management for ewes during late summer.

II. METHODS

(a) *Representational model*

The model used in this study is essentially a FORTRAN version of the one described earlier by Freer et ***al.*** (1970). Briefly the model carries out a day-to-day budget of plant material on a specified area over 100 days from January 1, assessing fresh growth as a result of rain, losses due to weathering and ageing, the amounts eaten and trampled by sheep at any given stocking rate and the resultant change in liveweight. The area may be either set-stocked or divided into a number of paddocks, through which the flock may be successively grazed, evaluating the quality and quantity of material on each as a criterion for selection.

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Should liveweight fall below a given level, the sheep are removed to drought-yards and fed wheat grain to maintain liveweight until pasture conditions are again suitable for grazing.

(b) *Objective function*

To optimize a management system it is first necessary to construct an objective function which combines in quantitative terms those components of the output on which a value must be set. This function can be expressed as a single value which is obtained as output from the representational model. The optimization procedure maximizes this function under any particular set of input conditions.

In constructing the objective function, weighting functions are applied to each component; the relative importance of these functions will naturally vary with each type of enterprise involved and must be determined in the context of whole-farm considerations, of which this model is only a part. Assessments will therefore be to some extent subjective and require reconsideration under changing circumstances.

TABLE 1

The component terms in the objective function
(objective function $= V_1 + V_2 + V_3 + V_4 + V_5$*)*

Value of liveweight at start of mating	$((W_{80} - 40.0)0.05 + 1)\ S.L$	(V_1)
Value of liveweight change during mating	$(W_{100} - W_{80})0.025.S.L$	(V_2)
Cost of moving sheep	$-N.M(0.5 + \log(F/S.P)).S/F$	(V_3)
Value of remaining and likely food after day 100 (VR)	$VR = (DR + DG) - \frac{(W_{100} + 30)R.S.70}{2}$	
	If $VR<0 ; V_4 = VR.C$	
	If $VR>0 ; V_4 = VR.E.0.01.L$	(V_4)
Cost of supplementary feeding	$-30.R.S.C.D$	(V_5)

Key

C	Cost of feeding wheat ($/kg)	N	No. of moves in 100 days
D	Days of supplementary feeding	M	Cost of labour ($/h)
DG	Digestible food grown from day 100 to day 170	P	No. of paddocks in system
DR	Digestible food remaining at day 100	R	Maintenance requirement (kg DOM/kgW)
E	Efficiency of retention of digestible organic matter (DOM)	S	Stocking rate (sheep/ha)
F	Size of flock	W_{80} W_{100}	Liveweight on days 80 and 100
L	Market value of a lamb ($)		

In the present model we examined a system in which a ewe flock is mated in late March. The terms in the objective function (Table 1) take into account the effect of the weight of the ewe during mating on the output of lambs, the cost of moving sheep in a nine-paddock system, the value of residual food in the system at day 100 and that of grass that is likely to grow in the next 70 days. For such time as there is insufficient food to maintain the ewes at a weight of 30 kg, the cost of feeding wheat is assessed. Other considerations such as costs

