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Chapter 7

DairyMGT: A Suite of Decision Support Systems in Dairy Farm Management

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/50801

1. Introduction

Dairy farming is a highly dynamic and integrated production system that requires continuous and intense decision-making. Several dairy farm components that include 1) cattle, 2) crops, 3) soils, 4) weather, 5) management, 6) economics, and 7) environment are extremely interrelated [1]. These components and their sub-components dynamically affect and are affected among them. Therefore, an efficient decision support system (DSS) framework within an integrated systems approach is critical for successful dairy farming management and decision-making [2-5].

This chapter describes the development, application, and adoption of a suite of more than 30 computerized DSS or decision support tools aimed to assist dairy farm managers and dairy farm advisors to improve their continuous decision-making and problem solving abilities. These DSS emerged in response of dairy farm managers' needs and were shaped with their input and feedback [6-7]. No single or special methodology was used to develop each or all of these DSS, but instead a combination and adaptation of methods and empirical techniques with the overarching goal that these DSS were: 1) highly user-friendly, 2) farm and user specific, 3) grounded on the best scientific information available, 4) remaining relevant throughout time, and 5) providing fast, concrete, and simple answer to complex farmers' questions [2, 8-11]. After all, these DSS became innovative tools converting expert information into useful and farm-specific management decisions taking advantage of latest software and computer technologies.

All the DSS object of this chapter are hosted at http://DairyMGT.info, *Tools* section and are categorized within dairy farming management and decision making such as: 1) nutrition and feeding, 2) reproductive efficiency, 3) heifer management and cow replacement, 4) production and productivity, 5) price risk management and financial analysis, and 6) environ-

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mental stewardship. Depending on the complexity, the specific purpose, and the requirements of dairy farm decision makers, some DSS are completely online applications, others are Macromedia Flash tools, others are Spreadsheets, and others are self-extractable and installable programs.

This chapter discusses the challenges on the development of these DSS with respect to the trade-offs among user-friendly design, computational detail, accuracy of calculations, and bottom line efficiency performance and effective decision-making. It portrays DSS development strategies, within the computational resources available, that succeeded in their primary objective of providing dairy farm mangers fast and reliable responses to perform efficient and effective decision-making.

The chapter reveals practical and real-life applications of a number of these DSS to demonstrate satisfactory system assessment, acceptable future predictability, adequate scenario evaluation, and, consequently, satisfactory decision-making.

The chapter also covers aspects of DSS dissemination and adoption evaluation, including the inception and development of a dedicated webpage; local, national and international usage, requested presentations, and academic publications.

The chapter also infers the possible role of emerging and evolving new technologies such as smart phones and tablets in the intersection of DSS, real-time applications, and mobile devices, which is a fast growing area of development within the dairy farming industry.

2. Description of DairyMGT.info Decision Support Tools

This section lists and describes the DSS object of this chapter. These DSS are categorized in main areas of dairy farm management, as they appear in the DairyMGT.info: *Tools* webpage.

2.1. Nutrition and Feeding (DairyMGT.info → Tools→ Feeding)

Dairy farmers recognize that the largest item cost in a dairy farm system is feed, whether purchased or farm-grown. Obviously the major source of income in a dairy farm operation is the milk sale. Consequently, managing and optimizing the milk income over feed cost is a critical decision that affects not only economic sustainability, but also has large impacts regarding environmental stewardship[12]. Farmers also recognize that every farm is completely different and that market conditions are constantly changing. Therefore, beyond established farm feeding rations, there is a need for tools to permanently adjust strategic feeding decisions. Take as an example corn grain and its highly volatile price. Corn is a staple feed commodity for dairy farm feeding and consequently its price influences largely diet costs. With sudden corn price swings farmers confront permanently the question of re-considering the amount of corn in the diet. This question can be responded by estimating the marginal value of milk (also depending on highly volatile prices) to corn according to lactation stage and current amount of corn in the diet. The optimal use of corn would occur when the marginal value of milk equals the marginal value of corn, which at research-based

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feed efficiency levels [13], would solely depend on the ever-changing price relationship of milk and corn. The tool "*Corn Feeding Strategies*" shows these relationships in a graphical, dynamic, and interactive way so dairy farmers can optimize the amount of corn grain in each farm feeding group according to ever-changing market price conditions.

Take as another example the price of the main dairy cattle feed commodities and their relationship with milk price according to feed efficiency changes throughout lactation states. Research data indicate that the use of concentrates (i.e., corn, soybean meal) have a substantially higher impact on milk production during early or mid-lactation than in late lactation [14]. Under this premise, increased use of forages is justified in late lactation to maximize the overall milk income over feed cost, which however depends on ever-changing feed commodity prices. The tool "*Income Over Feed Cost*" graphs interactively the milk income over feed cost weekly for entire lactations and shows the impact of feed commodity prices on the dynamic milk income over feed cost value. Therefore, dairy farmers can fine-tune their feeding strategies to maximize their milk income over feed cost according to lactation states and feed prices swings.

Sometimes dairy farmers need additional help on formulating their diets to optimize feed concentrate supplementation. Research trails indicate that the optimal level of concentrate supplements in a diet could be achieved by using milk production response to crude protein (CP) and its components of rumen un-degradable protein (RUP), and rumen degradable protein (RDP), according to particular cow-group rations [15]. The tool "*Income over Feed Supplement Cost*" performs an optimization according to defined feed ingredients, prices, and CP (RUP, RDP) restrictions to maximize the net return. The tool helps dairy farm decision makers to select the most cost effective concentrate supplements in the diet, especially from the point of view of providing adequate amounts of RUP and RDP, which not only optimizes the net return, but also reduces the amount of nitrogen excretion and hence environmental impacts.

Dairy farmers also want to know what are the best-priced feed ingredient choices in the market. This information would drive farmer feed purchase decisions. The tool called "*FeedVal 2012*" is a dynamic and interactive matrix that finds the estimated price of a feed as an aggregated sum of its individual nutrients values according to the nutrient content and prices of a set of defined feed ingredients available in the market. The tool then compares the actual price of a feed ingredient with its calculated price. The result is a list of ingredients with their relative prices, indicating if an ingredient is a bargain or an expensive proposition.

Another critical factor in the quest for feed efficiency and maximum milk income over feed cost is the analysis of "benchmarking" with respect to feed efficiency, milk income, and feed costs [16]. Results from surveying dairy farm rations and farm prices reveals an impressive difference regarding to feed costs, feed consumption, and overall milk income over feed cost among otherwise similar dairy farms. A large and important opportunity exists then to improve the milk value net of the feed costs by comparing performance among farms. Therefore an online database structure and DSS was developed: "*Dairy Extension Feed Cost Evaluator*," Figure 1. This tool performs advanced benchmarking analyses for a group of users within a region, state, or country throughout a defined timeline by querying an online database, which is permanently being updated by the users. The tool allows users to "drill-

down" the analysis and find out the driving factors for differences, an important step toward improving dairy farm feed efficiency and income over feed cost.



Figure 1. Screen snapshot of DSS *Dairy Extension Feed Cost Evaluator*.

Dairy farmers also require some simpler evaluation tools for feed additives. The tool "*Optigen® Evaluator*" analyzes the economic value of including this slow release urea additive while maintaining diets at the same level of protein and dry matter intake. The tool "*Dairy Ration Feed Additive Break-Even Analysis*" determines any additive's additional milk production needed to justify its economic inclusion in the diet.

Finally, regarding nutrition and diets, there is some evidence that dairy farmers might be over-feeding a large proportion of lactating cows when they feed the same diet ration to a large group of animals. Diets are normally formulated to provide enough nutrients to the most productive animals, which in turn gives extra nutrients to the less productive animals within the same group. Therefore, splitting lactating cows in smaller groups and offering group-specific feeding rations provide more precise nutrient requirements, increase herd's income over feed cost, and decrease nutrient excretion [17]. The tool "*Grouping Strategies for Feeding Lactating Dairy Cattle*" calculates dynamically individual cow nutrient requirements and optimizes cow grouping feeding strategies within particular farm constraints.

