# An Economic Analysis to Feeding Legume Forages to Organic Dairy Cows

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# I. INTRODUCTION

Demand for organic dairy milk rose in the 1990s in the Upper Midwest and Northeast (USDA-ERS, 2010) as an increasing number of consumers switched to a milk product free of pesticides, growth hormones and antibiotics. Yet, in recent years, the demand for organic dairy milk has diminished. Consumers are drinking less milk on average, with daily per capita consumption of fluid milk decreasing. Between 1990 and 2019, daily consumption fell from 0.78 cup to 0.49 cup, a 37 percent decrease (Stewart & Kuchler, 2022).

Furthermore, rising feed costs and declining milk prices pose new obstacles for dairy farmers, particularly in the Midwest and Northeast. Given that feed costs account for 60 to 70 percent of a dairy farm's production costs, increases in these costs impose increased financial strain on producers (Strauch & Stockton, 2013). Additionally, milk prices directly impact a farmer's revenue. Therefore, when demand for milk is low, milk prices are reduced, ultimately negatively affecting dairy famer's profit. Faced with these challenges, dairy farmers must optimize feed costs and improve milk quality to secure favorable milk prices, even during periods of low demand.

As a solution, organic dairy farmers are seeking to implement alternate feeding methods and feed types to minimize feed costs and enhance milk quality, allowing them to take advantage of industry premiums. One such solution is substituting a portion of feed with legume-forages in pasture rotation, as an alternative feed source. Legume forages optimize the nutritional value of a cow's diet due to their rich protein content and broad spectrum of nutrients, compared to grass, which enhances milk quality by increasing both fat and protein content. This improvement in milk content boosts profit for dairy farmers. In addition, feed costs are reduced when cows graze legume pastures during the grazing season, May to October, as they require less supplemental feed, with legume pastures serving as their primary source of feed.

In this study, the profitability of incorporating legume-based forage diets is analyzed. The analysis in this study compares the economic considerations associated with organic milk and organic grazing milk production. Organic dairy milk production entails feeding cows forages only 53 percent of the time, while organic grazing milk production entails feeding cows forages 80 percent of the time (Benbrook et al., 2018). Three distinct organic legume-grazing production scenarios are compared to organic milk production to analyze profit differences between the two.

Incorporating a legume-based pasture as a source of feed requires renovating a third of the grazing pasture every three to five years, which is a large financial investment. These costs must be factored into the decision-making process to accurately evaluate the total costs and revenues. While it is well documented that legume-grazing has been shown to have benefits on cow health, conducting economic analysis is necessary to establish whether improvements in cow health from legume-grazing can translate to increased profit for dairy farmers.

In addition to providing farmers with deeper insight into the economic profitability associated with implementing this method, this research seeks to present a broader perspective on the advantages of incorporating legumes beyond profit considerations. These advantages include capitalizing on “grass-fed” and specialized milk market premiums, enhancing milk nutritive value and promoting environmental sustainability.

*RESEARCH OBJECTIVES*

This research aims to conduct a comparative analysis of the profitability associated with increasing forage legume proportions in dairy cow diets. The basis of this study lies in feeding trials conducted at the University of New Hampshire (UNH) and the West Central Research and Outreach Center (WCROC), where legumes were incorporated into forages for cow grazing. Legumes targeted include red clover and alfalfa, which are common to pastures in the Northeast and Midwest in the United States, where the feeding trials were conducted. The data collected for this study include annual revenues and costs for the year 2021 for each legume-based diet. The data were analyzed using stochastic partial budgets. The research outcome aims to provide valuable insights for decision making to enhance the profit potential of organic dairy farmers, while also diversifying feed sources.

The subsequent sections of this thesis are structured as follows: firstly, an overview of existing literature pertaining to legume forages, partial budgets, and Monte Carlo Simulations is presented. Then, methods employed for this study are outlined, followed by a description of data used. Finally, results from the study are presented and their outcomes are discussed.

## II. LITERATURE REVIEW

While many perceptions exist regarding the distinctions between organic and conventional farming, there are specific differences that exist between them. Organic farming involves producing products from animals without the use of growth hormones and antibiotics. Unlike conventional farming, organic farming abstains from using conventional pesticides and fertilizers made with synthetic ingredients (USDA-NIFA, 2012). Organic farms rely on crop rotations and natural fertilizers, such as manure, which improve soil fertility, as an alternative to synthetic pesticide use and genetically modified organisms (**GMOs**) (Pradhan et al., 2018; Gomiero et al., 2011). Conventional farming involves using synthetic fertilizers, pesticides, and genetically modified seeds to promote fast growth, disease resistance and high yields (USDA, 2015).

