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End of Project Report - Project 4229

Replacement Strategies to Maximise Profitability in Dairying

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Contents

1. Summary

The overall objective of this project was to develop a dynamic model which would determine the optimum replacement rates for dairy herds under an Irish system of production.

Actual cow disposal rates from dairy herds participating in DairyMIS were analysed over a five-year period (1990-1994). The primary reasons for dairy cow disposal together with the effect of parity of animal, seasonality of disposal and farm effect were retrieved from the computer records. Cow disposal rates from the (NFS) data base were also analysed for the period 1990-1993. The average DairyMIS and NFS disposal rates were 15.2% and 15.6 % respectively. Culling for involuntary reasons on DairyMis farms accounted for 77.6% of the animals culled.

Reproductive problems were the most common reason given for involuntary culling and this was associated mainly with older cows (greater than 4 lactation's). Mastitis was the second most common single reason given for involuntary culling overall. The highest culling rates were recorded for older cows (20.8%). The seasonal distribution of cow disposals was relatively constant but the majority of cullings took place from December to June. Considerable variation in culling rates between herds was recorded, indicating the importance of management factors.

The breeding goal on many commercial dairy farms is to maximize profitability. The genetic quality of the dairy herd is an important determinant of farm profitability. The average culling rate in dairy herds in Ireland of ~16% is mainly for involuntary reasons with little or no culling for voluntary reasons.

Varying the level of voluntary culling will have an effect on the physical and financial performance level of the herd. One of the objectives of this study was to simulate the effect of alternate breeding goals and alternate levels of voluntary culling on herd physical and financial performance factors. A farm production model based on spring-calving herds was used for this analysis. Current input and output prices were used.

The physical and financial performance factors were simulated for two breeding goals:

(A) Where the average RBI of the sires used was 130:
(B) Where the average RBI of the sires used was 150.

In both cases, the RBI was increased each year to reflect improvements in sires used over time. Monte Carlo simulation techniques were applied to a herd with an initial size of 100 cows and with an average RBI95 of 100. Three contrasting levels of voluntary culling : 0, 10 and 20 % were evaluated.

Breeding the herd to high index sires had a large effect on the RBI of the herd .When there was no voluntary culling, increases in herd RBI of 13% and 23% ,after 10 and 20 years respectively, were recorded for the lower breeding goal (Sires with RBI 130) as compared with increases of 20% and 34% in herd RBI for the higher breeding goal (Sires with RBI 150). Increases in RBI had an associated increase in milk yield per cow. Because of milk quota constraints, the herd size had to be reduced, which had the effect of reducing the land area and capital required for the dairy herd. When there was no voluntary culling, farm profit increased by 3-5%, depending on the time frame. Higher rates of voluntary culling resulted in an improvement in the genetic merit of the herd, particularly in the early years. This resulted in higher milk yields, which had the effect of reducing herd size due to quota constraints. Increasing the rate of voluntary culling resulted in a reduction in farm profit by 6% and 12%, for a voluntary culling rate of 10% and 20% respectively.

A model was designed and applied to the Irish dairy replacement problem, which included in the decision making process production, fertility, calving interval, seasonality, month of calving and various economic factors. The output from the Hierarchic model is a series of rankings. The dynamic programming approach can enable one to inform a farmer which cows in the herd should be replaced, on the basis that a replacement heifer(and its future successors) are expected to be more profitable than the current cow. The optimum replacement rate was 17.8% from this analysis.

Several variations in the model were tested. These technical parameters were then used to analyse the effect of changes in the model on optimal policy. The effect of the costs and revenues associated with culling were also studied.

When the cost of a replacement heifer was 10% lower, the optimal policy resulted in a replacement rate of 20.7%, as compared with 17.8% in the basic model. An increase on the replacement cost (110 % of the basic replacement cost) had the opposite effect on the technical parameters calculated from the optimal policy. The replacement rate was now 16.1%.

As with changes in replacement costs, changes in the value of the cull cow were found to have a considerable affect on the optimal policy and its results. The effect of these changes were not as large as changes in replacement costs. When the value of the cull cow's carcass was 90 % of the basic situation, the associated replacement rate was 16.7%. When the value of the cull cow's carcass was 110 % of the basic situation, the associated replacement rate was 19.6 %.

