Precision Dairy Farming: What is it and when does it pay?

Jeffrey Bewley, PhD, PAS
University of Kentucky

What is Precision Dairy Farming?

Precision dairy farming involves using technologies for managing individual animals to improve management strategies and farm performance. With precision dairy farming, the trend toward group management may be reversed with focus returning to individual cows through technology use. Many precision dairy farming technologies are already being used by dairy producers including daily milk yield recording, milk component monitoring (fat, protein, and somatic cell count), pedometers, automatic temperature recording devices, milk conductivity indicators, automatic estrus detection monitors, and daily body weight measurements. Other theoretical precision dairy farming technologies have been proposed to measure ruminal pH, heart rate, feeding behavior, lying behavior, odor, glucose, vocalizations, progesterone (for estrus or pregnancy detection), individual milk components, color (as an indicator of cleanliness), and respiration rates. The main objectives of precision dairy farming are maximizing individual animal potential, detecting diseases earlier, and minimizing the use of medication through preventive health measures.

Potential Benefits of Precision Dairy Farming

Benefits of precision dairy farming technologies include increased efficiency, reduced costs, improved quality, and minimized environmental impacts. These technologies are likely to have the greatest impact in the areas of health, reproduction, and quality control. As dairy operations continue to increase in size, precision dairy farming technologies become more feasible because of increased reliance on unskilled labor and the ability to take advantage of economies of size. A precision dairy farming technology allows dairy producers to make more timely and informed decisions, resulting in better productivity and profitability. Real time data can be used for monitoring animals and creating exception reports to identify animals or situations needing attention.

Historically, dairy producers have used experience and judgment to identify animals needing attention. While this skill is invaluable and can never be fully replaced with automated technologies, the powers of human perception are limited. Often, by the time an animal exhibits clinical signs of stress or illness, it is too late for effective treatment. These clinical symptoms are typically preceded by physiological responses not seen by the human eye (for example, changes in temperature or heart rate). Thus, by identifying changes in physiological parameters, a dairy manager may be able to intervene sooner. Technologies for physiological monitoring of dairy cows have great potential to supplement the observations of skilled herdspersons.

Dairy Decision Making

Traditionally, dairy producers have made investment decisions using standard recommendations, thumb rules, or advice from professional consultants. Adoption of more sophisticated decision-making tools has been low in the dairy industry to this point. Yet, the dairy industry remains a perfect application of decision science for three reasons:

(1) Considerable price, weather, and biological variation and uncertainty exist.
(2) A variety of technologies designed to collect data for decision making are available.
(3) "Milk is milk," which limits potential competitive advantages for dairy producers.

One potential explanation for why producers have not endorsed some of the more simple decision making tools is that they do not always consider inherent business risk and uncertainty. In reality, every dairy producer recognizes that the profitability of any investment or decision will vary considerably depending on what combination of prices eventually occur. Formal investment analysis, through modeling, removes this "one size fits all" mentality to decision making.

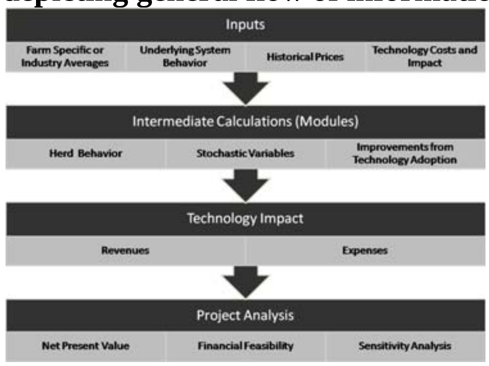
Simulation of Dairy Farms

Simulations are mathematical models designed to represent a system, such as a dairy farm, for use in decision-making. Simulation models are useful and cost-effective when dealing with complex scenarios involving a large number of variables with large groups of animals over a long period of time under a large range of conditions. The primary advantages of using mathematical computer simulation models in evaluating dairy production issues are the ability to control more variables within the model than with a field trial and the reduced costs associated with this kind of effort. Simulation captures the complexity of a dairy system because it can evaluate multiple biological and economic factors affecting performance, including management, feeding, breeding, culling, and disease.

Purdue/Kentucky Research Model

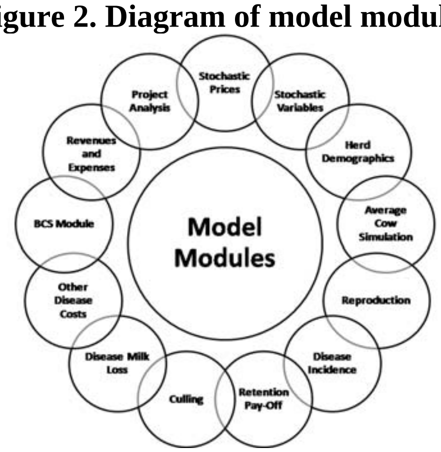
We have developed a simulation model of a dairy farm to evaluate investments in precision dairy farming technologies by examining a series of random processes over a ten-year period. The model was designed to characterize the biological and economical complexities of a dairy system using partial budgeting to examine the costs and benefits of investing in a new technology. Although the model currently exists only in a research form, a secondary aim was to develop the model for future use as a flexible, farm-specific decision making tool. The basic structure of the model is depicted in Figure 1. The underlying behavior of the dairy system was represented using current knowledge of herd and cow management. Historical prices for critical sources of revenues and expenses within the system were also incorporated into the model.

