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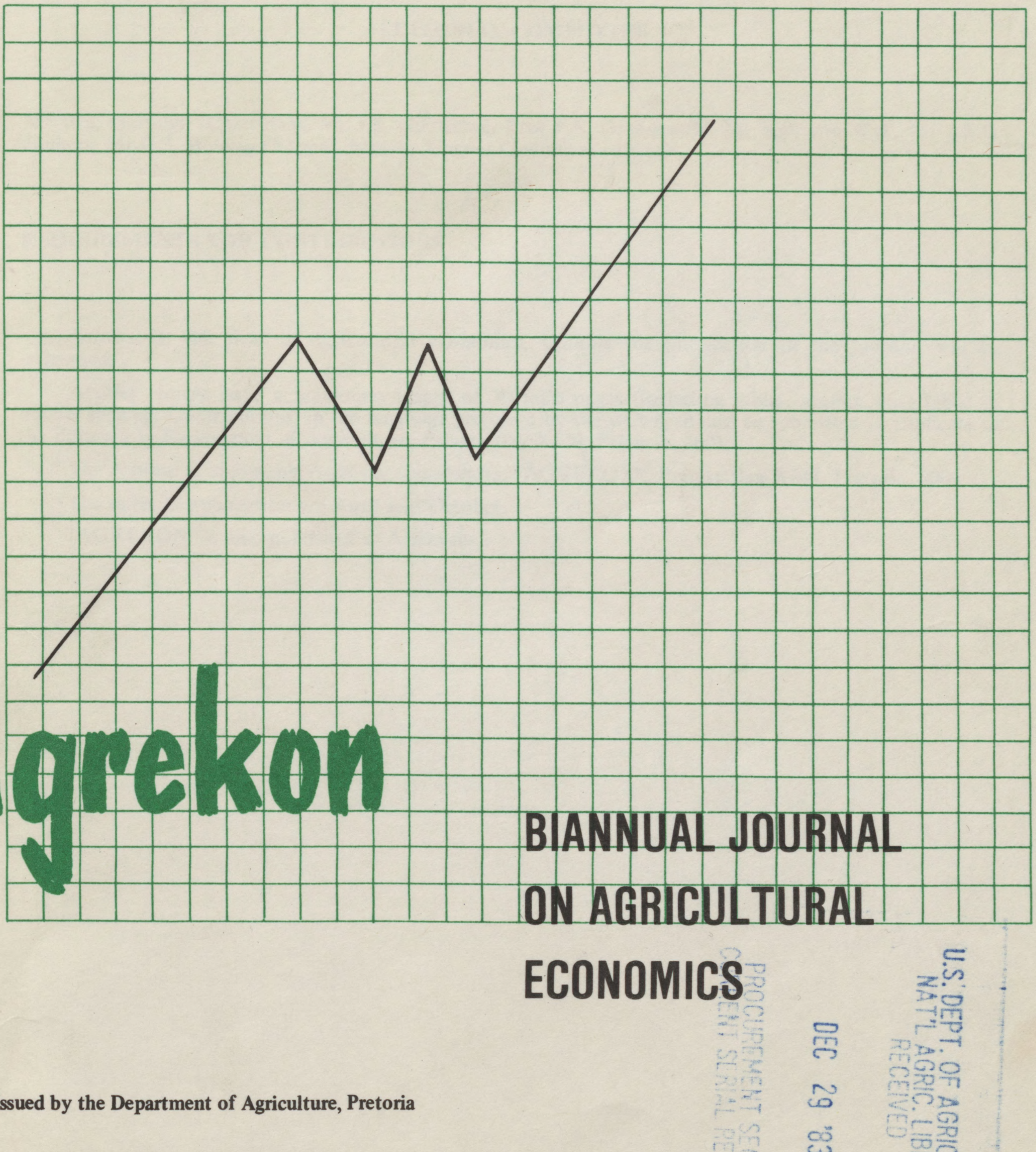

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FEED PLANS FOR DAIRY FARMS IN NATAL: RESULTS FROM A LINEAR PROGRAMMING MODEL*

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1. INTRODUCTION

Feed planning on dairy farms is important because of the seasonal character of pasture and crop production. A linear programmed feed model was developed for dairy farms in Natal, with the purpose of providing planning guidelines to individual farmers. The model includes profit maximisation features, a minimum cost ration formulation and an optimum machinery selection. The model was developed in such a way that it can be easily adapted to suit the resource availability of any specific farm. Data on which the model is based refer to bioclimatic groups 3 and 4 of the Natal Region (Phillips classification) since most dairy farms in Natal fall into these two bioclimatic groups. The Cedara College of Agriculture falls into bioclimatic group 3 and pasture trials are also more readily available for this group.