2. Introduction

The long term profitability of the dairy herd is affected by whether dairy cows leave the herd for 'voluntary' reasons such as low milk production or for 'involuntary' reasons such as animal disease, infertility or mortality. Actual herd culling rates can vary widely between herds and between years and are largely determined by herd management practices.

The overall objective of this project was to develop a dynamic model which would determine the optimum replacement rates for dairy herds under an Irish system of production and also to up-date the information available on dairy cow disposal rates on commercial dairy farms.

3. Dairy Cow Disposal Rates from Commercial Dairy Farms in Ireland

3.1 Introduction

The objective of this section of the study was to update the information available on dairy cow disposal rates on commercial dairy farms. The data used were assembled from the DairyMIS computerised recording system and from the National Farm Survey (NFS). The farms included in the DairyMIS system are representative of intensive dairy farms and are mainly located in the South of Ireland. The NFS database is representative of dairy farms nationally.

3.2 Results and Discussion

The disposal rates of cows in the NFS database for the years 1990-93 is shown in Table 1, with categories for dairy herd size.

Table 1 : Cow disposal rate by herd size category (NFS data)

	Year				
Herd size	**1990**	**1991**	**1992**	**1993**	**Average**
3 - 30 cows	**12.3**	**14.4**	**19.6**	**18.6**	**16.2**
31-60 cows	**13.8**	**12.8**	**15.2**	**15.6**	**14.3**
60+ cows	**12.9**	**16.6**	**17.6**	**15.1**	**15.6**
Average	**12.9**	**14.4**	**17.9**	**17.0**	**15.6**

The average disposal rate was 15.6%, ranging from 12.9% in 1990 to 17.9% in 1992. The range in cow disposal rates for different herd size categories was also relatively small (14.3% - 16.2%). The dairy herds participating in the DairyMIS system are representative of the larger more intensive dairy farmers in Ireland.

The average culling rate from the DairyMIS data set was 15.2% compared to an average culling rate of 15.6% from the NFS data base. The cow disposal rates for farms in the different herd size categories was relatively similar. This culling rate is lower than that found in a similar study in the early 1980s (Crosse and O'Donovan, 1989), when the average culling rate was 17.6%.

The disposal rates of cows by primary reason for disposal in the DairyMIS database are shown in Table 2. Up to 31 primary reasons for culling were recorded initially but it was found that five reasons consistently accounted for over 60% of the total disposal rate. The remaining group of 26 less important reasons for disposal were therefore grouped together under 'other reasons' for this analysis.

Table 2: Cow disposals (%) - by primary reason for disposal (DairyMis data)

	YEAR					
Primary reason for disposal	**1990**	**1991**	**1992**	**1993**	**1994**	**Avg.**
Infertility	**3.1**	**4.1**	**5.0**	**2.5**	**3.2**	**3.6**
Surplus	**2.6**	**2.9**	**1.4**	**2.1**	**2.0**	**2.2**
Mastitis	**1.6**	**1.8**	**2.8**	**1.2**	**1.8**	**1.8**
Low production + old age	**1.5**	**2.1**	**1.1**	**1.7**	**3.6**	**2.0**
Other reasons	**8.1**	**4.8**	**4.4**	**4.9**	**5.5**	**5.6**
Total	**16.9**	**15.7**	**14.7**	**12.4**	**16.1**	**15.2**

Chi square value = 80.6 ***

The most significant primary reasons for culling were infertility (3.6%), surplus (2.2%), mastitis (1.8%), and low production and old age (2.0 %). While there were differences in these figures between years, the relative importance of these reasons remained constant over the years. The major advantages of culling strategies for herd improvement are achieved by maximising the proportion of cows that are culled for voluntary as distinct for involuntary reasons.

Generally, culling for low production is considered to be voluntary culling. Since the advent of milk quotas, culling of surplus cows has assumed much more importance, and it is likely that dairy farmers would cull their poorer animals if they had surplus stock. Culling of surplus stock together with culling for low production is therefore considered to be voluntary culling.

