

INTEGRATED EXPERT SYSTEM FOR CULLING MANAGEMENT OF BEEF COWS

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Story in Brief

An expert system shell, written in the C computer language, served as the inference engine for a knowledge base developed to recommend whether to keep or cull commercial beef cows. Cows are classified into three categories, cull, keep or rank. The net present value of those classified as rank is estimated based on expected future performance and salvage value by calling a cow herd simulation model, also written in C, from within the expert system. The cow with the lowest net present value is culled first when cows in addition to those classified cull must be culled. The system can be either integrated with a computer database or interactive, querying a cow data file or the user for information about each cow, making a decision, and responding with its recommendation. Evaluation revealed rankings were most sensitive to pregnancy status, age and future market conditions.

(Key Words: Expert Systems, Net Present Value, Beef Cows.)

Introduction

Commercial beef cow herds are subjected to a wide variety of culling strategies. Cows are most often removed from the herd because of illness and failure to become pregnant. Some herd owners also remove cows from the herd based upon the low dollar return of the calves they produce. For herd size to remain constant, those cows culled and/or lost from the herd must be replaced. The growing or buying of replacement heifers is costly. First calf heifers are difficult to manage through their first calving and rebreeding season. Therefore, commercial beef producers become reluctant to cull mature cows until they are convinced that those cows can no longer provide an economical return. Each year at weaning time in herds with a single, short calving season pregnancy checking and cow re-evaluation occurs. Culling or keeping of healthy, mature but nonpregnant cows, at the

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productive peak of their lives, is a rather difficult and often very subjective decision that ranchers face. Some producers choose to automatically cull any cow that has not become pregnant during the previous breeding season. Others will cull only those that are non-pregnant and advanced in age or have a physical weakness. Yet other ranchers will place more emphasis on the previous production performance of the cow in question and tend to keep nonpregnant cows that have been previously very productive. Most of these culling strategies are adhered to with only occasional regard for current market conditions or future market projections. A previously reported expert system attempted to make culling decisions based on previous calving performance and current cow status (Oltjen et al., 1987). However, many cows could not be classified clearly. For these questionable cows, culling strategy would be improved by the incorporation of economic evaluations of the future potential return. Combining biological potential (cow production capabilities) with sophisticated economic analyses is a challenge at best and requires the utilization of every available tool. Therefore, the objective of this research was to develop a knowledge-based system integrated with an economic simulation model to assist commercial cow-calf producers make culling decisions at normal pregnancy checking time.

Materials and Methods

In order to develop an expert system to recommend whether to keep or cull commercial beef cows, a reproduction specialist, G. E. Selk, was interviewed by a knowledge engineer, L. G. Burditt. The expert's heuristic knowledge was inserted in an expert system shell programmed in C and developed by Plant (1988). The knowledge base was arranged as rules reflecting the expert's knowledge (Oltjen et al., 1987), and classified each cow to be culled, kept or ranked on future production value.

For cows that are to be ranked, a call to a subroutine written in C is made, and net present value (NPV) is estimated. Basically, NPV is the discounted income from calf sales and cow salvage minus the discounted expenses to maintain the cow. It is based on the modification by Trapp (1986) of Perin's (1972) discrete form:

$$NPV = \left\{ \sum_{t=a}^{c-1} P(t) \cdot (\text{Calf Return} + \text{Cull Cow Return} - \text{Maintenance Cost}) \right\} \\ + \text{Salvage Value}$$

where a is initial cow age (at time of pregnancy check, calendar year y), c is maximum cow age (the time at which cows are culled due to old age, rule 1)

and P is expected cow population. Calf and cow prices and maintenance costs are adjusted for future years; other parameter values are adjusted for cow age. All costs and returns are discounted. Calf return is

$$(1+r)^{-(t-a+1)} \cdot WR(t) \cdot \text{Calf Price}(y+t-a+1) \cdot \text{Calf Weight}(t)$$

where r is the discount or interest rate and WR(t) is subsequent weaning rate for cows pregnancy checked at age t. The first year WR(a) is zero for nonpregnant cows, but for pregnant cows it is WRP(a), the weaning rate of structurally correct pregnant cows at pregnancy check time. Hence:

$$WR(t) = (1-SC(t)) \cdot PR(t) \cdot WRP(t)$$

where SC(t) is structural culling rate and PR(t) is pregnancy rate of cows pregnancy checked at age t, except at age a, when PR(t) is one if the cow checks pregnant, zero if nonpregnant, or .5 if unknown. Nonpregnant cows at subsequent pregnancy checks are assumed to be culled. Also, SC(a) is zero, since the expert system would have already culled the cow if she was unsound. Cull cow return is

