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Application of replacement theory in dairy cows and its use in disease treatment

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ABSTRACT

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A model to simulate the costs and returns of an individual dairy cow over 14 years under various assumptions of genetic potential, health status and management was developed especially to evaluate the effects of diseases that reduce production and reproduction efficiency and to evaluate alternative management interventions. Data were collected from the Food Animal Health Resource Management System (FAHRMX), Today's Electronic Planning (TELPLAN), Today's Electric Farm Accounting (TELFARM) databases and secondary sources at Michigan State University. A case study of cystic ovaries was analysed using the model. The results showed that it is more economical to treat cystic ovaries than not to treat, and treatment with Gonadotropin Releasing Hormone (GNRH) was superior to Human Chrionic Gonadotropin (HCG). Four to five lactations were the optimum for keeping a dairy cow to replacement and it was estimated that there is a loss of US$0.45 per day of extended calving interval (days open beyond the optimal 70 days).

INTRODUCTION

Dairy cow replacement theory closely parallels the process outlined by Faris and Reed (1962) in determining when to replace Cling peach trees. Work by Jenkins and Halter (1963), Smith (1971), Stewart et al. (1977) and Dijkhuizen et al. (1985) have specifically applied the theory to dairy-cow replacement decisions. Except for Dijkhuizen et al. (1985), previous work addressed the issue with respect to replacement for production. Replacement

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questions related to disease and the decision to treat or not to treat have received lesser attention. The economic theory underlying the replacement rule is that a dairy cow should be retained as long as her marginal profit is higher than the expected average profit per given period of time during a young replacement heifer's life (Renkema and Stelwagen, 1979).

Most existing dairy herd databases, like the Food Animal Health Resource Management System (FAHRMX), can provide farmers with information relating to herd inventory data, lists of animals requiring reproductive examinations, calving lists (calendar), heat prediction, and comparative statistics. However, there is limited capacity for predicting the possible monetary consequences of one or more diseases and their treatment. Price fluctuations (of inputs and outputs) coupled with government programs aimed at reducing dairyherds and milk demand require the farmer to make quick decisions at both the herd and individual cow level for maximum economic gains. A computer model was built to (1) simulate the costs and returns of an individual dairy cow over a period of 14 years; (2) determine the optimal culling lactation given the potential output of a replacement heifer; (3) evaluate alternative health interventions to cystic ovaries; and (4) to estimate the loss from prolonged calving intervals (cost of days open).

MATERIALS AND METHODS

Benefits, costs and net returns for a dairy cow were simulated overtime based on known production relationships. Prediction of milk production, a major output, was based on milk production curves generated by Stallcup et al. (1978) but extended by linear extrapolation to generate production for at least a 14-month lactation period (Table 1). Lactation number and season of calving indices were used to adjust production levels based on lactation number and month of calving (Tables 2 and 3). The value of the calf was estimated using a formula adopted from Kuipers (1980). The formula takes into account the probability of a male or female calf being born, and the genetic and milk production potential:

$$\text{CALF} = 0.441 * (\text{AVFCP} + \text{EXTRA}) + 0.459 * \text{AVMCP} \quad (1)$$

where CALF is the estimated calf value; 0.441 results from a female sex ratio of 49% female, 10% mortality; 0.459 results from a male sex ratio of 51% male, 10% mortality; AVFCP is the average female calf market price; AVMCP the average male calf market price; and:

$$\text{EXTRA} = 3.813 * (\text{PRMLK} * \text{EBV} * \text{LACFAC}) * 0.68 \quad (2)$$

$$\text{EXTRA} = 0 \quad \text{If} \quad \text{Extra} < 0$$

in which EBV is the expected breeding value, LACFAC the factor to adjust the

TABLE 1

Calculated milk production of cows with different production potential by month of lactation