In this study, it was found that about three quarters of all cullings were involuntary and only one quarter were culled for voluntary reasons. Infertility was the most important single reason given for involuntary culling and while culling for infertility was particularly associated with older cows, a significant proportion of younger animals were also culled for this reason. Mastitis was the next single most important reason given for involuntary culling and this was associated more with older cows.

The disposal rate of cows was significantly (P<0.001) influenced by the parity (lactation number) of the animal (Table 3). The highest incidence of culling (20.8%) within each parity category was for cows with greater than 4 lactation's. This was associated with infertility, mastitis, age, low production as well as a collection of other reasons. The culling rates for the other parity classes were relatively similar. The relative ranking of animals within different parities in terms of disposal is important. The potential genetic gain from a selection policy is maximised by the disposal of older cows of inferior genetic quality.

Table 3 : Cow disposals (%) - by parity (lactation number) of animal (DairyMIS data)

	Year					
Lactation No.	**1990**	**1991**	**1992**	**1993**	**1994**	**Average**
1	16.5	10.8	9.1	8.4	12.1	11.4
2	11.6	11.1	9.4	7.4	10.8	10.1
3	13.1	11.4	10.9	10.5	10.9	11.3
4	14.2	14.4	13.0	9.5	13.1	12.8
4+	20.8	20.7	20.9	18.0	23.6	20.8

Chi-square value = 27.8 *

The reasons for culling by parity group are shown in Table 4.

Table 4: Cow disposal rate - reason for disposal by parity of cow (DairyMIS data)

Parity of dam						
Primary reason for culling	**1**	**2**	**3**	**4**	**> 4**	**All**
Infertility	19.5	27.3	28.6	30.8	21.7	23.5
Surplus	24.8	16.9	13.7	13.0	11.5	14.3
Mastitis	7.0	5.2	9.7	13.8	14.8	12.1
Low production +old age	10.4	13.9	13.9	6.1	15.2	13.4
Other reasons	38.3	36.7	34.1	36.3	36.8	36.7
Total	100.0	100.0	100.0	100.0	100.0	100.0

Chi square value = 149.9 ***

Infertility was the most important main reason for disposal, though for first lactation animals it was ranked second. A surplus is the second most important reason accounting for 14% of all cullings, though it assumes a somewhat higher importance in first and second lactation disposals. Mastitis, which accounts for 12% of cullings overall, was particularly important in later lactations.

Low production, on the other hand, was a relatively important reason in early lactations, but not later. The remainder of cullings were attributed to a very large number of reasons each of which accounted for only a very small percentage of cullings, and have been grouped together under "other reasons" (Table 4). While each reason was only of minor importance, the grouping accounted for approximately one third of all cullings.

The seasonal distribution of cow disposals for the years 1990-1994 is shown in Table 5, and it can be seen that there has been year-to-year fluctuations in the pattern.

Table 5 : Cow disposals (%) - by period of year (DairyMIS data)

	Year					
Period	**1990**	**1991**	**1992**	**1993**	**1994**	**Average**
1 (January-March)	**36.6**	**33.2**	**31.3**	**33.4**	**30.9**	**33.1**
2 (April-June)	**29.3**	**29.2**	**34.3**	**39.0**	**39.8**	**34.3**
3 (July-September)	**16.0**	**20.1**	**17.5**	**13.0**	**8.6**	**15.0**
4 (October-December)	**18.1**	**17.5**	**16.9**	**14.6**	**20.6**	**17.5**
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

A quarterly breakdown of the data shows that the period April to June accounts for the highest percentage of annual disposals averaged over the five years, but it does not represent the peak in every year. In general, however, it can be seen that the period January to June accounts for a high proportion of cullings, typically two thirds. During the other six months, July to December, disposals are typically low, though a quarterly breakdown shows occasional peaks for particular years. While most of the herds recorded were spring-calving, some of the distribution of cullings throughout the year may be due to the presence of some Autumn-calving herds in the survey.

Analysis of a matched sample of 23 farms showed that they had an average disposal rate ranging from 10% to 20%. The variation in disposal rates both across years and between individual farms was significant. The large farm-to-farm variation in culling rates recorded in this study as in the previous study would indicate that management is important. A reduction of involuntary culling should allow for more culling for low production and other reasons, which may enhance the genetic quality and general health of the dairy herd.

