Title of the paper: Profitability of Dairy Cattle Through Precision Livestock Farming Management Practices

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Abstract:

The purpose of this study is to compare and contrast the profitability of different dairy management practices through precision livestock farming. Feed analysis and crop yields were simulated. Mathematical model was used for profit maximization. The results indicated that the proposed modification had a higher profit than the base plan.

Key words: Management practices, environmental pollution, nutrients, profitability.

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Profitability of Dairy Cattle Through Precision Livestock Farming Management Practices

Abstract

While livestock farmers struggle to keep their farms competitive and profitable, livestock farming in United States (US) is being challenged with preventing pollution of water associated with manure and fertilizer nutrients. With finite land resources and increasing population, sustainability of dairy farming in the US is dependent on both environmental and economic viability. The purpose of this study is to compare and contrast the profitability of different dairy management practices through precision livestock farming while reducing nitrogen (N) and phosphorus (P) balance. Data from the Coldstream dairy farm at Lexington, Kentucky, were used, and nutrients were analyzed using the Cornell Net Carbohydrate and Protein System 5.0 (CNCPS). Yields of alfalfa hay/silage and corn silage were simulated from Integrated Farm System Model (IFSM) using 25 years of weather data. Mathematical programming technique was used to arrive at maximization of profit strategy. The model showed satisfactory performance when optimal solutions were compared with the current practice as the base plan. The results indicated that the proposed modification, the new feeding and own farm crops/forages had a higher profit than the base plan. While the own farm feeds were increased, this alternative proposed plan minimized the purchased feeds and thus reduced costs.

Key words: Management practices, environmental pollution, nutrients, profitability.

Introduction

Dairy farming in the US is facing, among others, economic and environmental challenges. While milk prices have remained stable or declined for many years, the costs of most production inputs have continued to increase (Rotz et al., 1999). One way to improve profits is to increase the efficiency of production systems, for example, by increasing the number of animals per unit of crop land. This, however, has a negative effect on the environmental impact to the farm and society if overall management is not carried out well. High concentration of animals is one of the causes of non-point source contamination due to N and P.

Due to its impact on water quality, phosphorus has been identified as a major pollutant of concern in the US. Nitrogen, on the other hand, can be a threat to air and water quality on a dairy farm when more manure nutrients are applied per acre than can be recycled through crops, including forage production. Large amounts of N and P are normally imported to the farm as feed supplements and fertilizers. These nutrients, if directly discharged into surface water in runoff or deposited in water from aerial emissions, can cause significant water pollution. Manure is an excellent fertilizer for grain and forage production and if applied at rates equivalent to crop needs, can minimize environmental impact. If manure is applied at higher rates, however, N can leach into ground water and P can build up in the soil and contaminate the surface water, harming the environment.

To increase milk yield, some dairy farms depend heavily on the use of commercial fertilizer and the import of supplemental feeds. While their use may have increased crop yields and milk production, and ultimately improved profitability of the dairy industry, there is a greater risk of buildup of nutrients in the soil and the loss of excess P and N to ground and surface water due to heavy imports of nutrients. Therefore, more efficient use of homegrown feeds and good crop planning can potentially reduce the environmental damage due to P and N. Dairy farms generally require large amounts of high quality and digestible forage to provide the effective nutrients such as fiber, energy, and protein for production, growth, and maintenance. As forage quality increases and greater quantities are fed, total feed cost typically declines and profitability improves. Efficient production of forage strengthens the economic position of a farm and limits the potential negative impact on the environment.

For long term profitability, consideration of the impact of various crop rotations, production costs, combination of feeds produced, and animal performance in the overall production systems is crucial. Management changes in crop production and feeding may help reduce the accumulation of excess P and N, while maintaining or improving farm profitability. Therefore, cattle feeding and crop programs may help dairy farmers manage their farms in a cost effective and environmentally acceptable manner that will comply with farming regulations.

Background

Over the last two decades, livestock industry has experienced intensification and expansion of dairy farms that have increased surpluses of P and N due to heavy inputs in feed and fertilizer (Haygarth et al., 1998. Water quality in the US is threatened by contamination with nutrients, primarily P and N. Precision livestock farming can contribute significantly to optimize environmental quality, efficient animal production, and ultimately improve profitability of a dairy farm. Precision feeding and whole-farm nutrient planning have not been adopted on a widespread basis because most dairy farms put emphasis on maximizing animal production and profits rather than on minimizing excretion of nutrients. For example, surveys conducted in the US indicate that producers typically formulate dairy diets to contain 0.45 to 0.50% P (dry basis) which is approximately 20 to 25% in excess of the National Research Council (NRC) suggested requirement (NRC 2001). Livestock excretes 60 to 80% of P consumed (Knowlton et al., 2004), an indication that a higher portion of P brought on to the farm in feed stays on the farm instead of being exported in meat or milk. A study by Klausner (1993) showed that on the typical dairy farm, N imported in feed, fertilizer, and N fixation in legumes is more than that exported in milk or meat by 62 to 79%, of which 62 to 87% of the excess N comes from imported feed. Approximately, 70% of the excess N escapes into the off-farm environment through volatilization and leaching into groundwater.