2.2. Reproductive Efficiency (DairyMGT.info → Tools→ Reproduction)

Reproductive efficiency plays a critical role in the economics of dairy farming. However, assess the economic value of it is extremely difficult and complex [5]. A first step on understanding the economic impact of reproductive programs is to demonstrate the milk value net of feed cost dependent on the pregnancy time. The tool "*Exploring Pregnancy Timing Impact on Income over Feed Cost*" shows interactively and dynamically a cow's total milk income net of feed costs to a fixed lactation's pregnancy time and defined lactation curves. The tool illustratesand quantifies the economic value of having cows pregnant at the right time.

Dairy farmers are also required to do complex decisions regarding the best reproductive programs for the lactating herd population. New reproductive management strategies, whether they use hormonal synchronization technologies, heat detection methods, or a combination of

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both, are continuously and permanently evolving. Dairy farmers need not only to keep up-to-date with all these technologies, but also make the best decisions according to their own conditions [5]. Dairy farmers usually know which reproductive programs are more efficient from the reproductive point of view of getting more cows pregnant. Farmers also have a good handle on costs incurred according to reproductive programs. Nonetheless, dairy farmers have difficulty assessing the overall profitability of reproductive programs. Not surprisingly, they have long demanded for a systematic economic analysis to analyze reproductive programs. The tool "*UW-DairyRepro$Plus*" is a complex, still user-friendly, decision support systems that assess the economic value of farm-defined alternative reproductive programs for a particular farm according to prevalent market conditions. These tools allow farmers to be highly specific regarding their current or alternative reproductive programs. Besides reporting the most important reproductive parameters for each alternative program, the tools find the reproductive program with the best economic outcome and calculates the difference in net returns a farm would have when using alternative reproductive programs.

Sex-sorted semen that increases the chance of female offspring is a relatively new technology being widely adopted in the dairy industry. Farm-specific sexed semen's economic value and, moreover, when and how to use it, are critical. The tool "*Economic Value of Sexed Semen for Dairy Heifers*" (Figure 2) finds interactively the gain (or loss) of different reproductive program management strategies that include sexed semen compared with solely using conventional semen [18].

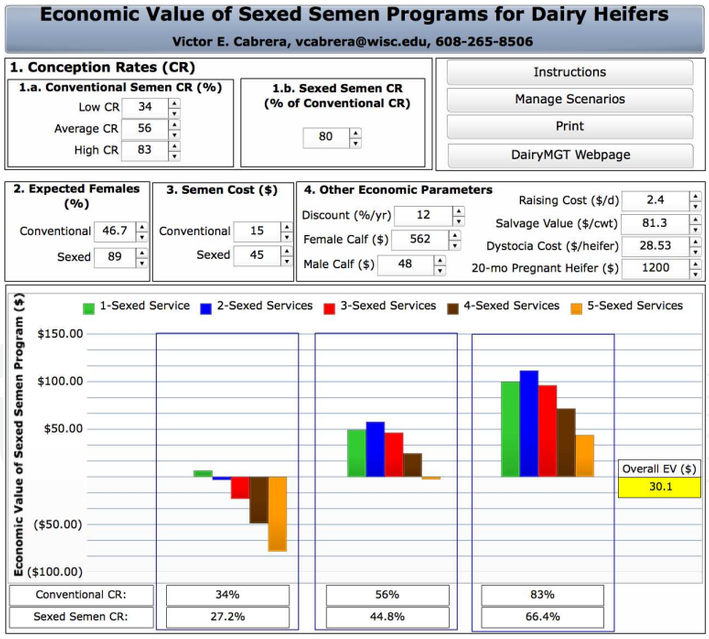


Figure 2. Screen snapshot of DSS *Economic Value of Sexed Semen for Dairy Heifers*.

As important as to find out the value of specific-defined reproductive programs is to explore the value of improving the overall reproductive efficiency. The tool "*Dairy Reproductive Economic Analysis*" is a Markov-chain stochastic dynamic model packed in a simple to use on-

line application. This tool integrates detailed parameters of pregnancy, abortion, and culling risks to perform iterations during 9 lactations until a herd reaches a steady state [19]. Then, the economic value of a reproductive program is determined by using predicted milk production curves, calve value, replacement costs, and other economic figures. The end result is a net return tied to a reproductive performance.

2.3. Heifer Management and Cow Replacement (DairyMGT.info → Tools→ Heifers / Replacement)

Whether farmers raise replacement heifers or not, they benefit from decisions related to this dairy farming enterprise. One first step on the economic decision about heifers is to determine the overall cost associated with rearing heifers according to estimated time to first calving. The tool "*Heifer Break-Even*" calculate the daily and accumulated cost for rearing heifers up to 12 months, 24 months, and beyond 24 months according to farm-defined prices for forages, corn, and soybean meal. Farmers use this tool to decide if to raise their own heifers, use custom-raising heifer services, or simply buy heifer replacements, according to market prices.

When farmers raise heifers on-farm, another decision comes along: to use or not to use accelerated feeding programs for boosting the early development of calves. The tool "*Cost-Benefit of Accelerated Feeding Programs*" gives dairy farmers the opportunity to compare hand-by-hand their current heifers' feeding program with an alternative accelerated feeding program within farm defined conditions. This tool shows economic differences at weaning and calving and calculates the amount of milk amount that would be needed to pay for heifer rearing costs.

In addition to the decisions of raising heifers and if to use accelerated feeding programs, dairy farmers want to know the number of heifers needed to maintain (or increase) the herd size according to farm long-term goals, reproductive efficiency, and heifers' culling rates. The tool "*Heifer Replacement*" calculates the number of replacement animals needed (springer heifers) responding to farm specific data inputs.

Dairy farmers would need to buy (or sell) springing heifers if the number of he replacements is fewer (or greater) than the required number to achieve the goal of maintaining or expand the herd size. Consequently, they need support on estimating the right price to pay (or to sell) springing heifers. The tool "*Value of a Springer*" performs a projection of the net return an animal would have under farm specific conditions. This value indicates the value of a replacement to break-even its costs. Because of the uncertainty in the milk price, milk production, and the productive lifetime, the model presents outcomes under different price and lifetime scenarios, so farmers can make decisions based on their assertion of the future prices and their risk preferences.

Furthermore, dairy farmers need to make critical decisions if to keep or replace a cow from the herd. The optimal decision will depend on which alternative would bring a greater net return in the future. The tool "*The Economic Value of a Dairy Cow*" (Figure 3) is a complex Markov-chain simulation model, still a user-friendly application that calculates interactively the economic value of a cow (or the value of each single cow in a herd) compared with its replacement [20]. Farmers use this value to make more informed decisions if to keep or re-

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place cows. This tool, in addition, calculates the expected herd demographics and the average herd net return for better and additional dairy farm management and decision-making.