4. A model for culling and breeding goals in Irish Dairy Herds

4.1 Development of a simulation model

The breeding goal on many commercial dairy farms is to maximise profitability, and in this regard, the genetic quality of the dairy herd is an important determinant of farm profitability. There has been a marked increase in the rate of genetic improvement in dairy herds in Ireland in recent years. These developments present new opportunities for increased profit on dairy farms as well as major challenges to milk production systems that are mainly based on grass.

The simulation techniques known as Monte Carlo methods were used in this study. A model using Monte Carlo methods was developed to simulate the physical and financial consequences of alternate breeding goals and alternative levels of voluntary culling for a hypothetical Irish spring-calving herd. The characteristics for this herd are based on the Moorepark Blueprint for summer milk production. This model farm represents a typical intensive dairy farming system in Ireland where the EU milk quota is the most limiting constraint on production and where there has to be a combination of enterprises to use the land available. This allowed the opportunity cost of capital and land to be evaluated.

4.2. State variables included in the model

A cow's relative breeding index (RBI'95) describes, in a single figure, a cow's genetic merit for the production of fat and protein. It also includes an economic component. RBI'95 was included as a state variable for each animal in the herd, as were lactation number and production level. Production level was described by one of 15 levels and defined relative to the mature cow equivalent production. In this model, the lactation of an animal was measured as 1st, 2nd and 3+.

4.3 Other Model Parameters

Current input and output prices were used in the analysis. An involuntary culling rate of 18% was assumed. It was further assumed that 50% of calves born were male and that an overall calf mortality rate of 6% prevailed. The RBI of a calf was calculated as the average of the sire and dam's RBI'95. At the end of each year, new heifers entered the herd until the quota could be expected to be met in the following year (although production levels for the following year were unknown, expected yields on the basis of current production levels could be calculated). Replacement heifers are 2 year-olds, which were bred and reared within the herd. The RBI'95 of these heifers was assumed to be equal to the average RBI'95 of female calves surviving from 2 years previously. Current (1997) costs and prices were used for milk, calves, cull cows, replacement heifers, non feed costs per cows and for the opportunity cost of land and capital.

The RBI'95 of an animal in the herd had an effect on physical performance and on financial factors. The following were dependent on the RBI'95 of animals in the herd; milk yield; feed costs; calf value; carcass value; land usage.

4.4 Culling and Breeding Goals Tested by the Model

The physical and financial performance factors were simulated for two breeding goals: (1) where sires with an average RBI'95 of 130 were used : (2) where the average RBI of the sires used was 150. For each of these breeding goals, the RBI95 of the average sire was allowed to increase (by 2 units per time stage) over time to reflect the improvements in sires used over time (i.e. RBI Sire (t) = BRI sire (0) + (2*t).

Three contrasting levels of voluntary culling 0, 10 and 20% were also evaluated. At the end of each stage of the simulation, a number of animals (based on the current herd size and on the voluntary culling rate) were culled according to the lowest lactation adjusted milk yield). At each stage of the simulation, the total yield, total revenue, land in use, and average RBI of the herd were calculated.

4.5 Stochastic Elements included in the model

A planning horizon of 20 years (20 stages) was used. At each stage, each animal in the herd could be culled involuntarily with a probability of 18%. Survival was determined stochastically, as were the transitions from one production level to another. Transitions in production levels were assumed to take placed at the end of lactation (stage).

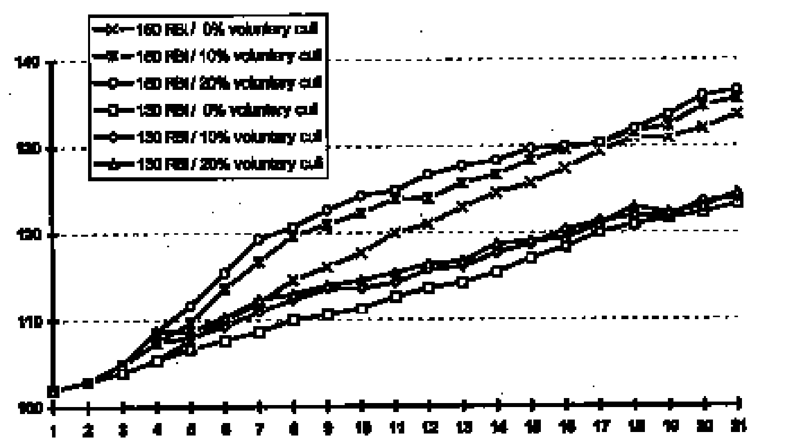
For each calf in the herd, sex and survival were also determined stochastically. Transitions in 'lactation number' could be determined deterministically since only one transition was possible for an animal at any stage (i.e. lact (n+1). An animal's RBI'95 remained constant for its lifetime, so again the transition for this stage variable were deterministic.