Production (lbs per 305 days)	14000	17000	19000	21000	21000
Lactation	Production (lbs/day)				
1	58.2	70.5	78.7	80.2	92.5
2	59.2	70.0	75.5	81.7	89.6
3	54.3	66.8	70.2	76.0	87.8
4	52.2	63.2	69.1	74.7	80.5
5	49.2	57.4	61.5	74.0	80.8
6	45.2	52.3	60.7	69.0	75.2
7	42.5	51.4	59.1	67.8	73.1
8	38.4	49.3	56.4	61.8	69.3
9	36.0	44.1	51.4	59.3	61.1
10	31.5	41.7	50.6	55.4	56.8
11	27.0	39.3	49.8	51.5	52.5
12	22.5	36.9	49.0	47.6	48.2
13	18.0	34.5	38.2	43.7	43.9
14	13.5	32.1	37.8	39.8	39.6

TABLE 2

Lactation factors for estimating milk production over 14 lactations

Lactation	1	2	3	4	5	6	7
Lactation factor	0.82	0.90	0.96	0.99	1.00	1.00	0.99
Lactation	8	9	10	11	12	13	14
Lactation factor	0.98	0.93	0.88	0.82	0.76	0.70	0.64

Source: Adapted from T. Ferris, Department of Animal Science, Michigan State University, East Lansing, MI, unpublished research work, 1985.

TABLE 3

Seasonal factors for estimating production levels as a function of season (Month) of calving

Month	January	February	March	April	May	June
Seasonal factor	0.9627	0.9676	0.9690	0.9814	0.9982	1.0320
Month	July	August	September	October	November	December
Seasonal factor	1.0554	1.0542	1.0229	0.9974	0.9814	0.9778

Source: Adapted from Hlubik, 1979.

TABLE 4

Feed requirements for different production levels

Lactation	(lbs/day)	ALF/HAY	CORN SIL	GR CORN	SOY44	PREMIX
(a) Lactations 1 and 2						
1	0.0	5.00	39.56	0.00	0.00	0.18
	30.0	5.00	79.65	0.00	0.00	0.38
	40.0	5.00	83.47	2.28	1.07	0.50
	50.0	5.00	76.06	7.34	2.67	0.63
	60.0	5.00	67.38	12.78	4.31	0.76
	70.0	5.00	57.55	18.58	5.98	0.90
	80.0	10.14	33.17	25.90	7.17	1.21
	90.0	12.90	26.06	28.09	8.49	0.99
	100.0	19.40	32.20	25.40	2.50	0.00
2	0.0	5.00	42.53	0.01	0.00	0.21
	30.0	5.58	76.31	0.00	0.00	0.37
	40.0	10.53	81.00	0.00	0.00	0.35
	50.0	9.83	95.61	0.00	0.77	0.46
	60.0	5.00	101.55	3.83	2.81	0.69
	70.0	5.00	94.37	9.00	4.36	0.82
	80.0	5.00	86.08	14.52	5.95	0.92
	90.0	5.00	76.73	20.37	7.56	1.09
	100.0	6.60	62.07	26.92	9.06	1.20
(b) cows in lactation 3 or above						
3	0.0	5.00	42.53	0.87	0.00	0.24
	30.0	6.60	71.63	0.00	0.00	0.35
	40.0	11.63	75.83	0.00	0.02	0.32
	50.0	14.31	84.53	0.00	0.33	0.35
	60.0	16.87	94.10	0.00	0.59	0.39
	70.0	15.20	106.33	1.17	1.63	0.53
	80.0	15.60	106.33	12.90	3.35	0.70
	90.0	10.28	106.33	10.25	5.12	0.89
	100.0	7.37	106.33	15.10	6.93	1.09

Source: Michigan State University, 1984.

EBV for a lactation, PRMILK the price of milk per lb (1 lb ≈ 0.454 kg), 3.813 a constant that expresses the expected extra income flow from a live heifer calf, and 0.68 the milk return over feed and health costs.

Feed requirements were generated as a function of the status of the animal (pregnant, lactating or dry), health, level of milk production, lactation number, animal size, feeding system and feeds. Today's electronic' planning (Telplan 31) version 5 (Michigan State University, 1984) database was used to generate feed requirements on a daily basis (Tables 4a and 4b).