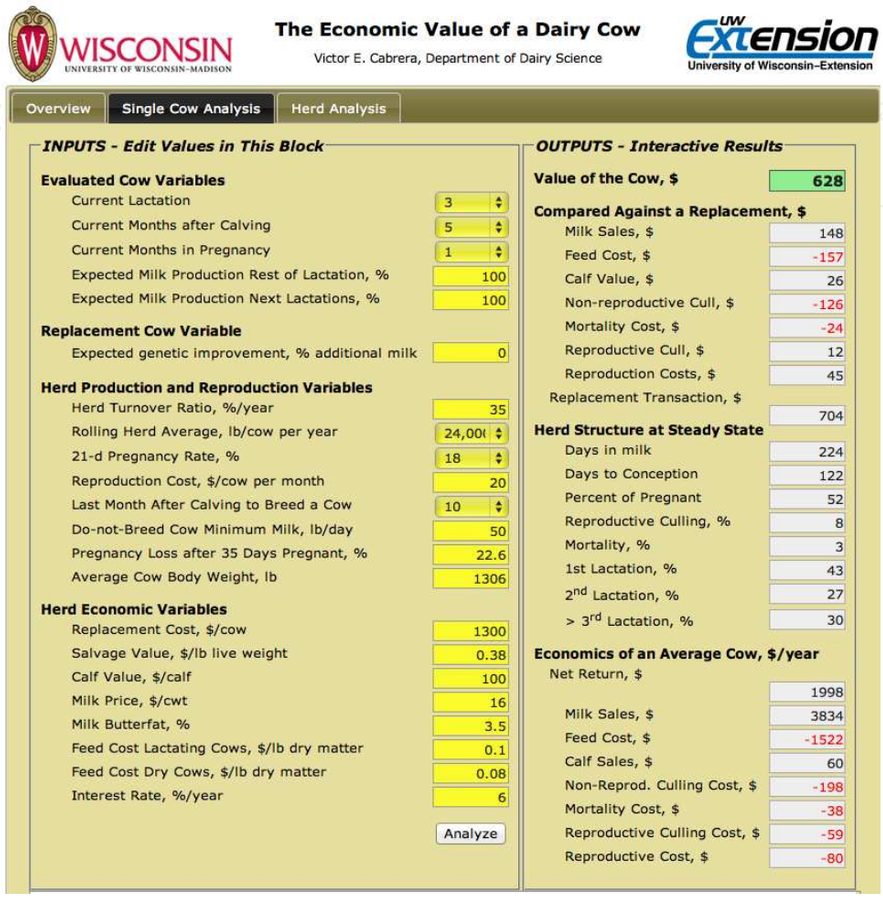
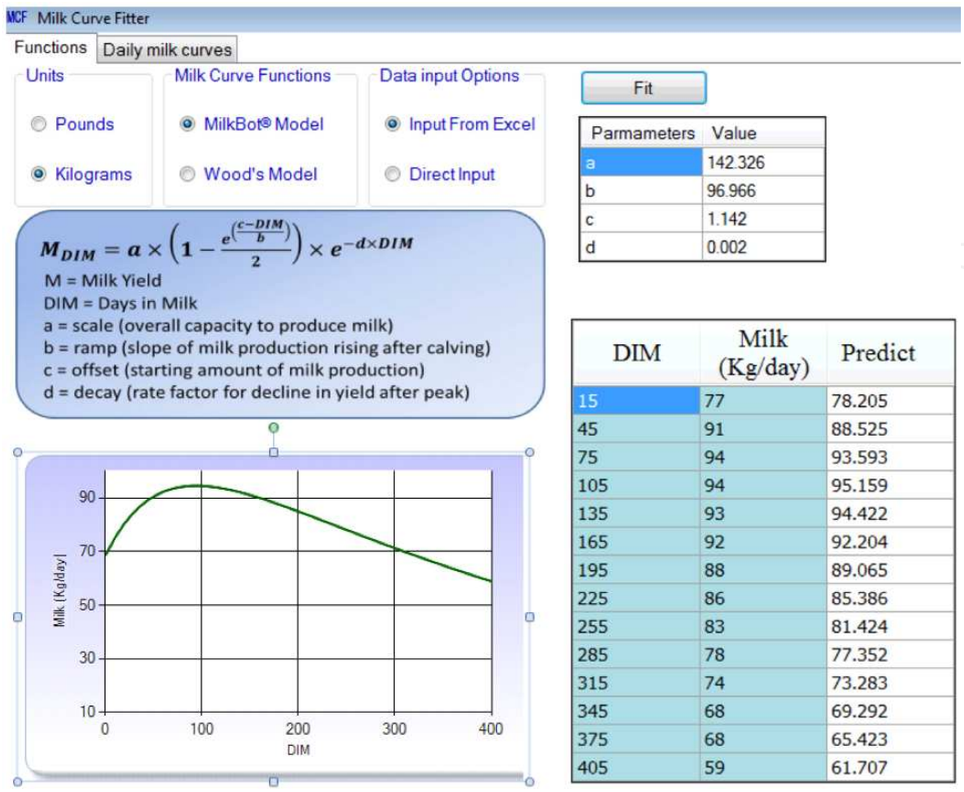


Figure 3. Screen snapshot of DSS *The Economic Value of a Dairy Cow*.

2.4. Production and Productivity (DairyMGT.info → Tools→ Production)

Dairy farmers face several decisions regarding production-related issues. In order to make best decisions, they would like to know how their farm milk production profile compares to other similar farms. Besides milk amount produced per animal, the shape of the herd's lactation curves is critical to pinpoint management weaknesses and strengths of a particular farm. The tool "*Lactation Benchmark Curves for Wisconsin*" displays different parity lactation curves for different production levels herds obtained by processing 3.6 million lactation records. Dairy farmers can define their own lactation curves to assess their production performance compared with the benchmarked records. Similarly, farmers find great benefit of projecting their own lactation curves and compare specific dairy herd cows to the standards of the whole herd, which can be accomplished by using the tool "*Milk Curve Fitter,"* Figure 4.



DIM	Milk (Kg/day)	Predict
15	77	78.205
45	91	88.525
75	94	93.593
105	94	95.159
135	93	94.422
165	92	92.204
195	88	89.065
225	86	85.386
255	83	81.424
285	78	77.352
315	74	73.283
345	68	69.292
375	68	65.423
405	59	61.707

Figure 4. Screen snapshot of DSS *Milk Curve Fitter*.

As a result of benchmarking their herd's lactation curves, dairy farmers may contemplate a new set of decisions to improve productive performance such as switching the number of milking times per day [21] or re-consider the use of recombinant bovine somatotropin (rbST), a synthetic metabolic hormone that improves milk productivity. The tool "*Economic Analysis of Switching from 2X to 3X Milking*" performs a farm-specific partial budgeting analysis of the projected gain (or loss) when a farmer decides to milk 3 times a day instead of 2 times. The tool "*Economic Analysis of using rbST*" displays the economic gain (or loss) of using rbST as an interactive sensitivity analysis according to ever-changing milk price and estimated milk increase because of rbST under specific farm conditions.

Some dairy farmers are also interested in the possibility of either expand or modernize their farm facilities or increase their herd size. Therefore, they require support on important decisions that will drive the future of the dairy farm operation. The tool "*Decision Support System Program for Dairy Production and Expansion*" is a Spreadsheet application that allows dairy farmers to outline their current farm conditions regarding herd structure and market conditions, define a possible plan of expansion or modernization including required loans (for facilities and animals), and project the cash flow of the entire farm up to a period of 54 months in the future.

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2.5. Price Risk Management and Financial Assessment (DairyMGT.info → Tools→ Financial)

Unfavorable prices of milk and feed commodities together with increased price volatility create large uncertainty in the dairy farm business. Recent unprecedented uncertain times have prompted to re-visit farm's financial status and look for alternatives to stabilize net returns. It is critical to explore price risk management alternatives such as the relatively new revenue insurance program called Livestock Gross Margin for Dairy (LGM-Dairy) and to assess farm financial performance compared with peers [22].

In brief, the LGM-Dairy can protect the net margin (milk value less feed cost or milk income over feed cost) at a much lower cost than using comparable options in the future markets. The tool "*LGM-Analyzer*" (Figure 5) is an online, easy-to-use, suite of real-time, data intense, simulation, and optimization integrated modules to help on the decision of using LGM-Dairy. The *LGM-Analyzer* not only replicates the official premium calculation from the U.S. Department of Agriculture Risk Management Agency, but also is capable of perform historical sensitivity analysis as well as complex optimizations to minimize the premium cost at a level of target guaranteed income over feed cost. This suite of tools is also capable of comparing the LGM-Dairy with more traditional price risk management tools such as puts (Class III milk) and calls (corn and soybean meal) for feeds as bundled price options. The *LGM-Analyzer* connects live with the dairy and grain-based futures and market (through a structured query language) to determine the premium cost a particular farmer could expect according to a guarantee income over feed cost ("*Premium Estimator*"). Furthermore, a unique module ("*Least Cost Optimizer*") lets the user to minimize the LGM-Dairy premium cost at a defined level of income over feed cost insured. Other tools in the area of analysis of the LGM-Dairy include the "*LGM-Dairy Feed Equivalent*," a tool to covert feed diet ingredients to corn and soybean meal equivalents needed for a LGM-Dairy contract and the "*Net Guarantee Income over Feed Cost*," a tool to help dairy farmers determine the income over feed cost to breakeven all other costs of production, which should be covered by using LGM-Dairy.

Also, performing a farm's financial benchmark assessment is critical in the process of measuring the financial health of a dairy farm. Moreover, this is usually required by lenders in order to consider loan applications. The "*Wisconsin Dairy Farm Benchmarking Tool*" is a database application that calculates 15 financial ratios including variables of liquidity, solvency, profitability, repayment capacity, and financial efficiency for a group of more than 500 Wisconsin dairy farms during a period of 10 years. The tool then compares each one of these ratios with those of a particular farm. Therefore, farmers can assess their financial health compared with their peers. Furthermore, the tool provides a *DuPont* analysis, in which a farm is compared against the population with respect to revenue and profit generated for every dollar invested. Another related tool, "*Working Capital Decision Support System*" assists dairy farmers in identifying cash flows, project expected incomes and expenses, and identifies cash excesses and shortfalls well in advance of their occurrence.