2. ASSUMPTIONS

Feed plans discussed in this paper are derived from several submodels. These submodels generated feed plans based on different assumptions with regard to fuel prices, fuel rationing, maize yields, fertiliser rates, capital constraints, herd size, mechanisation options and minimum areas under certain pastures.

It must be emphasised that any generalisations made in the ensuing discussion are subject to two important provisos. Firstly, the model is designed to provide guidelines for individual farms and not farms in general, and secondly generalisations are made from four similar submodels based on yields as realised by the top third of the dairy farms in Ixopo and the Natal Midlands.

The search for better data showed that although planning techniques are highly sophisticated information on important data requirements is often lacking. For instance, more research is required to determine the effects of fertilising on seasonal yield patterns of various pastures as well as loss factors.

*Based on M.Sc. thesis by D.W. Durham: *A linear programmed feed model for dairy farms in Natal.* University of Natal, 1980

3. ALTERNATIVE MODELS

The submodels used included six subherds, namely high producing cows (mean 26 ℓ/day), cows in production (mean 14 ℓ/day), dry cows, heifers 15-25 months, heifers 9-14 months and calves 0-9 months.

Energy, protein and dry matter are discussed using the rations formulated to provide for maintenance plus about 14 litres of milk per day. The basic requirements of the rations were:

maximum dry matter limit: 16,4 kg per cow per day
minimum energy limit: 9,7 kg TDN per cow per day (59% TDN)
minimum protein limit: 1,1 kg DCP per cow per day (6,5% DCP)

Feed plan 2D is used as a basis for comparison and includes unrestricted land use and no zero grazing or ensiling of pastures. The remaining eight feed plans differ from 2D as follows:

Feed plan 2C: Herd size 532 animal units and maize grain yield 7 tons/ha.
Feed plan 3B: Protein requirements of all rations increased by about 20%.
Feed plan 3E: As for 3B except that maize grain yield is 5 tons/ha using a fertilising rate required for a yield of 6 tons/ha.
Feed plan 3F: As for 3E except that maize fertiliser requirements are for a yield of 5 tons/ha.
Feed plan 4C: As for 2D except that zero grazing and ensiling of pastures are included as options.
Feed plan 4D: As for 4C except that fuel price has been increased by 10% of that used in feed plan 4C.

4. RESULTS

4.1 Energy (measured as Total Digestible Energy - TDN)

Energy was found to be the most important determinant of ration formulation and hence feed production. For all subherds and feed plans energy was never in surplus in the ration, even when the minimum protein requirements of the ration were increased by 20%. Shadow prices of energy for the same subherd of nine feed plans are presented in Table 1. Energy has its lowest value during the winter months, which is when the marginal value of protein is highest. Marginal values for energy are relatively stable, averaging 6c a kilogram of TDN overall and having a maximum variation of only 4c a kilogram within a given feed plan. This is not surprising since the basic source of energy in each feed plan is maize silage. Shadow prices of energy in the rations of different feed plans show the following trends:

(i) Increases as the cost of maize production increases;
(ii) decreases when the protein content of the ration is increased;
(iii) increases with increased fuel costs or fuel rationing;
(iv) minimal monthly variations when zero grazing and ensiling of pastures occur i.e. when ration ingredients are more constant.