Health costs were modelled as a function of lactation stage, level of milk production and direct costs associated with disease under consideration (Shanks et al., 1981, 1982):

$$\text{HLTH} = 20.0 * (1/K) + \text{MLKCOST} + \text{DISCOST} \tag{3}$$

where HLTH is total health costs per month, 20.0 is average health costs incurred in the first month of lactation, K is month number of the lactation including the dry months, MLKCOST is extra feed and health costs associated with level of milk production (0.32 cents per \$1.00 value of milk produced over 15 000 lbs), and DISCOST is direct costs associated with a particular disease.

A replacement cow was taken as a 2-year old heifer before calving with a first lactation milk production potential equal to the herd's production average (16 000 lbs per 10-month lactation was used in the base-run). The market value for the heifer was \$1500 and \$500 for the carcass value of a mature cow. The calving interval was taken as 12 months, age at first calving 24 months and genetic capacity was assumed to increase by 1% annually. The mature cow was taken as one in the 3rd month of her third lactation with a production level of 14 000 lbs of milk per 10-month lactation. A rate of 12%, reflecting the going rates for inflation and real rate of interest was used to discount the flow of costs and benefits overtime. The relevant equations used in the model are presented below:

$$\text{NET}_i = \text{MILK}_i + \text{CALF}_i - \text{FEEDS}_i - \text{HEALTH}_i - \text{OPPCOST}_i \tag{4}$$

where NET is net returns in month i, MILK is milk returns in month i, CALF is calf value in month i, FEEDS is feed costs in month i, HEALTH is health costs in month i, OPPCOST is opportunity cost of the cow in month i, and i is the month under consideration ($i = 1, 2, \ldots, N$);

$$\text{DISNET}_i = \text{NET}_i * \text{DISFAC}_i \tag{5}$$

$$\text{ACCUMNET}_i = \text{NET}_{i-1} + \text{NET}_i \tag{6}$$

$$\text{STDINCC}_i = \text{ACCUMNET}_i * \text{ANNUITY}_i \tag{7}$$

$$\text{WSTDINC}_j = (\text{PD} * \text{STDINCD}) + \text{STDINCC}) + \text{STDINCS}(1 - (\text{PD}_{j-1} + \text{PINVC}_{j-1}) \tag{8}$$

where DISNET is discounted net returns in period i, DISFAC is discount factor; ACCUMNET is accumulated discounted net returns over period i; WSTDINC is weighted standardized income for lactation j, PD is probability of death in lactation j; PINVC is probability of involuntary cull in STDINCC, the standardized income, in the event of an involuntary cull in lactation j; STDINCDS is standardized income in the event of a voluntary cull in lactation j; STDINCD is standardized income in the event of death in lactation j, and j is the lactation number ($j = 1, 2, \ldots, 14$).

Probabilities of death and involuntary cull

The probabilities of death and involuntary cull were derived from the studies by Stewart et al. (1977) and Sol et al. (1984). These were extended by linear extrapolation to allow for 14 lactations. An adjustment factor was computed by taking the average of three previous interlactation probability differences and adding it to the probability of the previous lactation. The initial probabilities of death were adjusted downwards to make them more realistic, based on consultation with experts in the industry. The probability of involuntary cull is defined as the probability of culling a cow due to reproduction failure, disease and other ailments while the probability of voluntary cull is defined as culling primarily due to low production. For the purposes of the model, however, one would be interested in the transition probabilities. The probabilities were thus adjusted by considering the probability of a cow living to a certain lactation and the probability that it dies or is culled in a particular lactation (Tables 5 and 6). The following formula was used in computing the probability of a cow being in a particular lactation:

$$\mathrm{PR}_i = 1 - \left(\sum_{j=1} \mathrm{IC}_j + \sum_{j=1} D_j \right) \tag{9}$$

where PR_i is the probability of a cow being in lactation i, IC_j is the

TABLE 5

Calculated probabilities of a cow being in a particular lactation, involuntary culling and death over 14 lactations