4.6 Results of physical and Financial Factors

As the simulation model was run, certain physical and financial factors were measured at each stage. These were; Average RBI'95 of the herd; Total milk yield of the herd; Average milk yield per cow; Current herd size; Land in use for dairy enterprise; Capital investment; Total revenues.

Breeding the herd to high index sires was found to have large effect on the average RBI of the herd (Figure 1)

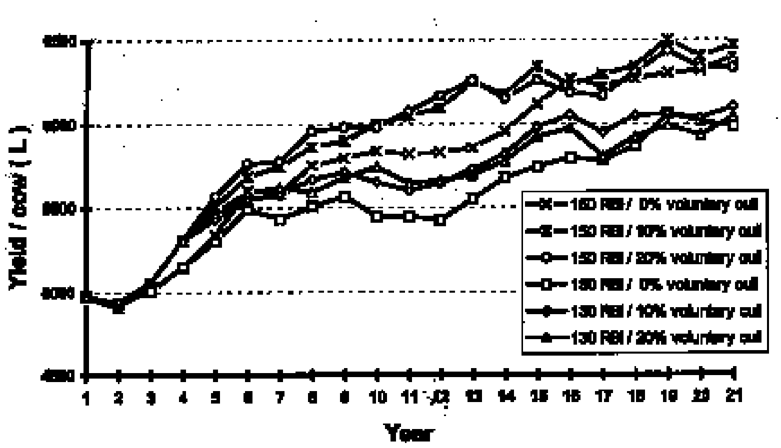
Figure 1: Change in Average RBI over Time



For the later half of the planning horizon, a higher breeding goal resulted in higher herd RBI95's, no matter what culling rate was chosen. Where the lower breeding goal was combined with high voluntary culling rates (20%), the average RBI95 of the herd rose quickly, but within 6-7 years, the average RBI95 where the higher breeding goal was used (regardless of the culling rate) was always higher. When there were no voluntary culling, increases of 18 and 35 units of RBI95 for years 10 and 20 respectively, were recorded for the lower breeding goal (sires with RBI95 130).

This compares with an increase of 24 and 47 units of RBI95 respectively, for the higher breeding goal (Sires with RBI95 of 150). The increases in RBI95 associated with higher culling rates are due to the faster introduction of genetically superior animals to the herd. The increases due to culling policy are greater for the higher breeding goal because, with the lower breeding goal, the genetic level of the herd soon approached that of the replacement heifers. The effect of breeding and culling strategy on milk yield is given in Figure 2.

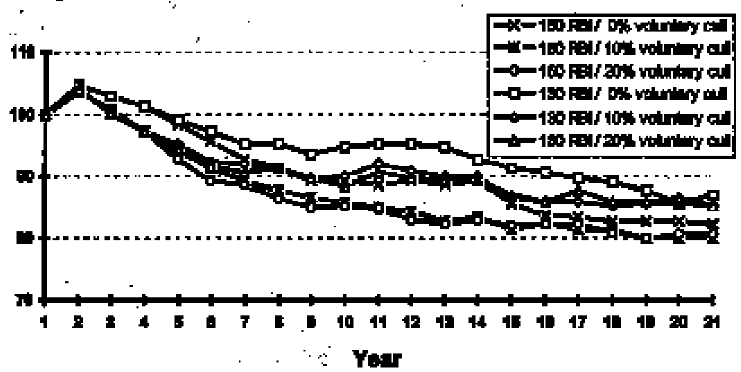
Figure 2: Change in Milk Yield over Time