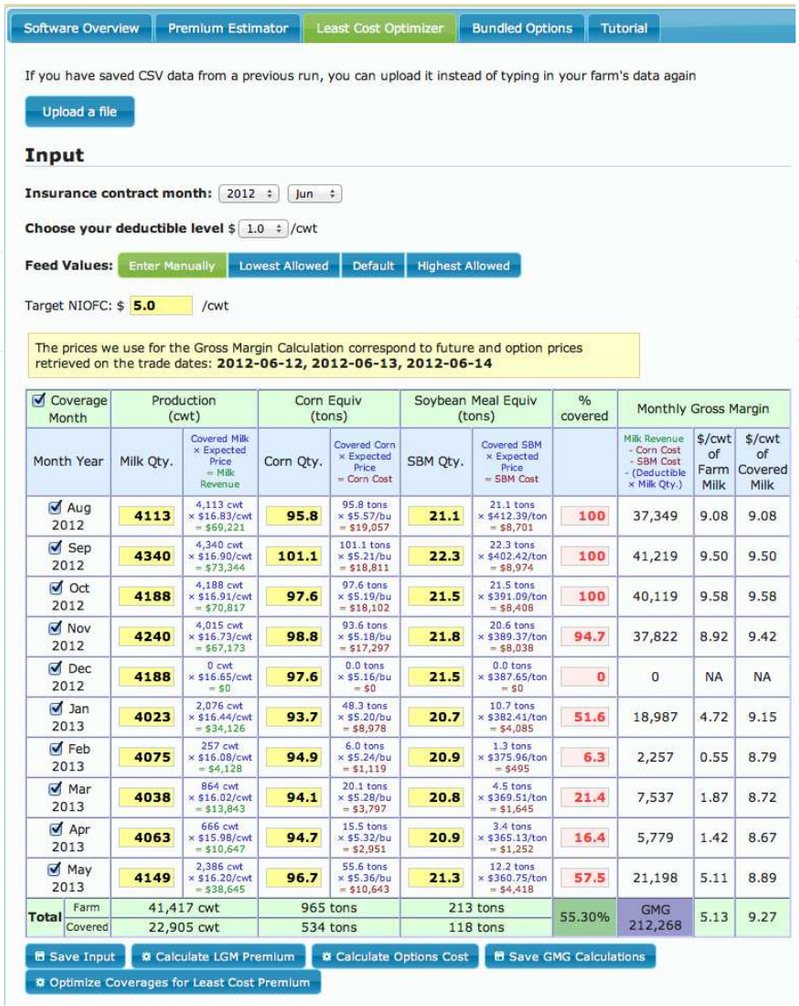


Figure 5. Screen snapshot of DSS *LGM-Analyzer*.

2.6. Environmental Stewardship (DairyMGT.info → Tools→Environment)

The dairy farm business faces important challenges regarding increased environmental scrutiny. An increasingly important dairy farm management task is to maintain a farm nutrient balance and therefore avoid over-concentration of nutrients in or around the farm. Opportunities exist to better utilize nutrients in dairy farming and not only improve the balance of nutrients coming in and going out of the farm, but also decrease fertilizer expenses and therefore environmental concerns. Depending on the farm herd and crop characteristics, additional expenses might be required to comply with environmental regulations. In any case, an economic assessment along with the environmental requirements promotes better decision-making. A series of decision support tools deal with these sensitive aspects of dairy farming. The tool "*Dynamic Dairy Farm Model*" (Figure 6) is an integrated, whole-farm, simulation and optimization model that maximizes the net economic return while minimizing nitrogen leaching to surface and ground water sources. A

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simplified version of nutrient balance between nitrogen and phosphorus manure excretion for a fast assessment is the tool with name *"Dairy Nutrient Manager."* Also related, the "*Grazing-N*" is an application that balances nitrogen for dairy farms with grazing activities and the "*Seasonal Prediction of Manure Excretion,*" as its name says, helps dairy farmers project seasonally the amount of cow manure (and consequently nutrients in the manure) will be produced and will be needed to be recycled.



Figure 6. Screen snapshot of DSS *Dynamic Dairy Farm Model*.

3. Decision Support Systems Development: Challenges and Trade-offs

A number of methodologies and software applications were used to develop the decision support tools above described (Table 1). The goal always remained to provide solid, but user-friendly DSS tools. The methodology as well as the software application approach followed the tool development and the ultimate goal pursued and not vice versa. It was usual to combine and adapt methodologies within a particular tool development. Following is a succinct description of the most important methodologies used for the DairyMGT.info DSS tools and a discussion of the approaches used for the software applications.

3.1. Methodologies used for the Decision Support System Tools

3.1.1. Partial Budgeting

Partial budgeting compares a current with an alternative technology by balancing the economics of 4 elements that are assessed before and after the adoption of the alternative technology: 1) additional returns (adds), 2) reduced costs (adds), 3) returns foregone (subtracts), and 4) additional costs (subtracts) [23]. Partial budgeting could be a robust methodology when a direct change is expected from the new technology without major interaction with other system components beyond the analyzed variables. Partial budgeting is the underline methodology to assess the break-even level of using feed additives, the economic benefit of milking 3 times a day, the economic evaluation of using rbST, the assessment of corn feeding strategies, and the assessment of income over feed cost by different diets under commodity price changes.

3.1.2. Cost Benefit

The cost benefit methodology is similar to partial budgeting but determines profitability of a new technology over longer periods of time and therefore requires the specification of a discount rate that is used to calculate a net present value [23]. The cost benefit is the underline methodology for calculating the value of adopting accelerated heifer liquid feeding programs and is as a supporting methodology to find out the economic value of sexed semen for dairy heifers, the value of reproductive programs in adult cows, and to assess the net present value of alternative scenarios of possible dairy farm expansion or modernization.

3.1.3. Decision Analysis

The decision analysis is appropriate when probabilistic distributions are important factors in determining the final outcomes [24] as it occurs when analyzing the value of using sexed semen on heifers, comparing the value of reproductive programs in adult cows, or projecting the replacement flow needed to maintain the herd size. In the first two cases, conditional probabilities were used to successively determine populations of pregnant, non-pregnant, and eligible to breed animals along with their respective expected monetary contributions. In the case of the replacement flow tool, transition probabilities are used to dynamically project the herd dynamics across time.

Decision Support System Tool	**Underline Methodology**	**Software Application**
Feeding and Nutrition		
Corn Feeding Strategies	Partial Budgeting	Flash[1]
Income Over Feed Cost	Partial Budgeting	Flash
Income over Feed Supplement Cost	Linear Programming	Spreadsheet/ Online[2]

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Decision Support System Tool	Underline Methodology	Software Application
FeedVal 2012	Matrix Solution	Online
Dairy Extension Feed Cost Evaluator	Database Management	Online
Optigen® Evaluator	Matrix Solution	Online
Dairy Ration Feed Additive Break-Even Analysis	Partial Budgeting	Flash
Grouping Strategies for Feeding Lactating Dairy Cattle	Mathematical Simulation	Online
Reproductive Efficiency		
Exploring Pregnancy Timing Impact on Income over Feed Cost	Mathematical Simulation	Online
Economic Value of Sexed Semen for Dairy Heifers	Decision Analysis	Flash/Online
UW-DairyRepro$	Decision Analysis	Spreadsheet
Dairy Reproductive Economic Analysis	Markov Chains	Online
Heifer Management and Cow Replacement		
Heifer Break-Even	Enterprise Budgets	Online/Spreadsheet
Cost-Benefit of Accelerated Feeding Programs	Cost Benefit	Flash/Online
Heifer Replacement	Decision Analysis	Spreadsheet/Online
The Economic Value of a Dairy Cow	Markov Chains	Online/Spreadsheet
Production and Productivity		
Milk Curve Fitter	Nonlinear Optimization	Installation[3]
Lactation Benchmark Curves for Wisconsin	Database Management	Flash/Spreadsheet
Economic Analysis of Switching from 2X to 3X Milking	Partial Budgeting	Flash
Economic Analysis of using rbST	Partial Budgeting	Flash
DSS Program for Dairy Production and Expansion	Markov Chains	Spreadsheet
Price Risk Management and Financial Assessment		
LGM-Analyzer	Mathematical Simulation	Online
LGM-Premium Estimator	Mathematical Simulation	Online
LGM-Least Cost Optimizer	Nonlinear Optimization	Online