Probabilities	Cow in a lactation	Involuntary culling	Death
Lactation			
1	1.0	0.018	0.059
2	0.923	0.082	0.081
3	0.772	0.115	0.102
4	0.604	0.130	0.124
5	0.451	0.196	0.145
6	0.298	0.210	0.167
7	0.185	0.301	0.198
8	0.088	0.335	0.211
9	0.040	0.392	0.232
10	0.015	0.356	0.251
11	0.006	0.445	0.275
12	0.001	0.450	0.296
13	0.0003	0.493	0.318
14	0.00005	0.519	0.339

TABLE 6

Calculated transitional probabilities of involuntary cull and death

Probabilities	Involuntary culling	Death
Lactation		
1	0.081	0.059
2	0.076	0.075
3	0.089	0.079
4	0.078	1.075
5	0.088	0.065
6	0.063	0.050
7	0.060	6.037
8	0.029	0.019
9	0.016	0.009
10	0.005	0.004
11	0.003	0.002
12	0.0004	0.0003
13	0.00001	0.00001
14	0.0	0.0

cross-sectional probability of involuntary cull in lactation j, and D_j is cross-sectional probability of death in lactation j. With the PR_i's computed then the transitional probabilities of death, involuntary cull and voluntary cull were computed as follows:

$$\text{PD}_i = \text{PR}_i * D_i \quad (10)$$

$$\text{PIC}_i = \text{PR}_i * \text{IC}_i \quad (11)$$

$$\text{PVC}_i = \text{PR}_i - (\text{PD}_i + \text{PIC}_i) \quad (12)$$

where PD_i is probability of a cow dying in lactation i, PIC_i is probability of involuntary cull in lactation i, and PVC_i is probability of voluntary cull in lactation i.

Optimal herdlife for a potential replacement heifer

Net returns are simulated up to a 14-year period (the assumed maximum lifespan), discounted, standardized (converted into the equivalent annual amounts of income such that one is indifferent between receiving the accummulated net income and some constant flow of income over a given time period (see Harsh et al., 1981, p. 258, and equation 7) and weighted by the probability of death, voluntary cull and involuntary cull over each lactation (weighted standardised returns, see equation 8). The lactation number with the highest weighted standardized returns represents the optimal lactations the replacement heifer should be kept in the herd and its value will represent the minimal accepted individual lactation returns for keeping the sick cow prior to replacement. The sick cow may be kept on the farm if at some point, her weighted standardized returns over the remaining lactations are above the highest of the weighted standardized returns for the replacement heifer.

Cystic ovaries

The characteristics of the disease have been defined elsewhere (Ngategize et al. 1987). Cystic ovaries are responsible for extended calving intervals and are closely associated with increased milk production. Indices were derived based on work by Bartlett et al. (1986) to adjust milk production with the occurrence of cystic ovaries (Table 7). Specifically three treatment strategies are contrasted. They are (1) two successive treatments with Gonadotropin Realising Hormone (GNRH); (2) two successive treatments with Human Chrionic Gonadotropin (HCG); and (3) successively administering no treatment (NT) and thus relying on spontaneous recovery.

Part of the data for this analysis were obtained from the Food Animal Health Resource Management System (FAHRMX) at Michigan State University and the rest were obtained from the literature. The mean cost per cow for a veterinary reproductive examination from a survey in Michigan was $3.00. Treatment costs were $8.00 for GNRH and $13.00 for HCG per treatment per animal. The value of cows purchased for dairy purposes was $1500 and $500 for cows sold for slaughter (Bartlett et al., 1986). These values were used to represent the value of the animal on complete recovery, and the carcass value of the cow that would failure to recover, respectively.

The probabilities for cow response to treatment and days to resumption of estrus were from Whitemore et al. (1979) and from Kesler and Gaverich (1982). Days to estrus were estimated as 30 days. There were no data available for response to successive treatments which HCG or for alternating treatments between HCG and GNRH. In those circumstances, the same

TABLE 7

Production indices for milk production changes for cystic cows over normal cows on a monthly basis

Month	1	2	3	4	5	6	7
Milk production factor	1.01	1.02	1.03	1.04	1.05	1.06	1.07
Month	8	9	10	11	12	13	14
Milk production factor	1.08	1.09	1.01	1.02	1.01	1.01	1.01

probability of response as on initial treatment was used. This, however, ignores the fact that response rates change with repeated treatments as observed by Whitmore et al. (1979). The analysis allowed for an animal to be treated a second time if there was no recovery on first treatment. This was based on the knowledge that at least 90% of the animals treated for follicular cysts recover by the second treatment (Whitemore, 1984). Therefore, if a cow fails to recover after two successive treatments, it is considered to be sterile and sold for meat in this analysis. The decision on which treatment to use was made based on the expected monetary value (EMV) within a decision tree framework (Ngategize et al. 1987).