Figure 1. Diagram depicting general flow of information within the model



After inputs are entered into the model, a series of calculations are computed within 13 modules which track changes over a 10-year period (Figure 2). Each of these modules eventually results in a calculation that will influence the cost and revenue flows necessary for the investment analysis. Finally, the costs and revenues are utilized for the project analysis examining the net present value and financial feasibility of the project along with sensitivity analyses. Because economic conditions and the profitability of investments can vary considerably depending on the prices paid for inputs and the prices received for outputs, the randomness in key prices (milk, corn, soybeans, alfalfa, replacement heifers, and cull cows) is considered within the model. Although there is probably no direct way to account for the many decisions that ultimately impact the actual profitability of an investment in a precision dairy farming technology, this model includes a Best Management Practice Adherence Factor to represent the potential for observing maximum benefits from technology adoption.

Figure 2. Diagram of model modules



Investment Analysis

In investment analysis, the time value of money, reflecting that a dollar received today is more valuable than a dollar received tomorrow, must be considered because returns are observed over a period of years. A discount rate for the project is selected to reflect the change in the value of money in future periods. Any investment must provide sufficient returns to compete with alternative uses of capital funds. When the costs of collecting and processing data obtained from a precision dairy farming technology exceed the benefits, the system should not be purchased. Costs of investment include product costs, implementation costs, and changes resulting from product use (for example, increasing milk production will also increase dry matter intake which increases costs). Because the true costs of investing in technologies are commonly underestimated, considerable emphasis should be placed on identifying all investment costs.

Investment Analysis of Automated Body Condition Scoring

To show how it can be used practically, this model was used for an investment analysis of automatic body condition scores on dairy farms. Benefits of technology adoption were estimated through assessment of the impact of body condition scoring on the incidence of ketosis, milk fever, and metritis, conception rate, and management of body reserves (body condition score) during early lactation. For this research example, industry averages for production and financial parameters, selected to represent conditions for a large U.S. dairy farm in 2007 were used. Net present value was used to assess investment profitability. The general rule of thumb is that a decision with a net present value greater than 0 is a "go" decision and a worthwhile investment for the business.

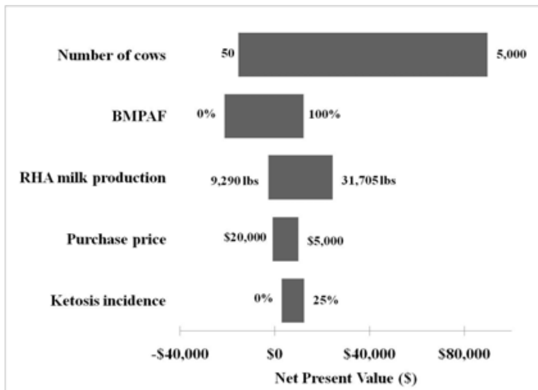
Profitability Analysis

In a simulation modeling an improvement in distribution of body condition scores, 86.6% of 1000 simulation iterations resulted in a positive net present value, while 13.4% of the time a negative net present value was observed. In other words, using the model assumptions, investing in an automated body condition scoring system was the right decision in 86.6% of simulated scenarios. The individual decision maker's level of risk tolerance would then determine whether they should make the investment. Although this shows how the model could be used for an individual decision maker, this profitability analysis should not be taken literally. In reality, an individual dairy producer would need to look at this decision using variables specific to their herd to assess technology profitability.

Sensitivity Analyses

Asking "what if" questions, through sensitivity analysis, is one of the most valuable parts of any simulation. In the analysis of automated body condition scoring, among random variables (things we are unsure about like milk price), improvements in reproductive performance had the largest influence on revenues followed by reductions in loss of body stores and then disease reduction. Sensitivity analysis provides further insight into the merits of an investment. In sensitivity analyses, tornado diagrams visually show the effect of either inputs (things that don't vary in the model, like herd size) or random variables (where uncertainty is modeled) on an output of interest. The tornado diagram (Figure 3) is arranged with the most sensitive input at the top progressing toward the least sensitive input at the bottom. For input variables in our example, herd size had the most influence on net present value (Figure 3). The next most important variable was the Best Management Practice Adherence Factor. This result was not surprising and reiterates that one of the most important determinants of project success is what the producer actually does to manage the information provided by the technology. The level of milk production was the next most sensitive input. As the level of milk production increased, the benefits of reducing disease incidence and calving intervals increased. As would be expected, the net present value increased with reduced investment costs or an increased base incidence of ketosis.

Figure 3. Tornado diagrams for inputs affecting Net Present Value (BMPAF is the Best Management Practice Adherence Factor, RHA milk production is rolling herd average milk production in lbs.)



Conclusions

Precision dairy farming technologies provide tremendous opportunities for improvements in individual animal management on dairy farms. Formal investment analyses can help producers in deciding which technologies should be purchased. Examining decisions with a simulation model accounts for more of the risk and uncertainty characteristic of the dairy system. Given this risk and uncertainty, a random investment analysis will represent that there is uncertainty in the profitability of some projects. Perhaps the most interesting take home message from the example presented here is that the factors that had the most influence on investment profitability were those related to what the dairy producer does with the technology after it has been purchased. Decision support tools, such as this one, that are designed to investigate dairy herd decisions, at a systems level, may help dairy producers make better decisions. This model could be used to help dairy producers make investment decisions for precision dairy farming technologies, or, with modifications, other on-farm investment decisions.