Studies have shown that implementing own farm feed plans that integrate nutrient management across herd, crop, soil, and manure components can decrease nutrient concentrations on dairy farms while increasing profitability (Rotz et al. 1999; Wang et al. 2000). Tylutki and Fox (2000) used CuNMPS model to integrate cattle and crop production on a dairy farm and found that profitability improved with environmental benefits of reducing erosion and P contamination of water bodies. There are other researchers who used linear programming (LP) model to find the best possible profitable combination of crops and herd type and size. Westphal et al. (1989) and Henry et al. (1995) used an LP to study the relationship of plant nutrient management strategies to optimal herd size and net farm return. Nicholson et al. (1994) and Urbina (1991) used an LP model to compare nutritional management strategies for dual-purpose herds in Latin America. Other studies have compared the economics of grazing-based dairy feeding systems to that of confined dairy operations. example, Hanson et al. (1998) and Dartt et al. (1999) did surveys of dairy operations utilizing grazing as a forage source and Turcker et al. (2001) did a case study analyzing cows fed on pasture or in confinement. Each of these types of studies contributed meaningful information towards analyzing the production of forages, cattle, and profitability of farms.

The amounts of nutrients, especially P and N, can be reduced without adverse effects on animals. Lower amounts of P and N in many diets can be met by removing mineral P added to supplemental feed. The reduction of added mineral can reduce the annual feed cost and thus improve farm profit. Changes in cropping strategies may also affect P and N balance if the crop change greatly affects the import of supplemental feed or fertilizer. Better utilization of crops such as grass and forage may provide some reduction in the excess P on a farm. Use of more grass on farms may provide an added benefit by reducing P runoff into streams and ultimately the reservoirs. Intensive use of grazing potentially reduces the whole farm accumulation of P.

Management changes can be made to eliminate or reduce the P and N balances on dairy farms. Crop rotation choices, driven by soil types, have a great impact on cost of producing forage and increasing quality and yield. The impact on the rotation is to increase the output per unit area in order to meet both forage and grain requirements. Whole farm simulation provides an effective tool that can assist in the evaluation and selection of sustainable production systems that reduce or eliminate excess P and N while maintaining or improving farm profit. Most importantly is to protect drinking water quality through the prevention of non-point source pollution. In all, nutrient accumulation and the potential for nutrients to enter the environment are influenced by the feeding program, herd productivity, and proportion of own farm feeds.

Comprehensive analyses are needed to evaluate the environment and economic impacts of various management practices that can be used for profit maximization of a dairy farm. These can be achieved through (a) decreasing nutrients brought on the farm by more accurately formulating rations based on farm specific animal requirements and feed contents, and (b) improving the efficiency of nutrient utilization through improved feed and crop management strategies that aim to increase nutrient recycling within the farm boundary. While some studies have been done to integrate crop and cattle production for optimum nutrient utilization, well documented comparisons of profitability of dairy farm with regard to different management practices are lacking. The purpose of this study is to compare and contrast the profitability of the current dairy management practices as a base plan to the proposed alternative management plan through precision livestock farming while reducing nitrogen (N) and phosphorus (P) balance This study illustrates the management changes that can be applied for profit maximization and possibly reduction of P and N loading while maintaining and likely improving the profitability of a dairy farm.

Materials and methods

This study used selected data as available from the Coldstream dairy farm located in Lexington, Kentucky (Tables 1(a and b) and 2(a and b)). These tables describe the herd and rations that are used in this dairy farm. As data for crops were not available, assumptions were made that the farm produces three feeds (alfalfa hay, alfalfa silage, and corn silage) for own farm use and the balance for sale. The rest of the feeds are purchased. The topography in this farm is very hilly. The animals were divided into eight groups as follows: lactating cows, far-off dry cow, close-up dry cow, outside pen cow, calan pen cow, maine chance pen cow, weaned calves, and baby calves. The Cornell Net Carbohydrate and Protein System version 5.0 (CNCPSv5) software was used for feed analysis and to simulate the results of alternative nutrient management plans that optimize herd nutrition. Two assumptions were made in developing a nutrient management plan with CNCPS 5.0: (i) the herd is in a steady-state condition (neither expanding nor reducing herd numbers); and (ii) the rations being fed are representative of the whole year.