Cost of days open

The estimation approach for costs of days open was to compare the difference in expected monthly returns over a situation where the cow had an extension of the calving interval (13 months) by 1 month with the situation where calving interval was less than 1 month (12 months). The difference was then divided by 30 days (a month) to estimate the costs of days open.

RESULTS AND DISCUSSION

Table 8 presents the simulated weighted standardised returns for the potential replacement heifer and the cystic cow treated with HCG over 14

TABLE 8

Weighted standardized returns for the replacement heifer and the cystic cow treated with HCG

Lactation	Heifer	Cow
1	−44.33	–
2	4.03	–
3	14.99	30.23
4	16.22	28.53
5	14.11	22.47
6	10.14	15.15
7	6.49	9.27
8	3.30	4.56
9	1.54	2.05
10	0.59	0.76
11	0.21	0.26
12	0.04	0.05
13	0.01	0.01
14	0.003	0.003

lactations. The results showed that for the potential replacement heifer, returns would be maximized if she is kept over four lactations. Over that period weighted standardized returns would be US$16.22 per month. For the cystic cow, returns would be maximized in the third lactation. However, based on the returns from the potential replacement heifer, the cow may not be culled until the end of the fifth lactation during which period it would be generating US$22.55, 22.47, 22.68 per month for GNRH, HCG, and NT, respectively, if recovery occurs on first treatment. If the cow recovered only under the second treatment, then the simulated returns would be $21.79, 21.63 and 22.04 for GNRH, HCG and no treatment, respectively. If a cow is treated with GNRH and recovers on the first treatment, then it may be kept on for at least two more lactations based on the fact that the weighted returns are higher on a lactation basis than for a replacement heifer over her potential optimal lifespan. At the end of the fifth lactation, the monthly flows are computed to be $22.55 per month over 33 months. This gives a present value $631.17 ($22.55 * 27.9897, the present value of a dollar received monthly at a 12% discount over 33 months). To have an equal comparison period with a recovery on second treatment, the additional (34th) month is represented by returns from a replacement heifer contributing a present value of $11.56($16.22 * 0.713). The total present value for the node 642.73(631.17 + 11.56) is multiplied by the probability of recovery on first treatment (0.76) under node 1 to arrive at the expected present value of $488.48.

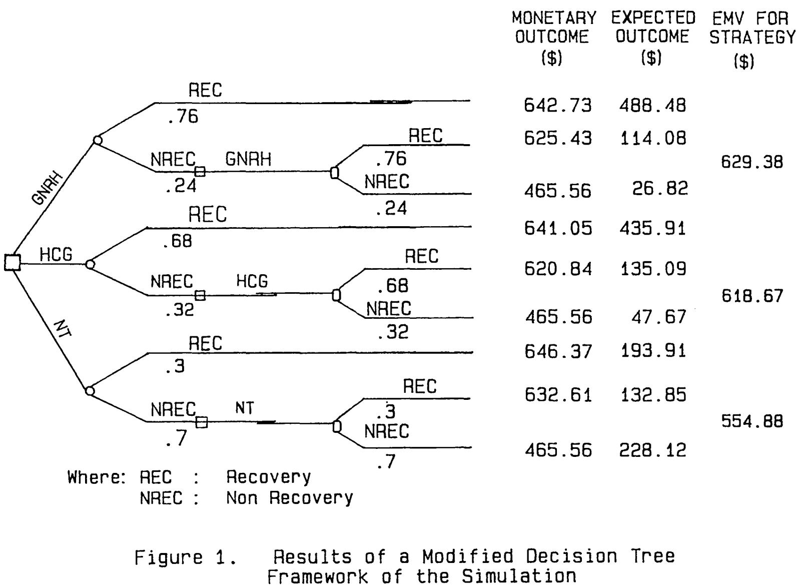

Fig. 1. Results of a modified decision tree: Framework of the simulation (where REC represents recovery, and NREC non-recovery).