$$(1+r)^{-(t-a)} \cdot (1-PR(t) \cdot [1-SC(t)]) \cdot \text{Cow Price}(y+t-a, t) \cdot \text{Cow Weight}(t)$$

except for the first year, t=a, when the cow must be kept for any future income to accrue and cull cow returns are zero. Annual maintenance costs are

$$(1+r)^{-(t-a+.5)} \cdot PR(t) \cdot (1-SC(t)) \cdot (1-.5 \cdot DR(t)) \cdot MC(y+t-a, t)$$

where DR(t) is annual death rate post pregnancy check of cows age t, and MC(y+t-a, t) is annual maintenance costs of cows pregnancy checked in year y+t-a at age t. The term PR(t) in the maintenance calculation is set to 1 when t=a. Salvage Value is

$$(1+r)^{-(c-a)} \cdot P(c) \cdot \text{Cow Price}(y+c-a, c) \cdot \text{Cow Weight}(c)$$

Since NPV is calculated for individual cows, expected cow population, P, declines with time:

$$P(a) = 1.0$$

$$P(a+1) = P(a) \cdot PR(a) \cdot (1-DR(a)) \cdot (1-SC(a))$$

Again PR(a) is set to 1, more generally:

$$P(t) = \prod_{i=a}^{t-1} PR(i) \cdot (1-DR(i)) \cdot (1-SC(i))$$

Parameter values are either input by the user, or a default set similar to that of Trapp (1986) is used.

The program is interactive, querying the user to input information about each cow in question. The expert system uses backward chaining to arrive at a conclusion. When enough information is available for a decision to be made the program reports its recommendation.

Results and Discussion

A number of relationships are required in the NPV simulation. For example, Figure 1 shows the effect of cow age on pregnancy rate (PR), weaning rate (WRP), death rate (DR), structural culling rate (SC), and cow

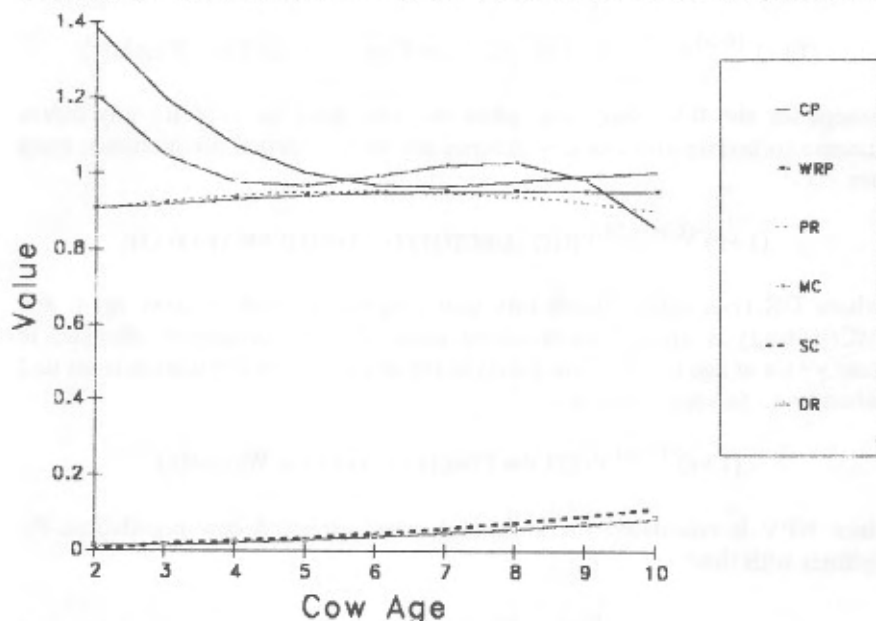


Figure 1. The effect of cow age on cow price adjustment (CP), weaning rate (WRP), pregnancy rate (PR), maintenance cost adjustment (MC), structural culling rate (SC) death rate (DR).

price and maintenance cost (MC) adjustments. These relationships can be changed to fit existing conditions to improve the reliability of projected NPV. However, the rankings of cows is relatively insensitive to changes in these in typical cow herds.