Table 1(a). Holstein herd description

Group	No. of heads	Age (months)	Weight (kg)	Days preg.	Lact. #	Milk kg/day	Fat%	Protein %
Lactating cows	80	43	658	119	2	33.6	3.8	3.1
F-dry cows	15	43	658	240	2	-	-	-
C-dry cows	6	43	658	270	2	-	-	-
Outside pen	20	9	340	-	-	-	-	
Calan pen	18	15	454	190	-	-	-	-
Maine chance	13	18	522	130	-	-	-	-
Weaned calves	19	4	227	-	-	-	-	-
Baby calves	6	<2.5	36	-	-	-	-	-
Totals	177							

Table 1(b). Jersey herd description

Group	No. of heads	Age (months)	Weight (kg)	Days preg.	Lact. #	Milk kg/day	Fat%	Protein %
Lactating cows	33	43	454	146	2	24	4.9	3.7
F-dry cows	7	61	454	240	3	-	-	-
C-dry cows	2	56	454	270	3	-	-	-
Outside pen	2	9	250	-	-	-	-	
Calan pen	5	15	318	190	-	-	-	-
Maine chance	5	18	386	130	-	-	-	-
Weaned calves	7	4	159	-	-	-	-	
Baby calves	6	<2.5	30	-	-	-	-	-
Totals	67							

Table 2(a). Rations fed for Holstein (lbs DM)

Ingredients	Lactating cows	F-dry cows	C-dry cows	Outside pen	Calan pen	Maine choice	Weaned calves	Baby calves
Corn silage	13	6.8	9.0	-	5.76	5.76	-	-
Alfalfa silage	10	-	2.0	-	1.98	1.98	-	-
Cottonseed	5.4	-	9.0	-	-	-	-	-
Grain	25.2	3.6	4.5	3.6	2.7	2.7	3.6	-
Alfalfa sq hay	1.7	12	-	8.2	5.1	6.4	4.3	-
Calf starter	-	-	-	-	-	-	-	1.4

Table 2(b). Rations fed for Jersey (lbs DM)

Ingredients	Lactating cows	F-dry cows	C-dry cows	Outside pen	Calan pen	Maine choice	Weaned calves	Baby calves
Corn silage	13	6.8	9.0	-	5.76	5.76	-	-
Alfalfa silage	10	-	2.0	-	1.98	1.98	-	-
Cottonseed	5.4	-	9.0	-	-	-	-	-
Grain	25.2	3.6	4.5	3.6	2.7	2.7	3.6	-
Alfalfa sq hay	1.7	7.1	-	5.1	2.22	2.22	2.0	-
Calf starter	-	-	-	-	-	-	-	1.1

The yield results for corn silage, alfalfa hay and silage were simulated from the Integrated Farm System Model (IFSM), a component of DAFOSYM, using 25 years of weather data. While agronomic field trials are preferred, such information that allows a series of production strategies under several similar weather data was not available. For alfalfa crop, irrigation was included for two levels (low and high) as well as for no irrigation. The simulation model used four soil types (clay loam and loam each with deep and shallow top soils) and four rates of Potash (K) fertilization per acre (160 lbs, 200 lbs, 240 lbs, and 260 lbs). Land for crop production was limited to 400 acres for each soil type. Corn silage used three levels of irrigation (low, medium, and high) using four soil types in the simulation model (deep and shallow clay loam, shallow loam, and shallow sandy loam). Three fertilizer types were used each with three levels per acre: N (125 lbs, 160 lbs, and 180 lbs), P (40 lbs, 60 lbs, and 80 lbs), and K (30 lbs, 58 lbs, and 65 lbs). Land for corn silage crop production was limited to 100 acres for each soil type.

As IFSM is not equipped with weather data for Kentucky, the nearest state weather data at Roanoke weather location in Virginia was used. The labor requirements per month, input prices and input requirements per acre were taken from the University of Tennessee (2004) and the Southern Region SARE Training Project (1998). Relative Feed Quality (RFQ) of alfalfa was calculated from the neutral detergent fiber (NDF) and total digestible nutrients (TDN) both obtained from simulation results. Relative feed value (RFV) of alfalfa was obtained from the relationship equation of RFQ versus RFV estimated by Undersander and Moore (2002). RFV has been widely used to ranking forage for sale, inventorying and allocating forage lots to animal groups according to their quality needs (Undersander and Moore, 2002). It is based on the concept of digestible dry matter (DM) intake relative to standard forage. Price adjustment in relation to RFV levels was made and the factor was plugged into the price regression equation developed.