The second node represents a situation where the cystic cow recovers only after the second treatment. The monthly returns are \$21.79 per month. This value, multiplied by the annuity factor (28.7027) gives a present value of \$625.43. Given the probability of occurrence for this state of nature, the expected present value comes to be \$114.08 (625.43 × 0.24 × 0.76).

The third node represents a situation where the cow does not recover even on second treatment and is replaced by the potential replacement heifer. The returns are estimated by those of the potential replacement, \$16.22. Over the 34-month period, this gives a present value of \$465.56. This value, weighted by the probability of occurence for the state of nature gives an expected value of \$26.82 (465.56 × GNRH is \$629.38 (488.48 + 114.08 + 26.82)). Similar computations are made for the treatment of HCG and NT. The results (Fig. 1) show that the management strategy of using GNRH results in the highest expected value, \$629.38 compared to HCG (\$618.67) and NT (\$554.88).

The cost per day open beyond the optimal was computed based on the no treatment alternative of the decision tree. The difference between recovery on first treatment and recovery on second treatment is \$13.76 (646.37 − 632.61). Since there is a difference of 30 days between the two this gives a daily loss of \$0.45 (13.76/30) as the cost per day open beyond the optimal.

SENSITIVITY ANALYSIS

Sensitivity analysis was conducted on the level of milk production, lactation number, treatment cost and animal value and salvage value. Table 9 represents weighted standardized returns of potential replacement heifers at different levels of milk production in first lactation. In general, high production in first lactation results in higher standardized returns over the first several lactations. As the cow lives beyond lactation 8 or so, the expected standardized returns will diminish to such an extent that the distinction between initially high producers and low producers become less pronounced. All the heifers would reach their highest production level, based on weighted standardized returns, in the fourth or fifth lactation. However, the major impact of higher producers would be to lower the timing when a cystic cow would be replaced. With low producing heifers, the cystic cow in the base run would be kept for one lactation or longer.

Table 10 presents weighted standardized returns for a cystic cow at four levels of milk production in first lactation. High first lactation production levels are reflected in higher returns in the first several lactations and later the differences diminish as the cow gets older. Higher returns also mean that one would prefer to treat and keep the cystic cow longer based on monetary expectations than with low level producers. The lactation number has a

TABLE 9

Weighted standardized returns for potential replacements at different levels of milk production in the first lactations

Production	12000	14000	16000	18000
Lactation				
1	−61.69	−52.04	−44.33	−38.64
2	−10.05	−1.94	4.03	8.62
3	3.96	10.38	14.98	18.71
4	7.95	12.76	16.22	19.16
5	8.11	11.59	14.11	16.34
6	6.26	8.51	10.14	11.62
7	4.17	5.51	6.49	7.39
8	2.18	2.83	3.30	3.74
9	1.03	1.32	1.54	1.73
10	0.40	0.51	0.59	0.66
11	0.14	0.18	0.21	0.24
12	0.03	0.04	0.04	0.05
13	0.01	0.01	0.01	0.01
14	0.001	0.002	8.003	0.003

definite impact on the model results. Table 11 shows the simulated results of a cystic cow at different initial lactations. If a cow is in lactation 5 or above, replacing the cow would be a most economical decision.

