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# A NOTE ON LIVESTOCK BREEDING POLICIES IN STABLE AND DEVELOPMENT SITUATIONS

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Multi-stage linear programming is used to develop sheep replacement policies in a number of different situations. Policies are developed for eight and sixteen year periods assuming, firstly a constant feed supply, and secondly, an increasing feed supply over the period. The results show the optimal flock composition together with the sheep sale activities for each year of the plan. The marginal value products indicate which constraints are the most important and whether any should be relaxed in order to make the model more realistic. It is concluded that it is not necessary to use a very long planning period in order to determine the activities for the early years. The results from the shorter planning period appear to be consistent with long-term goals.

## *Introduction*

Two recent studies have examined the relative profitability of different sheep replacement policies in a breeding flock.<sup>1</sup> These studies suggested "optimal" flock structures under various assumptions. However, neither study allowed for stochastic influences nor was the best method of changing from the current to the suggested policy indicated. The major emphasis of this study is to examine the latter of these two aspects. It has been limited to the deterministic case and no attempt has been made to examine the effect of variability, of either prices or biological parameters. While the examples considered deal only with sheep, the method can be readily adapted to other types of livestock such as beef cattle.

Scobie [2, p. 137] prepared some budgets to indicate how a change in flock structure might be effected. Here we aim to determine the optimal means of making the change in a situation where the grazier, for some reason, does not wish to, or cannot purchase sheep. In addition we examine the case where feed supply is constant and where the feed supply is increasing over time—the typical situation with pasture improvement.

## *Method*

Multi-stage linear programming is used to determine the optimal breeding and culling policy. Townsley and Schroder [4] demonstrated the use of linear programming to determine the optimal breeding flock composition. Again this was a static solution to the problem and did not indicate how a change should be carried out. We extend that type of model to a multi-stage model. Basically it consists of a *run* and a *sell* activity for each age group of ewes and for each group of young sheep.

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<sup>1</sup> See Byrne [1] and Scobie [2]. The latter contains much of the relevant information that was originally presented in [3].

Since we are examining a situation where changes in the livestock inventory are likely, we must account for this in the objective function. Thus, in all cases the objective is to maximize discounted net revenue plus the discounted terminal value of the flock. A discount rate of 6.5 per cent is used.

The most important information required is the *relative* difference in performance of the different age groups of ewes. By performance we mean items such as wool production, fertility, and the survival from one year to the next. Since we use the information used previously by Byrne [1, p. 148] it will not be listed. Some of these data are presented in Table 1, the first sub matrix of a block-diagonal matrix.

### *Results*

A number of situations were examined and two main factors that were varied are the annual feed supply and the lambing rate of ewes. The starting flock composition was the same as that given by Scobie [2, p. 137], the actual numbers that he presented being scaled by a factor of 0.5.

When the feed supply is constant, we are virtually considering the same problem that was examined by Byrne and by Scobie as well as considering the transition stages. Table 2 shows the optimal plan under these conditions. The last row of Table 2 (REV) is the amount of revenue or cash drawn. These figures are undiscounted although in all cases the objective was to maximize discounted revenue.

After year six the flock structure remains stable and is very similar to the optimum suggested by Byrne previously [1, p. 152] where the ewes are kept for three years and 13 per cent are kept for another year. It is apparent that it does pay to move almost as quickly as possible to the optimal structure as determined by the static methods. It would have been possible to reach the stable "optimal" structure one year earlier by having only 865 maiden ewes in the second year but apparently it is more profitable to have a large number of young ewes in the second year. This policy is one where all ewe hoggets except the culls are put into the ewe flock.

A drop of 20 per cent in lambing percentage did not change the optimal policy of putting as many young ewes as possible into the breeding flock. In other words, no 1.5 year old ewes, apart from the culls, are sold. Again the flock structure becomes stable by about year six, the pattern being similar to that indicated in Table 2. With the lower reproductive performance it is necessary to retain 85 per cent of the ewes for their fourth breeding season once the structure has stabilized.

### *Development Situation*

We now examine the use of multi-stage linear programming for determining dynamic breeding policies in a development situation. Usually this involves pasture improvement which results in a change in the quality as well as the quantity of feed produced. In cases where there is little or no improved pasture at the start, the change in feed quality is likely to cause changes in biological parameters such as reproduction, wool production, and the survival rates. Since the proportional change