In the model, a herd member's milk yield was adjusted for RBI'95 level, So, for a certain age and production level, an animal with higher RBI'95 would have a higher yield than one with a lower RBI'95 level. Therefore, it is not unexpected that the use of the higher breeding goal (which results in higher average RBI'95 per animal

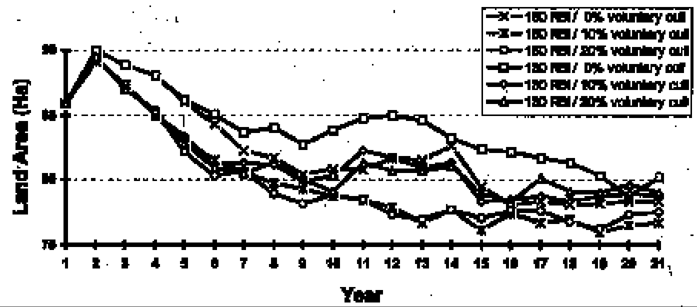
(Figure 1) results in a higher milk yield per animal as shown in Figure 2. Because of the inclusion of a milk quota higher milk yields per cow (associated with higher breeding goals) meant that herd sizes had to be reduced, as illustrated in Figure 3. When a voluntary culling rate of 10% was applied, herd sizes of 85 and 76 were recorded for years 10 and 20, respectively, when the lower breeding goal was applied. While for the higher breeding goal rather than the lower, results in a 11% reduction in herd size after 10 years and a 30% reduction in herd size after 20 years.

Figure 3: Change in Herd Size over Time



The land used for the dairy enterprise was based on the genetic makeup of the herd. For the higher breeding goal, the average RBI was greatest (Figure 1). However, the fewer animals required in the herd to reach quota (Figure 3) had the effect of reducing the land area required for the dairy enterprise (Figure 4). A measure of farm profit was taken at each stage under the various breeding and culling strategies. These measures are shown in Table 6. The calculation of these figures was based on milk revenue, calf sales, feed costs, replacement costs, land usage and capital expenditure.

Figure 4: Change in Land Area Required



A cull policy with no voluntary culling resulted in higher profits (Table 6) than either a 10% or 20% voluntary culling rate (and the 10% rate resulted in higher profits than the 20% rate). The use of higher merit sires (150 RBI95) resulted in higher profit rates over the 20 year planning horizon.

Table 6 : Change in Actual revenues (per year) relative to a breeding goal with 130 RBI sires and no voluntary culling (set at 100%)

RBI - sire	***130***	***130***	***130***	***150***	***150***	***150***
Vol. Culling	***0%***	***10%***	***20%***	***0%***	***10%***	***20%***
Period :						
0-5 years	***100***	***93***	***89***	***103***	***97***	***92***
0-10 years	***100***	***93***	***89***	***104***	***97***	***93***
0-15 years	***100***	***94***	***89***	***104***	***98***	***94***
0-20 years	***100***	***94***	***89***	***105***	***98***	***93***

4.7 Conclusions from the Simulation Model

The results of the simulation suggest that the use of high merit sires had a large effect on the genetic merit of the herd and consequently on milk yield per cow. This resulted in increased farm profit even though cow numbers had to be reduced to stay within the quota. Increasing the rate of voluntary culling also increased the genetic merit of the herd, especially in the early years. This had a positive effect on milk yield per cow as well as on other farm parameters. However, the cost of achieving this higher milk yield per cow was outweighed by the corresponding higher cost of providing replacement animals. Therefore, culling on the basis of production alone resulted in a reduction in total farm profit.

5.0 Optimum Replacement Policies

A model was designed and applied to the Irish dairy replacement problem, which included in the decision making process milk production, fertility, calving interval, seasonality, month of calving and various economic factors. The output from the Hierarchic model is a series of rankings. The dynamic programming approach can enable one to inform a farmer which cows in the herd should be replaced, on the basis that a replacement heifer (and its future successors) are expected to be more profitable than the current cow.

The purpose of this research has been to investigate methodologies for determining optimal culling decisions on dairy farms. The typical technique applied for replacement problems, where the traits of the asset in question are affected by random variation overtime and between assets (e.g. animal replacement problems), is dynamic programming.