The costs of treatment including examination costs were some of the lowest items influencing the flow of returns over an animal lifespan. This is

TABLE 10

Weighted standardized returns for a cystic cow at different levels of milk production

Production (1st lactation)	14000	16000	18000	20000
Lactation				
3	30.23	43.94	45.89	52.90
4	28.53	36.65	37.75	42.88
5	22.47	27.92	28.63	31.88
6	15.15	18.54	18.87	21.05
7	9.27	11.26	11.51	12.75
8	4.56	5.52	5.64	6.24
9	2.06	2.49	2.55	2.82
10	0.76	0.94	0.96	1.06
11	0.26	0.32	0.34	0.37
12	0.05	0.06	0.07	0.07
13	0.01	0.02	0.02	0.02
14	0.003	0.004	0.004	0.005

TABLE 11

Weighted standardized returns for a cystic cow at different beginning lactations

Beginning lactation	2	3	4	5	6
2	41.98	–	–	–	–
3	36.83	30.23	–	–	–
4	29.49	28.53	29.15	–	–
5	22.34	22.47	23.91	21.01	–
6	14.81	15.15	16.07	15.43	13.27
7	9.00	9.27	9.79	9.51	9.09
8	4.41	4.56	4.81	4.71	4.59
9	2.00	2.06	2.17	2.13	2.08
10	0.76	0.76	0.81	0.79	0.78
11	0.26	0.26	0.28	0.27	0.27
12	0.05	0.05	0.05	0.05	0.05
13	0.01	0.01	0.02	0.01	0.01
14	0.004	0.003	0.004	0.004	0.003

expected given the cost of drugs that were the focus of the model. Table 12 shows the weighted standardized returns over 14 lactations with cost of drugs ranging from \$0.0 to \$26.0. The \$26.0 represents a doubling of the \$13.00 cost of HCG and \$6.5 represents half the price. Similary \$4.0 represents half the price of GNRH and \$16.00 twice the GNRH price. Clearly treatment cost has insignificant impact and hence where the effectiveness of each treatment is not well known, selection between the treatments

TABLE 12

Weighted standardized returns for a cystic cow with different treatment cost

Treatment cost (\$)	0.0	4.0	6.50	8.00	13.00	16.00	26.00
Lactation							
3	31.39	31.03	30.81	3.68	30.23	29.96	29.07
4	28.94	28.82	28.74	28.69	28.53	28.43	28.12
5	22.68	22.62	22.58	22.55	22.47	22.43	22.27
6	15.25	15.22	15.20	15.19	15.15	15.12	15.04
7	9.32	9.31	9.30	9.29	9.27	9.26	9.22
8	4.59	4.58	4.58	4.57	4.56	4.56	4.54
9	2.06	2.05	2.05	2.05	2.06	2.04	2.04
10	0.76	0.76	0.76	0.76	0.76	0.76	0.76
11	0.26	C.26	0.26	0.26	0.26	0.26	0.26
13	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	0.003	0.003	0.003	0.003	0.003	0.003	0.003

TABLE 13

Weighted standardized returns at different heifer and cow values

	Cow/Beef value = 500			Heifer value = 1500		
	Heifer value			Cow value		
	1750	1500	1000	250	500	750
Lactation						
1	−70.73	−44.33	8.46	–	–	–
2	−7.70	4.03	27.49	–	–	–
3	8.27	14.98	28.43	52.75	30.23	7.71
4	12.11	16.22	24.45	36.54	28.53	20.52
5	11.54	14.11	19.27	26.51	22.47	18.44
6	8.66	10.14	13.10	17.21	15.15	13.09
7	5.68	6.49	8.11	10.31	9.27	8.23
8	2.94	3.30	4.03	5.01	4.56	4.12
9	1.38	1.54	1.84	2.23	2.05	1.87
10	0.54	0.59	0.70	0.82	0.76	0.70
11	0.19	0.21	0.25	0.28	0.26	0.24
12	0.04	0.04	0.05	0.06	0.05	0.05
13	0.01	0.01	0.01	0.02	0.01	0.01
14	0.003	0.003	0.003	0.004	0.003	0.003

may remain to be based on other factors rather than cost especially in Michigan.

The impact of changing market values for both the potential replacement heifer and the cow are represented in Table 13. As the results show the assumption on the value of the potential replacement heifer has an impact on returns and hence optimal replacement as determined by the model.

The limitations of the model are related to weak or insufficient data used in the analysis. With good economic analysis, projects like FAHRMX will be able to provide farmers with sufficient information for decision making. The growing use of microcomputers at farm level in developing countries and the development of computer models as decision tools will lead to better farm management decisions.