Decision Support System Tool	Underline Methodology	Software Application
LGM-Dairy Feed Equivalent	Matrix Solution	Online
LGM-Net Guarantee Income Over Feed Cost	Mathematical Simulation	Spreadsheet
Wisconsin Dairy Farm Benchmarking Tool	Database Management	Online/Spreadsheet
Working Capital Decision Support System	Enterprise Budgets	Spreadsheet
Environmental Stewardship		
Dynamic Dairy Farm Model	Markov Chains	Spreadsheet
Dairy Nutrient Manager	Mathematical Simulation	Spreadsheet
Grazing-N	Mathematical Simulation	Spreadsheet
Seasonal Prediction of Manure Excretion	Markov Chains	Spreadsheet

Table 1. Principal methodology and software application of DairyMGT.info decision support system tools.[1]Flash: Macromedia Flash. [2]Online tools use a combination of software including HTML, PHP, JavaScript, C, CSS, and MySQL. [3]Requires software installation in local machine.

3.1.4. Enterprise Budgets

Enterprise budgets are a systematic way to list returns and costs and evaluate profits from inside a specific business enterprise [25] within the dairy farm. This methodology is used to calculatethe heifer break-even by contrasting heifers' rearing costs with potential benefits. This methodology is also used, in more detail, in the tool working capital to project the cash flow of a dairy farm enterprise.

3.1.5. Linear Programming

Linear programming is a mathematical optimization algorithm to maximize or minimize a goal (e.g., maximum profit or minimum costs) within a set of constraints represented as linear relationships [26]. Linear programming is at the core of the tool income over feed supplementation cost in determining the diet composition that results in the maximum net return within a set of constraints of available feed ingredients. Linear programming is also used recursively in the dynamic dairy farm model to maximize the farm net return while minimizing nitrogen leaching.

3.1.6. Markov Chains

Markov chains are a mathematical system that undergoes transitions from one state to the next within a finite space of states as random processes. In dairy farming, Markov chains are widely used for decision-making to predict herd demographics or to project cows' probabilistic life [2, 10, 12, 19-20]. Markov chains are also very useful to implement decision support

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tools, as these are less computationally demanding than alternative methods. Markov chains are therefore important part of the DairyMGT.info DSS tools and are the backbone structure of the tools: seasonal manure prediction, dynamic dairy farm model, reproductive economic analysis, and the economic value of a dairy cow. Markov chains are also important part of the tools dealing with expansion and modernization and the one comparing the value of different reproductive programs for adult cows.

3.1.7. Mathematical Simulation and Projection

Mathematical simulation and projection is a general description that encompass a group of diverse and integrated empirical techniques and algorithms that have as main goal to represent observed data as it happens in real-life situations when not a single method fits this condition to satisfaction. Mathematical simulation and projection is used in most of the DairyMGT tools. However, it is a core methodology in a group of them. For example, mathematical simulation is used in the grouping tool to calculate feed nutrient requirements for every single cow in a herd; in the timing of pregnancy tool to aggregate the overall milk production and feed consumption a cow will have depending on the time of pregnancy; and in all LGM related tools to generate thousands of replicates and calculate the statistics of net margins that will determine insurance premiums [27]. Also mathematical simulation and projection is important to predict cash flows within the expansion tool and to perform nutrient balances in tools such as dairy dynamic model, dairy nutrient manager, and grazing-N.

3.1.8. Nonlinear Optimization

Nonlinear optimization deals with finding an objective function of maximizing or minimizing a variable within a set of simultaneous constraints, where the objective function or some of the constraints have nonlinear relationships. Nonlinear optimization adds a set of complexity to the implementation of decision support tools because it is computational demanding. However, for some applications it is required. Since finding the global maxima for nonlinear problems it is not always possible, a compromise between finding a satisfactory answer and maintain the applications as user-friendly as possible is needed. Nonlinear optimization is used in the grouping, milk curve fitter, and LGM least cost optimizer tools. For the grouping tool, a nonlinear optimization algorithm groups lactating cows according to nutritional requirements with the objective function of finding the aggregated maximum income over feed cost through recursive iterations by allocating cows to size-defined groups. In the milk curve fitter tool, the user enters farm herd milk production and a nonlinear algorithm minimizes the residual difference between the farm observed data and the predicted data adjusted to a pre-defined milk lactation function such as Wood [28] or MilkBot [29]. The results are coefficients of the defined function that best represent farm-specific lactation curves. The LGM-least cost uses a nonlinear optimization to find out the minimum premium price to a defined target guarantee net income over feed cost according to future projected commodity prices and farm specific conditions, replicating the rules governing the insurance product. The result is the least cost premium for a determined level of coverage within the LGM-Dairy insurance structure [30-31].

3.1.9. Matrix Solution to Multiple Equations

Matrix or algebra simultaneous equation solution is helpful in the area of nutrition and feeding to replace feed ingredients and maintain same level nutritional of the diet and same level of feed intake. It is also useful to value feeds depending on their nutrients content. Each feed ingredient is defined in function of its nutrient contents and its market price. When the number of nutrients equals to the number of feed ingredients (same number of equations as unknowns) the result is an exact value for each nutrient and therefore the predicted value of a feed ingredient is equal to the input value as it is the case in the Optigen Evaluator tool [32]. Similar approach is used for the LGM-feed equivalent, which converts any feed ingredient into equivalents of corn and soybean meal, as it is required for LGM-Dairy insurance contracts. The tool FeedVal 2012 goes beyond and analyzes a set of user-defined matrix between 2 and 50 ingredients and between 2 and 13 nutrients to find out the difference between the feed ingredient market price and the estimated price based on the nutrient composition value of the ingredient.

3.1.10. Database Management and Analysis

Some tools require a database interface and some mechanism of querying the database to retrieve information and to perform analysis dynamically and efficiently. Databases are permanently being updated. Database tools are the lactation benchmark curves and the dairy farm ratio benchmarking. The user does not update these database applications directly, but a server manager. The user queries the database and is able to compare specific farm data with a set of filtered information within the databases. Other type of database application is the feed evaluator tool that registers users in the system and allows them to enter and save their data. The users update the database and the queries retrieve real-time information anytime. Users can then compare their own data against to a filtered group of other farms. A different concept is portrayed in all LGM related tools for which all the data (commodity prices of milk, corn, and soybean meal from the future markets) is retrieved real-time from the official sources anytime the user performs an analysis [29]. The calculation of either LGM premiums or least cost premiums changes depending not only on the user inputs, but also based upon the time of the query. The system saves historical information, so users can also do retrospective analyses.

3.1.11. External Simulation Models

Some tools require to be integrated with more complex, fully developed and established models. That is for example the case of the Dynamic Dairy Farm Model and the Grazing-N tools. In the first case, model requires assessments of crop production (corn, soybean, pastures, etc.), which are performed by using external crop simulation models from the family of Decision Support System for Agrotechnology Transfer [33]. The dynamic dairy farm model feeds the crop simulation model with data of soils, weather, and crop management schemes and the crop simulation models return predicted biomass produced, nutrient utilization, and nitrogen leaching from the soil. The Grazing-N application is integrated with

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the National Research Council model of nutrient requirement for dairy animals [34] according to a set of characteristics that include age, production, and live weight.

3.2. Software Applications

According to the type of application, the methodologies used in the tool, and, most importantly, the goal of the tool as a DSS, different software application approaches were used (Table 1). Most of the tools have been developed in different software applications with the objective of better meeting user styles and therefore capture larger audiences of users.

Spreadsheet applications are a very popular format among dairy farmers and consultants because of their familiarity with them, the possibility of using the same spreadsheet for further analyses, and the capacity of save and maintain a copy of it in a personal computer. Spreadsheet application was the elected method for a number of DairyMGT.info tools (Table 1). Most of the spreadsheet applications, however,required some type of Visual Basic code embedded into the application (macros).