4.2 Protein (measured as Digestible Crude Protein - DCP)

Protein is an important determinant of the ration formulation, particularly during winter months. The shadow prices in Table 2 reflect the value of protein (cents per kg of DCP) in milk production. According to Table 2, the value of protein is high in winter. This is attributed to the feeding in winter of silage which is low in protein. An analysis of all feed plans shows that except in the calf subherds, the protein content of rations is greater than the minimum required for only 12 - 14% of the time, and then almost always during October and November, when the protein production from pastures is highest. Table 2 contains shadow prices for the same subherd and eight feed plans as Table 1 and illustrates the inverse relationship that exists between the shadow prices of energy and protein. Seasonal fluctuations in protein prices are far greater than those for energy and are a result of the inconsistent production of protein from pastures, the prime source of protein in each ration when zero grazing and ensiling of pastures are included. Where rations are largely based on pastures, increasing the minimum protein requirements does not have nearly as great an effect on profits as where rations are based largely on maize. Pasture-based rations generally have a surplus of protein for part of the year and require purchased protein during few if any months.

4.3 Dry matter

Table 3 shows the difference between dry matter contained in the ration and the maximum dry matter limit for cows producing 14 litres of milk per day for eight different feed plans. Average surplus capacity is just over 5 kg per cow per day, but this varies from month to month within feed plans and is different for the same months of different feed plans. The following conclusions are derived from Table 3:

(i) A maximum dry matter limit is generally not an important factor in determining ration formulation, although a minimum one may well be, particularly if large quantities of concentrates are fed as part of the base ration.
(ii) As the pasture content of the ration increases, so surplus dry matter capacity decreases.

TABLE 1 - Production cows - shadow prices of energy (in c/kg of TDN)

	2D	2C	3B	3E	3F	4C	4D	4J	Average
Jan.	5	6	5	8	8	7	8	8	7
Feb.	5	7	4	8	8	7	8	8	7
March	6	8	5	8	8	8	8	8	7
April	5	7	4	7	7	7	7	8	6
May	4	6	4	7	7	7	7	8	6
June	3	5	3	6	6	7	7	8	5
July	2	4	2	6	5	7	7	8	5
Aug.	3	4	2	5	5	7	7	8	5
Sept.	5	8	6	8	8	7	7	8	7
Oct.	6	8	6	7	8	7	8	8	7
Nov.	6	8	6	8	8	7	7	8	7
Dec.	6	7	6	8	8	7	8	8	7
Average	**5**	**7**	**4**	**7**	**7**	**7**	**7**	**8**	**6**

TABLE 2 - Production cows - shadow prices of protein where limiting or surplus where not limiting (in c/kg of DCP);( ) refers to surplus above minimum required in kg/cow/day

	2D	2C	3B	3E	3F	4C	4D	4J	Average
Jan.	29	34	21	0	7	7	6	0	14
Feb.	23	19	34	(0,2)	3	7	6	0	13
March	14	9	23	(0,5)	2	3	0	(0,8)	8
April	29	25	33	11	14	15	11	(0,2)	19
May	37	35	42	18	22	12	9	1	24
June	47	47	51	28	32	14	11	3	31
July	61	62	66	36	41	14	11	3	40
Aug.	59	61	63	38	42	12	9	1	38
Sept.	16	7	6	(0,5)	(0,2)	11	9	1	7
Oct.	4	0	(0,1)	(1,4)	(1,4)	7	6	(0)	2
Nov.	5	5	0	(1,2)	(0,8)	9	7	(0,6)	3
Dec.	16	18	9	0	3	7	6	0	8
Average	**28**	**27**	**29**	**11**	**14**	**10**	**8**	**1**	**17**

TABLE 3 - Surplus dry matter capacity of production cows (kg of dry matter/cow/day below maximum intake limit)

	2D	2C	3B	3E	3F	4C	4D	4J	Average
Jan.	5,0	9,6	3,8	4,1	4,1	5,0	5,0	5,0	5,2
Feb.	5,2	9,9	4,3	3,8	4,1	5,2	5,2	5,2	5,3
March	5,3	10,2	4,4	3,8	4,8	5,3	5,3	3,5	5,3
April	4,7	9,3	3,6	3,9	3,7	4,6	4,6	4,1	4,8
May	5,2	9,9	4,5	4,5	4,5	5,0	5,0	5,0	5,4
June	5,1	9,7	4,4	4,4	4,4	5,0	5,0	5,0	5,3
July	4,5	8,6	3,7	3,7	3,7	4,7	4,7	4,7	4,8
Aug.	4,7	9,1	4,1	4,1	4,1	4,7	4,7	4,7	5,0
Sept.	5,2	9,9	4,7	3,8	4,4	4,7	4,7	4,7	5,3
Oct.	5,2	10,0	4,6	2,0	1,9	5,0	5,0	4,9	4,9
Nov.	5,1	9,7	4,7	2,0	3,1	5,1	5,1	3,7	4,8
Dec.	4,9	9,3	4,3	4,3	4,3	4,9	4,9	4,9	5,2
Average	**5,0**	**9,6**	**4,3**	**3,4**	**3,9**	**4,9**	**4,9**	**4,6**	**5,1**