The model developed allowed decisions to be made at certain stages of a cow's lactation. Replacement decisions were considered at the time of calving and 2, 3, 4, 5, and 6 months after calving. Insemination decisions were made 2, 3, 4 and 5 months after calving. These replacement and insemination decisions were made on the basis of level of production, fertility, calving interval, season, month of calving and various economic factors. The seasonality of grass production in Ireland meant that it was necessary to include seasonality in the model. The parameters used in the Hierarchic model for Irish dairy herds are shown in Table 7. The model calculated optimal culling and insemination policies under these parameters.

Table 7. The basic economic parameters applied in the dairy replacement model

	£
Carcass value (£)	400
Replacement heifer cost (£)	800
Milk price/litre (£)	0.22
Cost of grass/ kg DM (£)	0.028
Cost of silage/ kg DM (£)	0.085
Cost of concentrates/ kg DM (£)	0.17
Sundry costs per cow/year (£)	320
Insemination costs (£)	10
Loss in carcase value due to involuntary disposal (£)	50
Mature equivalent yield per cow (L)	5500
Age at first calving (Months)	24

The technical results calculated for the optimum policy were: Average milk yield per cow per year, Average replacement rate per year, Average number of calves born, per cow, per year, Average return from milk, per cow per year, Average feed costs, per cow, per year, Average gross margin, per cow, per year, Average calving interval.

These technical results, calculated under the optimal policy (and where the economic inputs of Table 7 were applied) are presented in Table 8.

Table 8. Results from the basic model.

Average milk yield/cow/year	(L)	5258
Average replacement rate/year	(%)	17.8
Average calves born/year/cow	(Number)	1.11
Average return from milk/cow/year	(£)	1158
Average feed costs/cow/year	(£)	321
Average gross margin/cow/year	(£)	775
Average calving internal/cow/year	(months)	11.7

The output from the model was a series of rankings, based on retention payoffs (RPO). RPO was calculated as the expected future profit from keeping (or keeping and inseminating) a cow for an additional stage, rather than replacing her at the end of the current month. These RPO's allowed animals in a herd to be ranked, and for culling decisions in a herd to be made on the basis of these rankings (i.e. the lowest ranked cows in the herd would be culled first).

Several variations in the model were tested (e.g. with and without transitions in production level), and for each resulting optimal policy (and ranking), certain technical parameters were calculated. These technical parameters were then used to analyse the effect of changes in the model on optimal policy. It was found that, if transitions in the state variable "production level" were not allowed, the optional policy changed greater (the optimal policy was found to be different in 11.5% of cases).

The model was also reformulated with the variable "production level" not included, and this resulted in the replacement rate increasing from 17.8% to 24.57%. The optimal policy was also found to be highly seasonal, which was to be expected as lactation curves, based month of calving, for milk yield, protein yield, fat yield and feed costs, were included in the model.

When insemination was attempted in the model, conception occurred with a certain probability of success. The effect of this uncertainty of conception was studied by subsequently removing it from the model. This showed that in fact the inclusion of the uncertainty of conception had a considerable impact on the model results. Higher milk yields per cows, shorter average calving intervals and more calves per cow could be achieved when insemination could be assumed to be always successful. The effect of the costs and revenues associated with culling were also studied. When the cost of a replacement heifer was 10% lower, the optimal policy resulted in a replacement rate of 20.7%, as compared with 17.8% in the basic model.

This increased the average milk yield per cow to 5281 litres and the gross margin to £826. An increase on the replacement cost(110% of the basic replacement cost) had the opposite effect on the technical parameters calculated from the optimal policy. The replacement rate was now 16.12%.

As with changes in replacement costs, changes in the value of the cull cow were found to have a considerable affect on the optimal policy and its results. The effect of these changes were not as large as changes in replacement costs.

When the value of the cull cow's carcass was 90% of the basic situation, the associated replacement rate was 16.7% and the average gross margin was £755 (decrease of 2.5%). When the value of the cull cow's carcass was 110% of the basic situation, the associated replacement rate was 19.61% and average gross margin £806 (an increase of 4%).

References

Crosse, S. and O'Donovan, S. 1989. Dairy cow disposal rates from commercial dairy farms participating in the DairyMis II computerised management information system in Ireland. Irish Veterinary Journal 42: 75-78.

Notes