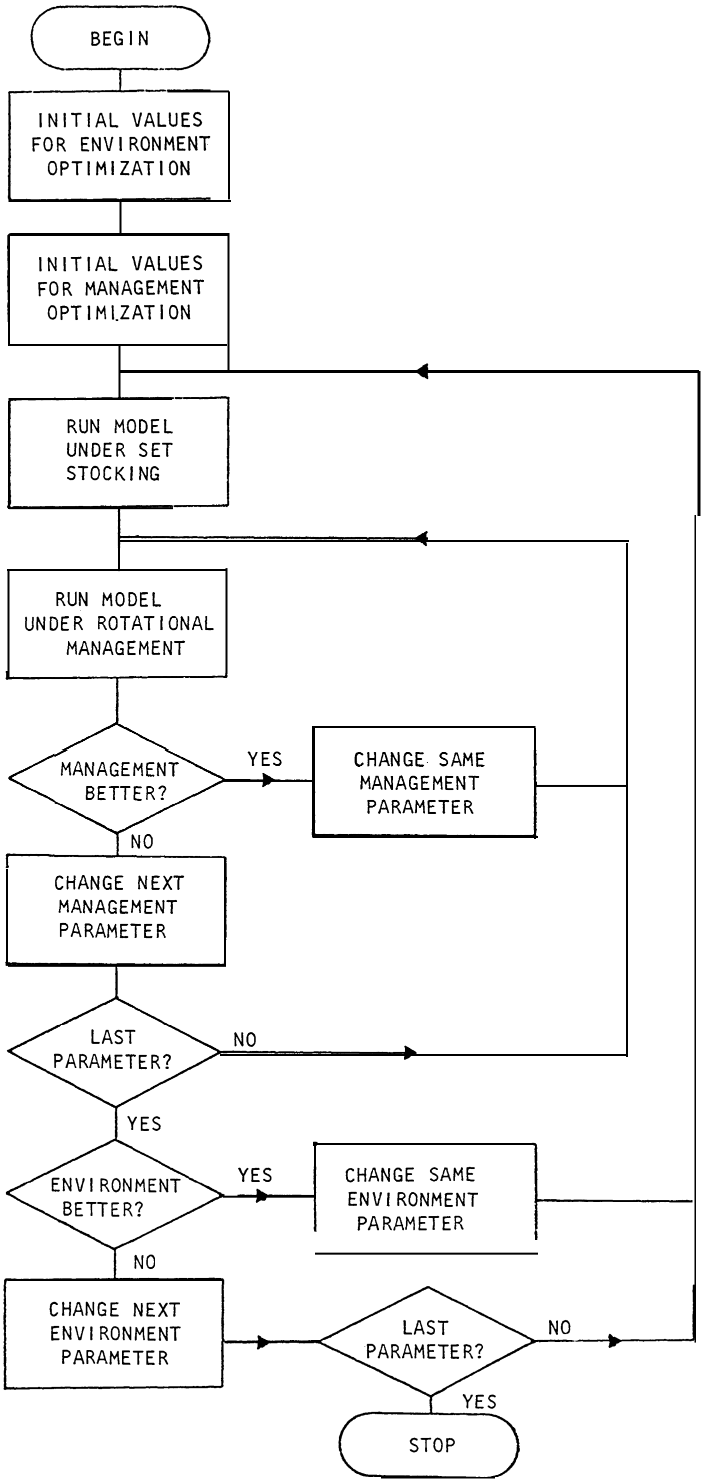

Fig. 1. — Outline flow chart of the optimization procedure.

of sub-division and differential wool production may also be economically important, but require no added principles to those already mentioned.

(c) Parameters used in optimization

Parameters can be classified according to whether they are internal to the system, involving management decisions, or external, i.e., uncontrollable and environmental conditions. In scope, this study examined a range of rotational management practices, including the deferment of grazing. The specific parameters selected were number of paddocks, number of deferred paddocks and the period of deferment. Only three external parameters were treated as relevant: initial amount of dry food present, rainfall pattern (Table 2), and stocking rate. Although the last of these would usually be regarded as being under management control, the number of animals carried over this period is dictated by those operating over the remainder of the year, and it is not normally possible to alter them substantially for this time without prejudicing overall production.

TABLE 2

Rainfall (mm) in each 10 day interval for each rainfall pattern

Pattern No.	Interval 1	2	3	4	5	6	7	8	9	10	Total rain
1	7	14	1	5	83	24	0	40	26	22	222
2	7	14	1	5	83	0	0	0	0	0	110
3	7	97	1	5	0	0	0	0	0	0	110
4	90	14	1	5	0	0	0	0	0	0	110

(d) *Optimization programme*

The programme is outlined in Figure 1 and is initiated by choosing values for the environmental and management parameters within the expected range; these values are not critical, but will naturally bring about a more rapid solution if chosen judiciously. The order in which the parameters are arranged will also be a matter of choice, guided by intuition. The grazing model is first run as a one-paddock system, and the value for the objective function which is obtained thereby is used as a standard or control against which all management systems in this particular environment are compared.