4.4 Crop and pasture selection

Given the limited range of crops and pastures included and the conditions under which they are tested, it is not possible to be very specific as to the range of crops and pastures that should be considered in a feed planning model. However, at the risk of generalising, results indicate that the following points should at least be considered.

(a) Pasture selection

(i) Mixed clover pastures would appear to have a distinct advantage over pure pastures and should be included in a model for areas where it is possible to grow them.

(ii) A winter pasture is important, even on a relatively small scale, particularly if pasture silage making or a stored protein crop is not considered. If an alternative source of farm-produced winter protein is available, the presence of a winter pasture is not as important.

(b) Crop selection

Only maize was included in the model. Maize silage provides the basic source of energy in the feed plans and as it is available all year, this has the effect of stabilising the shadow price of energy, which varies very little during the year.

It is quite possible that a similar result could be achieved with protein, if a protein crop were included in the model. For areas where they can be grown, beans should be included as options in the model.

(c) Purchased feeds

Results show clearly that reasonably high levels of production can be obtained by dairy farmers without their having to resort to purchased feeds in any large quantity. In particular, a high quality basal ration for production cows should not rely on purchased concentrates.

It is however, important to include a purchased feed option in a model, since this places a realistic ceiling on the production cost of protein on the farm, which is usually highest in winter.

4.5 Effects of increased fuel prices

Possible effects of changes in fuel prices and rationing were estimated for a mixed dairy/maize farm using a submodel which included all five pasture conversion options (grazing, zero grazing, hay, silage and foggage), maize grain, maize silage and purchased concentrates.

In Fig. 1, the effects of fuel price increases above the base level of 42c (1980) per litre are shown.

Elasticities of demand for each segment of the

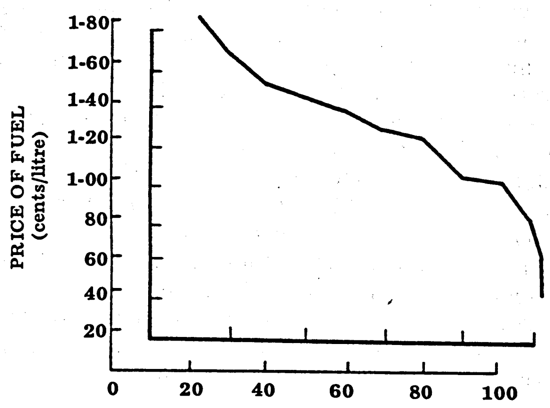

FIG. 1 - Demand curve for fuel

demand curve are presented in Table 4 and show that at the prevailing price of about 42c per litre (1980 price) demand is highly inelastic.

TABLE 4 - Elasticity of demand for fuel

Price (cents/litre)	Elasticity
21 -42	0,00
42 -52½	0,04
52½-63	0,11
63 -83	0,27
83 -84	9,82
84 -106	0,58
106 -110	4,15
110 -121	1,91
121 -126	6,11
126 -133	4,83
133 -151	3,16
151 -168	3,98

More than doubling the price of fuel relative to other prices makes maize grain production for sale uneconomic and demand is very elastic. Thereafter, demand is relatively elastic, becoming more inelastic at a more than trebling of the fuel price.

At a price of 42 cents per litre for fuel (1980 price) the optimum feed plan includes 5% grazing, 22% pasture silage and zero grazing, 1% hay, 5% maize grain and 66% maize silage.

After a trebling in the fuel price, the optimum feed plan changes to: 50% grazing, 17% pasture silage, 2% hay, 3% maize grain and 28% maize silage.

The following trends can be observed with different feed sources as the fuel price increases.

(i) *Grazing*. The total tonnage grazed increases as grazing replaces more fuel-intensive feed sources such as zero-grazing and maize silage.