An economic model with the objective function of maximizing net farm returns above selected relevant costs was developed using mathematical programming. The information computed by the CNCPSv5 and the simulation results from IFSM were used in this model for profit maximization. Decision variables included alfalfa hay, alfalfa silage and corn silage production under various soil types management practices (various irrigation and macronutrient application levels), dairy cow production under alternative feeding strategies, crop sales, and mean net returns. Constraints included limited land, herd size, field labor, and relevant accounting equations. Two profit scenarios were analyzed and compared in this study: 1) Current dairy management practices as a base plan and 2) Own farm production of feeds was increased while reducing purchased feeds.

Results and discussion

The simulation yield results obtained from all crops were reasonable estimates compared with the various yields estimated from other research studies. The results for the selected dairy management scenarios are presented in Table1. The revised farm management practice provided a mean profit above selected variable costs of US$202,656 and a coefficient of variation (CV) of 9.06% compared to current management practice that provided a mean profit of US$ 203,169 and a CV of 8.67%. However, the mean of 100% of the profit maximizing level of current management practice was higher by 0.25% than that of the revised scenario (99.75%). The revised farm practice has a higher chance of making higher maximum profit but lower minimum profit than the current farm practices.

Table 2. Results of the analysis

Indicators	Current farm practices	Revised farm practices
Average profit ($)	203,169	202,656
Minimum profit ($)	167,725	165,397
Maximum profit ($)	237,939	238,464
CV %	8.67	9.06
% optimum	100.00	99.75

The intake of homegrown feeds was increased and that of the purchased feeds were reduced in the revised scenario. As expected, the farm profitability was increased as more homegrown feeds and less purchased ones were fed. However, the higher loading of N in the manure excretion was not expected (Table 3). The recycling of manure was not analyzed in this study because of unavailability of sufficient data. However, when recycled, manure has an added advantage to the farm crops including grass. The recycling of manure back to the farm crops will replace part of the purchased fertilizers. Thus reducing the costs of farm production, and hence improve profitability. If properly recycled with good crop planning, manure is expected to have an environmental benefit of reducing the potential for P and N contamination of water bodies. Increasing homegrown feeds has an advantage of reducing imported feeds. As more feeds and fertilizers are imported by a farm to meet dairy farm requirements, phosphorus and nitrogen are usually imported in quantities much higher.

Table 3. Manure and nutrient excretion (ton/yr)

Item	Current farm practices	Revised farm practices
Total manure (ton)	4255	4551
Nitrogen (ton)	25	26.4
Phosphorus (ton)	3.2	3.2

The analysis in this study indicates that the revised scenario is more profitable compared with the current management. The fact that Kentucky receives a lot of rains throughout the year is an indication that most areas do not need irrigation water, and thus cutting more costs. This means that use of more homegrown feeds has a greater probability of earning more profits. However, dairy farmers need to consider which management practice to follow in respect to location, weather condition, and soil types.

Summary and conclusion

One of the most important keys to economic sustainability of livestock enterprises is to maximize yields and increase both quantity and quality of homegrown feeds which are related to increasing profitability. Soil types and management practices as well as variation in feeding strategy are some of the factors that can affect net farm returns. This study analyzed profitability of dairy management practices under various soil types and variable rates of fertilizer and irrigation. The CNCPSv5 was used for nutrient analysis using the dairy herd at Coldstream farm. The yields of alfalfa hay/silage and corn silage were simulated from the IFSM using 25 years of weather data.

The study employs a mathematical programming model for profit maximization. Through this revised dairy management practices, it was predicted that profits will increase while maintaining herd performance. This was accomplished by increasing the intake of homegrown feeds and reducing the purchased feeds. In conclusion and evaluating this study, it became apparent that the herd feeding and crop production plans need to be integrated with each other and to develop farm business records for the most feasible and profitable farm plan. Dairy farmers need to consider important factors such as activity location, weather condition, and soil types. In this regard soil testing before planting is very crucial. The study had some limitations. While risk management has long been considered to be an important component of the agricultural producer's decision-making environment, this study did not accommodate risk analysis in management decisions. Some risk sources such as fluctuation of yields, price changes, and risks of days unsuitable for fieldwork as a result of weather need to be considered for future research. Soil mapping is another component that needs to be considered for future research.

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