Other group of tools uses Macromedia Flash as the software application. Macromedia Flash has the advantage of having a nice interactive visual interface connected with a calculator. From the point of view of the user, Flash tools are probably the easiest to use. They havethe additional advantage of becoming stand-alone applications and therefore of being used offline or embedded in Power Point presentations or Portable Document Format (PDF) files. One problem with Flash applications is, however, its limited computational functionality. Flash applications have only a set of limited mathematical functions without the possibility of using macros or combinethemwith code programming. Also Flash applications are not compatible with Apple smart phones and tablets. Current tools that are only Flash applications within the DairyMGT.info DSS tools will eventually be converted also to be online applications.

Other group of tools can be classified in the general category of online tools. These use an array of different software applications. What they all have in common is that these work in any web browser and eventually in any device and in any platform including smart phones, tablets, Apple, Linux, PC, etc. Calculations and analyses are normally performed in the DairyMGT.info web server, so the online tool is only an interface between the device of the user and the server. In general, online tools are very efficient and reliable tools that have the advantage to be always up-to-date: users always experience the latest version of the tool. Other important advantage is that complex processes and mathematical calculations can be managed using a combination of web code such as HTML (hyper text markup language), PHP (hypertext preprocessor), JavaScript (prototype-based scripting language), C (general-purpose language), CSS (style sheet language), MySQL (relational database management system), or others. Another advantage of online tools is that their design layout can be very efficient and solid once the tool is deployed. A drawback for developing online tools, however, is the need of expertise in web-based code writing. Nonetheless, online tools are very efficient and probably a trend to which many of the tools of DairyMGT.info will continue to gravitate.

4. Illustration and Practical Decision-Making

4.1. Group Feeding

The value grouping feeding strategies was analyzed by applying the grouping tool to 30 dairy farms in Wisconsin. Test records were collected and adjusted to datasets consisting of cow identification, lactation, days after calving, milk production, and milk butterfat for each cow in each farm. The aim of this exercise was to demonstrate the value of grouping compared to no grouping without knowing studied farms' actual feeding strategies. Therefore, same procedure and assumptions were followed on each analyzed farm: 1) comparison of no grouping versus 3 same-size groups, 2) prices at $15.89/45.4 kg milk, $0.14337/0.454 kg CP, and $0.1174/4.19 mega joules (MJ) net energy, 3) average body weight of 500 kg for first lactation cows and 590 kg for cows in second and later lactations, 4) requirements of CP and net energy at the 83rd percentile level of the group (mean + 1 standard deviation), and 5) a cluster grouping criterion (grouping cows depending on their CP and net energy requirements for maintenance and milk production).

Evaluations clearly and consistently demonstrated that the income over feed cost (IOFC) in all analyzed farms was greater for the 3 feeding groups strategy than the no groping strategy (Table 2).

	Number of lactating cows on analyzed farms (n = 30)	No grouping IOFC	3 same-size feeding groups IOFC	Additional IOFC of doing 3 same-size feeding groups
		----------$/cow per year----------		
Mean	788	2,311	2,707	396
Minimum	<200	697	1,059	161
Maximum	>1,000	2,967	3,285	580

Table 2. Comparison of income over feed cost (IOFC) of no grouping versus 3 same-size feeding groups for Wisconsin dairy farms assessed by the tool: *Grouping Strategies for Feeding Lactating Dairy Cattle*.

The analysis indicated that farms could realize between $161 and $580/cow per year (mean = $396) of additional IOFC by switching from no grouping to 3 same-size feeding groups using the cluster criterion for grouping. These values represented an increase of between 7 and 52% of farm calculated IOFC. It was concluded then that grouping would have important economic implications in farm profitability and that further analysis should be done at farm-specific level and in a permanent basis by using the *Grouping Strategies for Feeding Lactating Dairy Cattle* DSS tool.

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4.2. Sexed Semen

The *Economic Value of Sexed Semen for Dairy Heifers* tool was used for general conditions of Wisconsin dairy farms based on data of a sample of 309 dairy farms and 38 custom heifer growers, a survey performed by county extension agents [35]. At the time of the analysis, using the aggregated data of the 347 operations, the average economic benefit of using sexed semen, as calculated by the tool, was $30 per heifer. Results confirmed that most of these farmers were using optimally this new technology. They were using it for first and second service only, which was the same optimal strategy found by the tool [35]. A main conclusion of this analysis was that the sexed semen technology has an economic benefit, but it would be mostly recommended when the conception rate of the sexed semen is at least 80% of the conventional semen, the value of the heifer calf is high, and when the price of the sexed semen is twice or less than that of the conventional semen. Due that the conception rate of both the conventional and sexed semen and the market prices are important determinant parameters, a main recommendation was that the analysis should be performed on a farm-specific basis and on a permanent basis, for which the decision support tool plays an important role.

4.3. Dairy Reproductive Economic Analysis

Published data along with dairy farm records were collected and summarized to create a representative farm to assess the value of improving reproductive efficiency measured as improving the 21-day pregnancy rate using the tool *Dairy Reproductive Economic Analysis*. Data consisted of detailed information on transition probabilities arrays of replacement and abortion risks; definition of lactation curves, and several economic parameters. Then, the DSS was used multiple times to represent incremental gains in reproductive efficiency.

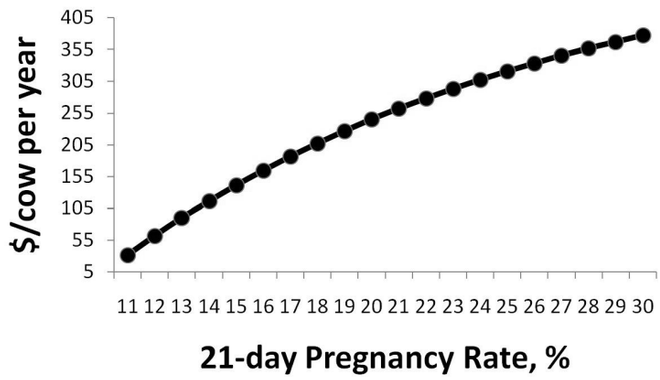


Figure 7. Projected net economic gain of improving 21-day pregnancy rate from a baseline of 10% assessed by the tool: *Dairy Reproductive Economic Analysis*.

Figure 7 portrays a marginally decreasing trend of economic gain with respect to 21-day pregnancy rate: the higher the original 21-d pregnancy rate, the lower the gain. Nonetheless the tool shows clearly that even at 30% 21-day pregnancy rate, an extremely (and unusual) good pregnancy rate, there is still an opportunity of additional gains because of improved reproductive efficiency. The tool, furthermore presents the main factors from which the additional value

comes (in order): higher milk income over feed cost, lower culling costs, higher calf revenues, and lower reproductive costs. These results are being used in a large extension undertaking to promote improved reproductive efficiency in hundreds of dairy farms, but always with the final recommendation that specific farm data and information from current market conditions should be used with the DSS tool to have a more precise assessment.

4.4. Decision Support System for Expansion

Three hundred dairy farms completed a mailed questionnaire regarding their desires and needs of expansion or modernization [36]. Seventy eight percent of farms (26% of respondents) indicated that were planning to expand or modernize their installations and listed as the most important reason of doing that the expected increase on farm net return. Importantly, they acknowledge largely the uncertainty of the process of expansion as a large hindrance and therefore they asked for decision support tools that would allow them project systematically their options and analyze scenarios. More than 20 of these farmers were then contacted and offered to perform those projections by using the tool *Decision Support System Program for Dairy Production and Expansion*. The overall outcome was that all farmers visited agreed that the tool represented reasonably well their farm sand therefore they would trust its future projections. Further analyses were used to confirm or reject their pre-conceived evaluations and to assist farmers to make more informed decisions throughout the process of expansion or modernization. More than 10 farmers did some adjustments in their expansion or modernization process because of the tool and all of them indicated will continue using the DSS tool throughout their expansion or modernization operation.