The grazing model is then run as a rotationally-grazed system, using the well-known “hill-climbing” technique to find the best management strategy. After the first run, the value of the first parameter is changed by a finite step, and the grazing model is re-run. If the objective function has increased in value, the process is repeated until either the objective function falls or the parameter has reached the end of its allowed range. If the objective function falls on the first change, a step in the opposite direction is tried. Having set the first parameter at its best value, the next one is tested in the same way, until finally the combination resulting in the maximum objective function is achieved. This may require two or three cyclings through all the parameters.

The environment is then modified by a change in one of the parameters in this group and the whole procedure is repeated, again relating the management system with the highest objective function to the control, no-management system.

However, since the optimum system has already been found for a reasonably similar environment, the number of runs required to find the new optimum is now much smaller.

III. RESULTS AND DISCUSSION

The model was first used to establish optimum stocking rates for set stocking over a range of initial levels of dry food and for each rainfall pattern. These stocking rates for initial levels of 1500, 2500 and 3500 kg dry material per ha became the initial conditions for optimizing the management parameters. At this stage no significance is attached to the apparent superiority of rotational management at high stocking rates (Tables 3 and 4); the results are presented to illustrate the procedure.

TABLE 3

Simulated effect of grazing management and stocking rate on the value of the objective function and its component terms after grazing for 100 days with an initial weight of 1500 kg/ha dry food and rainfall pattern 2

Management	Stocking rate (sheep/ha)	Objective function	Component terms of objective function				
			V_1	V_2	V_3	V_4	V_5
Set stocking	10	46	40	2	0	4	0
	15	59	52	2	0	5	0
	20	62	58	1	0	3	0
	25	61	61	−1	0	1	0
	30	54	65	−2	0	−3	−6
	35	43	73	−1	0	−11	−18
	40	28	80	0	−1	−19	−32
	45	17	90	0	−1	−29	−43
Rotational management	10	47	42	2	−1	4	0
	15	60	55	2	−2	5	0
	20	66	63	2	−2	3	0
	25	63	65	0	−3	1	0
	30	56	69	−3	−6	−4	0
	35	44	68	1	−6	−16	−3
	40	32	78	1	−6	−24	−17
	45	23	89	0	−6	−38	−22

TABLE 4

Effect of rainfall pattern and the initial weight of dry food on the value of the objective function after 100 days grazing under set stocking (SS) or rotational management (RM) at the stocking rate optimal for the set-stocked system

Initial weight of dry food (kg/ha)	Rainfall Pattern 1		2		3		4	
	SS	RM	SS	RM	SS	RM	SS	RM
1500	119	114	62	65	68	73	66	73
2500	149	154	98	106	92	102	88	100

The investigation to date has emphasized some of the difficulties involved in an appropriate definition of the objective function. A realistic assessment of the costs involved in management practices and the future benefits in production to be expected as a result of Iiveweight gains and pasture conserved over this limited period has been found to pose the major problem in the optimization of the model so far. More accurate values for some of these may in fact require extending the period of simulation.

The method indicates that a goal-seeking approach of this kind may be more instructive and economical in investigating the response surface of such a problem in the areas of greatest interest than a random sensitivity analysis of single parameters- or factorial testing of the very limited number of parameters which is otherwise possible.

IV. REFERENCE

Freer, M., Davidson, J. L., Armstrong, J. S., and Donnelly, J. R. (1970). ***Proceedings of the Eleventh International Grassland Congress, Surfers Paradise.*** 9 13.