TABLE 1

*Linear Programming*

		YEAR 1											
		B	Run Ewes of Age Group							Sell Ewes of			
OBJECTIVE			1	2	3	4	5	6	7	1	2	3	4
YEAR 1													
Cash	0		1	1	1	1	1	1	1	-4	-8	-6.5	-4.5
Feed	5215		1.44	1.62	1.7	1.8	1.8	1.7	1.62				
Ewe Age Group 1	524		1							1			
2	514			1							1		
3	504				1							1	
4	489					1							1
5	469						1						
6	0							1					
7	0								1				
8	0												
Weaners	0												
Cull Ewe Weaners	105												
Ewe Weaners	942												
Wether Weaners	1047												
Cull Ewe Hoggets	480												
Ewe Wool Revenue	0		-4.3	-4.4	-4.3	-4.2	4.0	-3.4	-3.2	-4.3	-4.4	-4.3	-4.2
Weaner Wool Rev.	0												
YEAR 2													
Cash	0												
Feed	5215												
Ewe Age Group 1	0												
2	0		- .98										
3	0			- .98									
4	0				- .97								
5	0					- .965							
6	0						- .96						
7	0							- .95					
8	0								- .93				
Weaners	0												
Cull Ewe Weaners	0												
Ewe Weaners	0												
Wether Weaners	0												
Cull Ewe Hoggets	0												
Ewe Wool Revenue	0												
Weaner Wool Revenue	0												

## YEAR 3

- (a) All Sheep sales take place immediately after shearing, hence these activities supply wool revenue.  
 (b) Weaner transfer activity (WTF) separates weaners into three groups.  
 (c) The following abbreviations are used; (CEW) cull ewe weaners; (EW) ewe weaners, and (WW) wether weaners.

is not likely to be the same for each parameter, or for each age group, the respective matrix coefficients must be adjusted in the appropriate years.

In cases where there is a considerable amount of improved pasture at the start, it is less likely that there will be any change in the relative values of the various biological parameters. In such cases, changes in quality can be taken into account in the estimates of the total feed supply. In the example considered below, we assume this to be the case. Table 3 shows the flock composition and sales for a typical development situation. The first row of this table shows the number of feed units available.

These results show that in a developing situation it is necessary to retain ewes for longer periods in order to utilize the available feed. In years four to seven there is a total of seven age groups. The flock com-

Matrix—Year 1

Age Group (a) 5 6 7 8				WTF(b)	Run Young Sheep CEW EW(c)		Sell Young Sheep(a) WW EW(c)		Sell Wool Ewe Wean.		Draw	Run Ewes			
					1	2	·	·	Cash	1	2	·	·		
-3.0 -2.5 -1.5 -1.2					.8 1	.8 1	-.3 -2.5	-1 -1	1						
1 1 1 1															
-4.0 -3.4 -3.2 -2.7					1 -1.05	1 -1.05	1 -1.05	1 -4.3	1 1						
												1 1.44 1	1 1.62 1	·	·
				1 -.05 -.45 -.50											
															-4.3 -4.4 ···

position becomes relatively stable by year thirteen, six years after the feed supply becomes stable. The process is very similar from year seven to that observed in the previous examples from year one. Thus in both cases it takes about six years for the composition to become stable, given a constant feed supply.

Marginal Value Products

In the development situation we have considered, the rate of increase in the feed supply is fairly rapid, particularly from year two to year six when it is about 20 per cent per annum. Because of the rapid increase, a feed surplus occurred in years five and six (184 and 791 units respectively). This reflects the fact that it was not possible to increase sheep numbers sufficiently under the current set of constraints.

TABLE 2  
*Flock Composition and Sheep Sales with a Constant Feed Supply*

ID <sup>(a)</sup>	Year										
	1	2	3	4	5	6	7	8	9		
Run ewes of age group	1	R1	524	905	855	867	864	865	865	865	865
	2	R2	514	514	887	838	850	847	848	847	847
	3	R3	504	504	503	869	821	833	830	831	830
	4	R4	489	489	382	73	109	101	103	102	102
	5	R5	469	197							
Sell ewes at age of	4.5	S4			106	415	733	696	705	703	703
	5.5	S5		275	472	369	71	106	97	99	99
	6.5	S6		450	189						
Run Ewe Weaners <sup>(b)</sup>		REW	1047	990	1003	1001	1001	1001	1001	1001	1001
Sell Cull Ewe Hoggets		SCEH	481	101	95	96	96	96	96	96	96
Net Revenue \$'000		REV	15.9	18.2	19.2	20.1	20.7	20.6	20.6	20.6	20.6

<sup>(a)</sup> ID refers to the activity identification to be used in Table 3.

<sup>(b)</sup> The number of wether weaners sold at the start of the year is equal to the number of ewe weaners run. Of the total ewe weaners 10 per cent are culls that must be sold at the age of 1.5 years.

Examination of the marginal value products enables assessment of the importance of some of the constraints, in particular the exclusion of sheep purchasing opportunities. Table 4 shows the marginal value products for ewes for the first six years of the plan. They indicate the present value of the amount the grazier can afford to pay for sheep in full wool in the various age groups.

It can be seen that the marginal value products of young sheep are particularly high in the first four years. Since the values in the first five years generally exceed normal market prices it will pay to purchase sheep in any of these years. The highest marginal value product will be obtained from additional maiden ewes (1.5 years of age) in year four. No doubt the reason for these high values is the presence of surplus feed in years five and six.