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REFERENCES

Bartlett, P.C., Kirk, J.H., Mather, E.C., Gibson, C. and Kaneene, J.B., 1985. FAHRMX: a computerized dairy herd health management network. Compend. Contin. Educ., 7: 124–133.

Bartlett, P.C., Ngategize, P.K., Kaneene, J.B., Kirk, J.H., Anderson, S.M. and Mather, E.C., 1986. Cystic follicular disease in Michigan Holstein–Friesian cattle: incidence descriptive epidemiology and economic impact. Prev. Vet. Med., 4: 15–33.

Dijkhuizen, A.A., Renkema, J.A. and Stelwagen, J., 1985. Economic aspects of reproductive failure in dairy cattle. II. The decision to replace animals. Prev. Vet. Med., 3: 265–276.

Faris, E. and Reed, A.D., 1962. When to replace cling peach trees. Circular 512, Division of Agricultural Sciences, University of California, CA.

Harsh, S.B., Connor, L.J. and Schwab, G.D., 1981. Managing the Farm Business. Prentice-Hall, Englewood Cliffs, NJ, 384 pp.

Hlubik, J., 1979. An economic evaluation and replacement model for the lactating cow including biological components. Msc. Thesis, Michigan State University, East Lansing, MI.

Jenkins, K.B. and Halter, A.N., 1963. A multi-stage stochastic replacement decision model: application to replacement of dairy cows. Tech. Bull. 67, Oregon State University, pp. 3–31.

Kesler, D.J. and Gaverich, H.A., 1982. Ovarian cysts in dairy cattle: a review. J. Anim. Sci., 55: 1147–1159.

Kuipers, A., 1980. Development and comparison of selection criteria for cows and bulls with a dairy herd simulation model. Ph.D. dissertation, University of Wisconsin, Madison, WI, 408 pp.

Michigan State University, 1984. Today's electronic planning (Teleplan 31), version 5. East Lansing, MI.

Ngategize, P.K., Kaneene J.B., Harsh, S.B., Bartlett P.C. and Mather, E.C., 1987. A financial analysis of alternative management strategies of cystic follicles. Prev. Vet. Med., 4: 463–470.

Renkema, J.A. and Stelwagen, J., 1979. Economic evaluation of replacement rates in dairy herds. I. Reduction of replacement rates through improved health. Livestock Prod. Sci., 6: 15–27.

Shanks, R.D., Freeman, A.E. and Dickinson, F.M., 1981. Postpartum distribution of costs and disorders of health. J. Dairy Sci., 64: 683–688.

Shanks, R.D., Berger, P.J., Freeman, A.E., Kelley, D.H. and Dickinson, F.M., 1982. Projecting health cost from research herds. J. Dairy Sci., 65: 644–652.

Smith, B.J., 1971. The dairy cow replacement problem: an application of dynamic programming. Univ. Fla. Agric. Exp. Stn. Tech. Bull. 745.

Sol, J., Stelwagen, J. and Dijkhuizen, A.A., 1984. A 3 year herd health management program on 30 Dutch dairy farms. II: Culling strategy and losses caused by forced replacment of dairy cows. Vet. Q., 6149–6157.

Stallcup, O.T., Kellogg, W.D. and Rakes, J.M., 1984. Dietary protein requirements for high producing dairy cows. In: F.H. Baker and M.E. Miler (Editors), Dairy Science Handbook, 16. Westview, Boulder, CT.

Stewart, H.M., Burnside, E.B., Wilton, J.W. and Pfeiffer, W.C., 1977. A dynamic programming approach to culling decisions in commercial dairy herds. J. Dairy Sci., 60: 602–617.

Whitemore, H.L., 1984. Treatment of resistant cases of cystic ovaries. In: American Association of Bovine Practioners Newsletter, July 1984.

Whitemore, H.L., Hurtgen, J.P., Mather, E.C. and Sequin, B.E., 1979. Clinical response of dairy cattle with ovarian cysts in single or repeated treatments of gonadotropin releasing hormone. JAVM, 174: 1113–1115.