Examples of interactive sessions with the expert system are shown in Tables 1, 2 and 3. The five year-old cow in the first example (Table 1) has the necessary traits to be kept in the commercial cow herd. In contrast, the seven year-old in Table 2, which is not pregnant, is suggested to be culled. The expert system recommended culling for this cow because of her poor condition (rule 5). However, the cow in Table 3, which is not pregnant, would be culled only after all other cows with NPV less than \$650 had been culled (Ben-Ari et al., 1983). Had the cow in Table 2 been in a better body condition score of 5, the expert system would not have culled her, but rather she would have been ranked with a net present value of \$383. Her estimated current salvage value is \$519, suggesting her sale. However the younger cow in Table 3 was ranked with a net present value of \$650, considerably greater than her estimated salvage value of \$552. Consequently she is a better economic risk to remain in the herd. It can be seen that the order in which

Table 1. Example interactive session using the culling expert system.

Expert system	User
This knowledge base is designed to assist you in deciding whether to cull a cow from the herd	
How old is this cow?	5
What is the condition score of this cow?	5
How many functional quarters does this cow's udder have?	4
What is the average calving difficulty of this cow using the 1-5 scale?	1.4
Has this cow ever had a cesarean section birth?	NO
Does this cow have serious structural problems?	NO
How much damage does this cow have to her eyes? NONE SLIGHT EXTREME	SLIGHT
Is this cow pregnant?	YES
Are performance records available for this cow?	YES
Enter the average weaning weight of this cows calves.	515
What is the average calf weaning weight for your herd?	500
Has the cow missed any previous calves?	NO
This cow should be kept in the herd.	
This cow should not be culled.	

Table 2. Example interactive session using the culling expert system.

Expert System	User
This knowledge base is designed to assist you in deciding whether to cull a cow from the herd	
How old is this cow?	7
What is the condition score of this cow?	2
How many functional quarters does this cow's udder have?	4
What is the average calving difficulty of this cow using the 1-5 scale?	1.3
Has this cow ever had a cesarean section birth?	NO
Does this cow have serious structural problems?	NO
Is this cow pregnant?	NO
This cow's poor body condition is most likely why she is open. The cost of bringing her to a higher condition so that she will cycle would be prohibitively high so she should be culled.	

Table 3. Example interactive session using the culling expert system.

Expert System	User
This knowledge base is designed to assist you in deciding whether to cull a cow from the herd	
How old is this cow?	4
What is the condition score of this cow?	6
How many functional quarters does this cow's udder have?	4
What is the average calving difficulty of this cow using the 1-5 scale?	1.1
Has this cow ever had a cesarean section birth?	NO
Does this cow have serious structural problems?	NO
How much damage does this cow have to her eyes? NONE SLIGHT EXTREME	NONE
Is this cow pregnant?	NO
Has the cow missed any previous calves?	NO
Enter the average weaning weight of this cows calves.	520
What is the average calf weaning weight for your herd?	515
This cow is in good condition and is still open this year. She should be suspect and a candidate for culling next year if she is kept in the herd. Her estimated net present value is \$650.	

the consultation occurs is influenced by the backward-chaining reasoning process which the expert system employs. Thus, in the second example (Table 2), a recommendation is made as soon as enough information is collected to apply rule 5, and this session is shorter than the other two. This also shows the advantage of using an expert system to determine cow classification, if possible, before calling a computationally intense model to estimate NPV.

Rankings are relatively sensitive to expected changes in market conditions. For example, using current Oklahoma production parameters and May 1988 market conditions, a pregnant eight year old cow and a non-pregnant two year old cow weaning her first calf have similar NPV under the assumption of steady markets, \$682 and \$713, respectively. However, with declining markets (5% decline/year), the older, pregnant cow becomes relatively more valuable (\$605 versus \$419), and with rising markets (5% increase/year), the younger cow has greater relative NPV (\$1074 versus \$760). Thus, culling the open, young animal is the optimal strategy in the first case, while culling the older animal might be desirable with rising markets in the second case (particularly if she is a poor producer in any category). On the other hand, rank order of cow NPV was insensitive to general management changes which affected all ages of cows. For maximum profit, cows would normally be culled when estimated NPV was less than current salvage value. However, optimal culling policy must also include judgements regarding future herd size and availability, cost and value of replacement animals. Further, NPV sensitivity to the maximum cow age in rule 1 may change some rankings based on the cattle cycle (Trapp, 1986).

To make this a more useful tool, information for each cow may be stored in a database file, and the program modified to interact with the file to output a list of cows to keep and to cull. Also, additional rules reflecting optimal strategies which depend on economic considerations, such as replacement heifer cost, are needed. The rules included can and should be modified to better reflect environmental and economic situations of the potential user.

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