4.5. The Economic Value of a Dairy Cow

Representative data from Wisconsin farms were collected from official sources, farm records, and market reports to become a baseline scenario [20] from which users could select modifications according to their own conditions. Results of these data contained in the tool *Economic Value of a Dairy Cow* indicated that the expected milk production of the cow was the single most important factor for replacement decisions. The impacts of increasing or decreasing up to 20% (120 to 80 in Table 3) the average milk production of a cow, a reasonable assumption, are portrayed in Table 3. It is evident that the milk production expectancy of following lactations is a much more important factor for pregnant cows whereas the impact of milk production expectancy of this lactation and future lactations are similarly important factors for non-pregnant cows.

Although these numbers are good indicators for farm decision-making, the need of using the tool with specific farm conditions and under current market condition could not be over emphasized.

This tool *Economic Value of a Dairy Cow* was also used to value the animal farm assets in a farm. The tool was first set with all parameters concerning to the specific farm and with economic variables representing the market conditions. Followed, the farmer created a list of all cows in the farm including their current state (lactation, month after calving, and pregnancy status) and, importantly, their projected milk production. Then, a cow value was calculated

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for every single animal in the herd. Finally, the calculated salvage value was added to the cow value. The farmer was then able to use these data for continued monetary support from a financial institution.

Expected Milk Production (% of the average cow)		Cow Value of a 2-month pregnant, 8-month after calving cow, $			Cow Value of a non-pregnant, 7-month after calving cow, $		
Rest of Lactation[1]	Successive Lactations[2]	1st Lactation	2nd Lactation	3rd Lactation	1st Lactation	2nd Lactation	3rd Lactation
120	120	2,458	2,038	2,002	1,973	1,485	1,462
120	100	1,045	877	829	1,109	857	814
120	80	-380	-284	-345	244	230	165
100	120	1,891	1,499	1,477	1,184	796	809
100	**100**	**479**	**338**	**304**	**320**	**168**	**161**
100	80	-934	-823	-870	-545	-460	-487
80	120	1,325	961	952	395	106	157
80	100	-88	-200	-221	-469	-521	-491
80	80	-1,501	-1,361	-1,395	1,344	1,149	-1,139

Table 3. Impact of expected milk production on the cow value of a 2-month pregnant, 8-month after calving cow and a non-pregnant, 7-month after calving cow assessed by the tool *Economic Value of a Dairy Cow*. Bolded values represent the cow with average production in the herd (100%). [1]Cow's expected milk production (% of the average cow) from the current state to the end of the present lactation. [2]Cow's expected milk production (% of the average cow) in all successive lactations.

4.6. The LGM-Dairy Least Cost

During the months LGM-Dairy revenue insurance program was offered in year 2011, the average savings when using the LGM-Dairy Least Cost tool was 27.8% (Table 4). The tool was used during those months to assess the premium cost for a 200-cow farm producing 31 kg milk/cow per day. Based on experience and expertise with a number of dairy farmers and consultants in Wisconsin, the strategy was to insure a minimum income over feed cost of $5/46.4 kg milk during the effective insurance period that is 10 month s per contract (starting 2 months after the contract month).

Considering that the level of insurance protection is exactly the same whether to paying the regular premium or a least cost premium in Table 3, the savings are substantial. The main difference between regular and least cost premiums is the allocation of milk and feed being insured according to the covered months in the future. In the regular premium, the default situation is to assign the same level of milk quantity for protection every month. The least cost optimization, however, finds a better allocation that based on the

underline simulated data determines a better plan that results in a much lower premium, but the same level of protection.

Month	Regular Premium, $	Least Cost Premium, $	Savings on Premium, %
January	4,384	3,389	22.7
February	4,904	3,429	30.1
March	5,209	3,863	25.8
October	4,019	2,685	33.2
November	4,216	3,064	27.3

Table 4. Savings on premiums when insuring net margins using the LGM-Dairy insurance program during the year 2011 assessed by the tool *LGM-Dairy Least Cost* using default amounts of corn and soybean meal as feed insured and assuming a reasonable insurance deductible of $1/46.4 kg milk for a 200-cow dairy farm producing 31 kg milk/cow per day.

4.7. Dynamic Dairy Farm Model

The *Dynamic Dairy Farm Model* was applied on a typical North Florida dairy farm of 400 cows with a production of 7,711 kg/cow per year having 62 ha of crop fields and pastures. A dual optimization including maximization of profit while relaxing N leaching indicated that the nitrogen leaching ranged between 4,800 to 5,000 kg/year whereas the profit would change between $70,000 and $70,600 (Figure 8) [2]. Furthermore, strategies to reduce nitrogen leaching would compromise profit. Depending on the farm goals and environmental regulations, the *Dynamic Dairy Farm Model* proved to be an effective tool to screen options and study whole farm management strategies. As in previous cases, farm specific conditions along with current market conditions need to carefully be defined before doing those assessments.

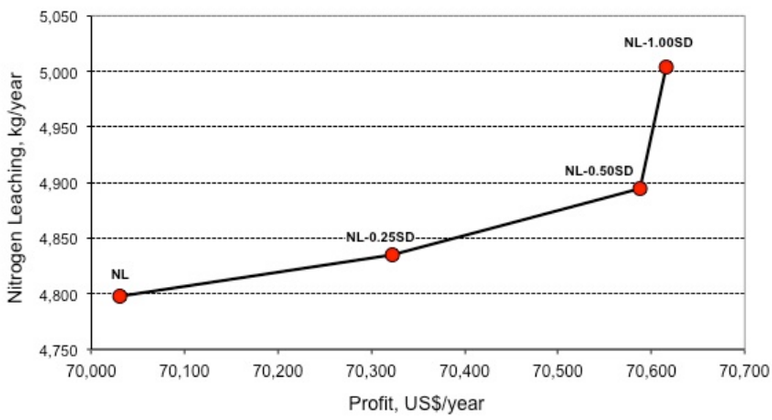


Figure 8. Dual optimization of profit maximization by relaxing nitrogen leaching assessed by using the tool *Dynamic Dairy Farm Model*. NL is average nitrogen leaching and SD is standard deviation.

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5. Evaluation of Dissemination and Adoption: Potential Impact

Following is some evidence that indicates the DairyMGT.info Website has become the place-to-go for decision-making tools related to dairy farm management in Wisconsin and a trusted reference with increased visibility in other states and internationally. The DairyMGT website was officially launched at the end of 2009. A predecesor webpage existed since June 2008. between April 2012, and a rate of when email registration was required. According to *Google Analytics (http://www.google.com/analytics/)* the Wisconsin Dairy Management domain (DairyMGT.info or DairyMGT.uwex.edu) received 45,307 page views during the year period ending on April 30, 2012. Fifty nine percent were visitors from the U.S.A. and the rest from other 135 countries. From these, the most important countries were: India (5.5%), Australia (3.3%), Argentina (2.6%), Canada (1.9%), Mexico (1.8%), Kenya (1.6%), United Kingdom (1.5%), Italy (1.5%), Turkey (1.3%), Brazil (1.2%), Peru (1.2%), South Africa (1.0%), Pakistan (1.0%), and Spain (1.0%). Inside the U.S.A., visitors came from all states, but 63% of them were from Wisconsin. Other important states were: California (7.4%), Minnesota (3.1%), Illinois (2.8%), New York (2.6%), Iowa (1.6%), Texas (1.5%), Florida (1.3%), Pennsylvania (1.3%), Michigan (1.3%), and Washington (1.0%).

During the same period of time, May 2011 to April 2012, 1,635 users of decision support tools elected to register their emails on the DairyMGT.info system. A thousand and fifty five did it during the months of 2011, a period in which email registration was optional. During January-to April 2012 a rate of 5 emails registrations a day was recorded. During the one year period May 2011 to April 2012 there were 9,336 downloads of the top 25 DSS tools as shown in Table 5.