In the first case examined, with the higher reproductive performance and the constant feed supply, the marginal value products of the first three age groups of ewes in year one are \$13.56, \$12.23 and \$10.80. If the market values are less than these then it will pay to purchase young sheep, provided finance is not limiting; this in turn will bring about a more rapid change towards the stable composition. This agrees with the budgets of Scobie where he found that it was more profitable to purchase young sheep in order to reach the optimal flock structure within one year.

#### *Planning Period*

Two planning periods were examined, eight and sixteen years. While all the results presented have been obtained from the sixteen-year model it is important to note that the results from the eight-year model are

TABLE 3  
Flock Composition and Sales with Increasing Feed Supply

ID	Year												
	1	2	3	4	5	6	7	8	9	10	11	12	13
FEED <sup>(a)</sup>	5.22	5.8	6.8	8.6	10.4	12.8	14.0	14.0	14.0	14.0	14.0	14.0	14.0
R1	524	905	855	987	1184	1482	1744	2050	2386	2306	2325	2321	2322
R2	514	514	887	838	967	1161	1453	1709	2009	2338	2260	2279	2274
R3	504	504	563	869	821	948	1137	1424	1675	1969	2291	2215	2233
R4	489	489	489	488	843	797	920	1103	996	474	227	286	272
R5	469	472	472	472	471	813	694						
R6		53	306	453	453	452	722	686					
R7				291	430	430	430						
S4													
S5													
S6		397	147				74	887	1065	1151	1682	1937	1876
S7			50				59	667		961	457	219	276
S8					270	400	400	400	638				
FEW	1047	990	1142	1371	1716	2019	2373	2762	2669	2691	2686	2687	2687
SCEH	481	101	95	108	132	165	194	228	265	256	258	258	258
REV <sup>(b)</sup>	15.9	16.8	17.8	19.5	25.4	30.3	36.1	47.9	50.5	54.1	55.0	55.4	55.3

<sup>(a)</sup> Feed is in terms of thousands of units. The unit is the amount of feed required to maintain one dry sheep for one year.

<sup>(b)</sup> Revenue is in terms of thousands of dollars.

TABLE 4  
*Marginal Value Products for Breeding Ewes Given an Increasing  
 Feed Supply*

Age Group	Year					
	1	2	3	4	5	6
Ewe Weaners	17.4	17.3	16.6	18.7	13.2	9.1
1	23.6	23.3	22.7	26.4	19.2	13.5
2	21.0	21.4	21.1	26.2	18.8	13.0
3	15.2	18.7	19.2	25.3	17.8	11.9
4	9.3	13.1	16.7	24.0	16.8	10.9
5	7.5	7.1	11.2	22.1	15.3	9.7
6	6.1	5.6	5.2	16.6	13.6	8.4
7	4.9	4.7	4.1	10.6	8.8	7.3

very similar. In all cases examined they are identical for the first six years of the plan. This indicates that the short-term goal, of maximizing the discounted net returns for eight years plus the discounted terminal value, is consistent with the longer-term goal of maximizing the same objective over sixteen years. Thus, for the purpose of planning it is not necessary to use the larger and more expensive model. This is particularly relevant when we consider the fact that both sheep and wool price changes are likely to occur making replanning essential well before the end of the planning period.

#### *Discussion*

In this paper we have shown that multi-stage linear programming can be used to determine optimal sheep breeding policies for any particular set of constraints. The technique provides a very convenient way of determining such policies in both stable and development situations. It is apparent that it is not necessary to apply this technique when considering situations similar to the example presented. For these cases it is possible to follow the rule of retaining all of the young ewes that are considered suitable for breeding. In different situations, for example, where sheep prices are of a greater magnitude, the above rule is not likely to apply.<sup>2</sup> In such cases, only by applying the multi-stage linear programming approach is it possible to see whether any simple rule can be used. Likewise for beef cattle it would be necessary to apply this technique to determine whether any general rules can be used.

When this technique is applied the marginal value products provide valuable information about the constraints imposed and indicate whether any should be relaxed. In the development situation examined, some of the marginal value products of the ewes and weaners were high relative to market values. This suggests that some ewe purchasing activities should be included in order to make the model more realistic.

The model that we have considered is limited to breeding and selling activities, but could be extended to include other livestock activities and other farm activities. It could form part of a whole farm development

<sup>2</sup> Such a case occurred in Western Australia where the price of the 1.5 year old ewes was considerably higher (\$11.00). The optimal policy was to sell approximately one third of these ewes and retain the rest of the ewe flock for seven years.



model incorporating a number of pasture improvement and other investment activities. While the size of the resulting matrix will present the usual difficulties, our experience suggests that this problem can be checked, to some extent, by limiting the length of the planning period.

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