(ii) *Hay*. The total hay fed increases rapidly to its maximum and thereafter remains constant. Hay is fed largely to calves and replaces grain in their ration as the fuel price increases. Initially, energy and protein are limiting factors in the calf ration, but as the hay content increases, dry matter intake and energy become the determining factors with protein in surplus. Any hay required for other rations must be forced into the feed plan.

(iii) *Zero grazing*. After a 50% increase in the fuel price, zero grazing is no longer economic and is replaced by grazing, reflecting the fact that the higher loss factor of grazing is more than compensated for by the higher costs of zero grazing.

(iv) *Pasture silage*. Initially pasture silage is largely a means of transferring the cheaper summer protein to winter. As the price of fuel increases, pasture silage increasingly replaces maize silage in the rations. The effect on the protein:energy balance in the rations is reflected by the higher shadow prices for energy and lower shadow prices for protein with increases in the fuel price.

The model is not completely flexible in respect of fuel utilisation since it does not allow for such conservation practices as more labour-intensive handling of food production, conservation and feeding such as the use of haystacks instead of bales. Furthermore, only one maize production technique was included in the submodel used for studying fuel consumption. Thus at a certain fuel price, the production of maize grain for the market becomes uneconomic, whereas in reality it could be profitable to market grain on a small scale using very little or no fuel, and the break-even point is continually being extended by the development of various fuel conservation techniques minimising tillage.

At the other end of the scale, the model does not allow for more fuel-intensive techniques of feed production, particularly with regard to maize production. The effect of this inflexibility in the model is seen in the increased inelasticity of demand at both ends of the demand curve. It is interesting to note, however, that at the prevailing fuel price of about 42 cents per litre, the techniques selected are almost all fuel-intensive. This leads one to the conclusion that at prevailing fuel prices optimum use of pastures is determined by other factors, particularly the various conversion "loss" factors rather than the cost of fuel. Fuel rationing results in high shadow prices for marginal fuel and a falling in land prices as profits are reduced.

5. CONCLUSION

A linear programming feed planning model was developed for dairy farming in Natal. The model illustrated the interdisciplinary nature of farm decision-making, showing the interactions between milk production, feed production and machinery selection. The total matrix contained 3 200 rows and 16 000 columns. Planning the ration on a dairy farm can mean anything from simply providing enough dry matter for the herd's requirements throughout the year to balancing macro and micro nutrients on a daily basis. Feed selection based on providing a minimum energy and protein level in the rations of six different subherds, given a maximum dry matter intake, indicates that while all three have an effect on ration selection, energy is the most important determinant of ration content. This could be largely as a result of the availability of maize silage (an energy source) all year, allowing the model to provide a steady minimum supply of energy to all subherds. Protein is important, particularly during winter months where pastures are at a premium. This supports the argument in favour of including a cheap source of protein in any feed planning model, at least pasture silage or a protein crop, preferably both. With quality feed production, dry matter is seldom a limiting factor, although for higher production levels it is more likely to be a deciding factor. For maintenance rations, a lower limit on the dry matter content of a ration should be considered.

Harvesting and feeding loss factors have an important bearing on the overall cost of farm feed production as well as the relative profitability of different feed sources.

Maize silage provided a cheap source of energy in feed plans all the year, which stabilised the shadow price of energy. Sufficient protein could be obtained from pastures during summer. This is clear from the fairly low shadow prices for protein during the summer (Table 2). During winter, protein was insufficient owing to the unavailability of pastures and the fact that maize silage fed during winter is low in protein. Protein shadow prices were consequently high during winter (Table 2), indicating that the value of additional protein feed is high and that protein should be purchased.

Dry matter intake of production cows was below maximum intake (Table 3), implying that maximum dry matter intake is not an important consideration in ration formulation.

The model predicts that if fuel prices increase, maize silage will become uneconomic as a feed source and more reliance will be placed on grazing.

At a price of 42 cents per litre for fuel (1980 price), the optimum feed plan includes 5% grazing, 22% pasture silage and zero grazing, 1% hay, 5% maize grain and 66% maize silage.

After a trebling of the fuel price, the optimum feed plan changes to: 50% grazing, 17% pasture silage, 2% hay, 3% maize grain and 28% maize silage.

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