Rank	Decision Support Tool	Downloads
1	The Wisconsin Dairy Farm Ratio Benchmarking Tool	1,280
2	LGM-Dairy Insurance Related Tools	1,279
3	Dairy Reproductive Economic Analysis	1,030
4	Corn Feeding Strategies	655
5	UW-DairyRepro$: A Reproductive Economic Analysis Tool	592
6	Optigen® Evaluator	482
7	Economic Analysis of Switching from 2X to 3X Milking	479
8	Lactation Benchmark Curves for Wisconsin	454
9	Grouping Strategies for Feeding Lactating Dairy Cattle	432
10	Heifer Break-Even	346
11	Milk Curve Fitter	313
12	The Economic Value of a Dairy Cow	312
13	Decision Support System Program for Dairy Production and Expansion	252
14	Economic Value of Sexed Semen Programs for Dairy Heifers	245

Rank	Decision Support Tool	Downloads
15	Dairy Ration Feed Additive Break-Even Analysis	240
16	Herd Structure Simulation	228
17	Milk Component Price Analysis	218
18	Heifer Replacement	215
19	Exploring Timing of Pregnancy Impact on Income Over Feed Cost	196
20	Dynamic Dairy Farm Model	156
21	Cost-Benefit of Accelerated Liquid Feeding Program for Dairy Calves	113
22	Dairy Nutrient Manager	98
23	Grazing-N: Application that Balances Nitrogen in Grazing Systems	97
24	Economic Evaluation of using rbST	90
25	Seasonal Prediction of Manure Excretion	48

Table 5. Ranking of the most downloaded tools of DairyMGT.info Decision Support System tools during the period May 2011-April 2012.

A number of tools have been adjusted and translated to other languages to better represent conditions in other regions or in other countries following user inquiries and requests. This was the case for the tools: *Economic Value of Sexed Semen for Dairy Heifers*, *UW-DairyRepro$: A Reproductive Economic Analysis Tool*, *Value of a Springer*, and *Income Over Feed Supplement Cost* translated to Spanish and adjusted to Argentinian conditions. The *Economic Value of Sexed Semen for Dairy Heifers* tool was in addition translated to Chinese.

Another evidence of DairyMGT.info DSS demand is the world wide requests for talks regarding these tools. During the past 4 years (May 2008 to April 2012) 168 talks have been given regarding DairyMGT.info tools, a rate of 3.33 talks per month. These talks had a total attendance of about 6,500 people. One hundred and twelve of these talks were in Wisconsin (3,200 people); 25 in other states (1,700 people), and the rest, 31, in other countries such as Mexico, Chile, Peru, Argentina, Honduras, and Nicaragua (1,600 people).

Evidence of adoption together with functionality and benefits of the DSS tools can also be measured by comments and feedback reported by users and other stakeholders. Some anonymous test imonials about DairyMGT.info DSS Tools are listed below.

- "The Income over Feed Supplement Cost is a very useful tool that allows me to find out the best ingredients to buy and provide clear and practical advise in a number of clients I work with" – A dairy farm nutritionist.
- "I have used the tool 2X to 3X milking with a number of farms and consultants and it has always been well received. It does an excellent job of determining the economic impact of switching milking frequencies." – A county Extension agent.

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- "The Optigen tool is a very simple application, yet it makes a quite powerful impact because it opens a realm of opportunities in the field." – A dairy industry service provider.
- "…the Sexed Semen evaluator brings very useful information and it is a tool that people can really use and apply within field situations. This is a very useful tool" – A veterinarian attending dairy farms.
- "I think that the information and spins of using the Income over Feed Cost database tool are great and powerful" – A dairy farm consultant.
- "The tools related to economic evaluations of reproductive programs in dairy cattle are going to be incredibly useful." – A dairy Extension specialist.
- "The State of Wisconsin has led the nation in number of contracts and milk insured under the LGM-Dairy program, which reflects, at least in part, the usage and practical application of the LGM-Dairy Analyzer tool of the UW-Madison" – An Extension specialist. "[The LGM-Dairy Analyzer] …is having a direct and measurable impact [in our dairy industry]" – A University administrator.
- "We are defining reproductive strategies for our herd and we found invaluable the use of the [DairyMGT.info] management tools in our planning design. We specially appreciate the clarity of the applications and the simplicity of concepts that make these tools very practical and applicable." – A dairy farm manager of several dairy farms.
- "The [DairyMGT.info] decision support tools have really helped out our dairy farm in may aspects including financials, replacements, reproduction, and even nutrition." – A senior dairy science student and dairy farmer.
- "These [DairyMGT.info tools] are a collection of the most practical tools I have ever seen." – A well-established county Extension agent.

6. Future Developments: Keep Up with Technology and Needs

A number of emerging and evolving technologies are today available to dairy farmers more than ever. These include the use of smart phones, tablets and similar hardware devices; more efficient software resources; and improved data networks. There is no doubt the trend of fast technological improvement in the area of computer, software, and gadget development will continue even at a faster pace. Progressive farmers and an increasing proportion of Extension agents and dairy farm consultants are already using these technologies. New technologies bring challenges to keep information systems up-to-date, but at the same time bring great opportunities for improved DSS development.

One important advantage of smart phones and tablets is their portability along with connectivity. Nowadays farmers enjoy voice and, importantly, data network and therefore the capability to save and retrieve data eventually from anywhere at anytime. For example, a farmer can have complete information of a cow (e.g., age, lactation, pregnancy status, pro-

duction history, today's production, genetic background, health incidence, etc.) at the time the cow is being registered through a smart phone system whether the cow is in a corral, in the milking parlor, or out in the field grazing. This gives the farmer the opportunity to make critic a land time-sensitive decisions right away. This could be one of the major benefits of smart phones and tablets applications. Decision support systems have to be integrated with these new technologies and need to take advantage of these important advantages.

One drawback, however, of smart phones and tablet applications is their restricted screen size and some hardware and software limitations. Applications need to be especially designed for smart phones and tablets. Normally, the information entered and retrieved would need to be summarized or would require additional layers of navigation. Extra design details could, though, lead to more compact, more intuitive, and overall more efficient DSS.

There is a trade-off of functionality and payback. The industry seems to favor both types: application for conventional computers and laptops in addition to those applications for smart phones and tablets. The decision-maker selects what type of tool to use for a particular situation. From the developmental standpoint, this is an additional challenge that requires additional work and expertise.

Important considerations regarding upcoming and developmental technologies are the increasing need for integration of DSS with information systems currently used in a farm. Most of the farmers are already using some type of software or information systems for operational management such as feeding, general record keeping, reproductive synchronization programs, identification, heat devices, or others. The DSS portrayed in this chapter and similar have the opportunity of becoming a bridge among these information systems. Decision support systems can use live information from farm records and provide predictions that go beyond the simple record keeping summaries. Farmer expertise combined with real-time DSS projections using farm record keeping systems is a powerful combination for efficient and effective decision-making in dairy farm management.

7. Conclusion

More than 30 computerized decision support system tools have been developed to assist dairy farmers in their continuous decision-making needs. All these tools are openly available at http://DairyMGT.info under the *Tools* section. Tools are grouped in major management areas of dairy farming such as feeding and nutrition, reproductive efficiency, heifer management and replacement, production and productivity, price risk management and financial assessment, and environmental stewardship. A number of methodologies and combinations of methodologies as well as different software applications were used to develop these decision support systems with the ultimate goal to always provide solid, but still user-friendly management tools for dairy practical farm decision-making. Methodologies included partial budgeting, cost benefit, decision analysis, enterprise budgets, linear programming, Markov chains, mathematical simulation and projection, nonlinear optimization, matrix solution, database management, and use of external simulation models. Software used to develop the tools included Macromedia Flash, HTML, PHP, JavaScript,

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C, CSS, MySQL, Spreadsheet applications, and executable programs. The DSS have proven to be effective decision-making tools for improved dairy farming operation. Large dissemination and impact of these DSS tools can be verified by having 9,336 downloads of these DSS tools during the one-year period between May 2011 and April 2012 and the request of 168 talks with 6,500 people in attendance across the world during the 4-year period between May 2008 and April 2012.

Acknowledgements

The development and maintenance of the DairyMGT.info tools has been possible by the partial support of several extra-mural grants: Agriculture and Food Research Initiative from the USDA National Institute of Food and Agriculture Competitive Grants No.: 2010-51300-20534, 2010-85122-20612, 2011-68004-30340 and several Hatch grants to V.E.C from the College of Agriculture and Life Sciences at the University of Wisconsin-Madison. Acknowledgement is extended to a number of people involved at different levels in the development of these tools; Collaborators: B.W. Gould, R.D. Shaver, M.A. Wattiaux, L. Armentano, J. Vanderlin, K. Bolton; Students: J.O. Giordano, J. Janowski, M. Valvekar, E. Demarchi, A. Kalantari; Programmers: A. Kalantari, N. Suryanarayana, K. Nathella, V. Vats, A. Gola.

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