Comparing conventional and organic dairy farming, the strongest distinctions between the two are in milk composition, milk yield and the environmental impacts associated with their production. Of these aspects, nutritional components of milk stand out as a common incentive for consumers to purchase and consume organic dairy milk, given its perceived healthier benefits as compared to conventional dairy milk. Studies have shown that three daily servings of organic milk may provide as much as 32 percent of daily omega-3 needs for women and 22 percent for men. In comparison, conventional dairy milk supplies less than half of these quantities (Benbrook et al., 2018;). Omega-3 fatty acids are essential to human nutrition as they are part of the structure of the membranes surrounding every cell in the human body (National institute of Health, 2023). Many studies find that omega-3 fatty acids have a multiplicity of health benefits, including reduced heart disease risk, increased cognitive well-being and reduced cancer risk (Ruxton et al., 2004; Dighriri et al., 2022; Swanson et al., 2012; Hardman, 2002; Simopoulos, 2002). As evidenced by numerous studies, organic milk contains high levels of fatty acids, in particular, omega-3 fatty acids (Butler et al., 2011; Brodziak et al., 2021; Ellis et a.l, 2006; Bergamo et al., 2003; Heins, 2013) in contrast with conventionally produced milk. The higher fat content in organic dairy milk can be attributed to the higher volume of forage fed to organic dairy cows, as compared to conventional dairy cows (Heins, 2021), given that organic dairy cows are required to graze pasture for at least 120 days (Rinehart & Baier, 2011) during the grazing season.

The higher fat content in milk is even more relevant for organic grazing cows, as they depend even more heavily on pasture grazing as their primary source of feed compared to traditional organic dairy cows, which rely on a combination of forage and supplemental feed mixtures. During the grazing season, May to October (Heins, 2018), grazing cows consume pasture grass that is rich in nutrients, such as omega-3 fatty acids and conjugated linoleic acid (**CLA**). During the non-grazing season, grazing dairy cows consume feeds including forages such as alfalfa, grass, and clover (Heins, 2021). Benbrook et al. (2018) found that cows fed a diet of organic grass and legumes produced milk with high omega-3 and CLA content. Additionally, the omega-6/omega-3 ratio of grass and legume-fed organic cows' milk is nearly 1 to 1, a desirable ratio, compared to 5.7 to 1 in conventional dairy milk (Benbrook et al., 2018). Thus, these findings suggest that the contents of organic grazing milk are a nutritionally beneficial alternative to conventional dairy milk for consumers.

In addition to nutritional differences, organic grazing dairy milk and conventional dairy milk differ in their yield. Organic grazing milk yield is lower than conventional milk yield (Roesch et al., 2005; Schwendel et al., 2015; Sundberg et al., 2009; Hanson et al., 1998) as organic dairy cows produce about 30 percent less milk than conventional dairy cows (McBride &

Greene, 2009). These dichotomous outcomes can be attributed to the type of feed the cows consume and their grazing habits (Becker & Stone, 2020). Organic grazing dairy cows consume high quantities of forage-based feeds, compared to conventional cows, which are primarily fed using a method known as Total Mixed Ration (TMR) (Heins, 2021). TMR is used to provide cows a balanced diet with a variety of feeds, including grains and concentrates such as minerals, protein, vitamins, and other additives, all in one feed mix (Linn, 2020). This method supplies cows with a complete diet, providing the energy needed to maximize milk production. Organic cows grazing forages have a comparatively less complete diet, given they are not primarily fed TMR diets. The diet of organic grazing dairy cows consists of 80 percent forage-based feeds and 20 percent TMR. In contrast, organic cows that do not rely on rotational grazing have a diet consisting of 53 percent forage-based feeds and 47 percent TMR (Benbrook et al., 2018). Santa et al. (2022) studied the effects of grazing pasture diets and TMR diets on milk production and found that cows fed primarily TMR produced more milk than organic grazing cows due to their higher intake of concentrates and a consistent balanced ration. As a result, milk yield greatly differs between organic cows that rely on grazing pastures and cows fed primarily TMR. This is also shown in Figure 1, which illustrates the differences in annual milk yield for conventional and organic Minnesota dairy farms, using FINBIN and USDA data for 2021. [1] While annual milk yield was 24,271 pounds (USDA-ERS, 2016) and 25,030 pounds (FINBIN, 2023) for conventional dairy farms in 2021, annual milk yield was much lower for organic dairy farms, at 13,376 pounds (USDA-ERS, 2016) and 16,014 (FINBIN, 2023).

[1] USDA-ERS data for this figure was sourced from 2016 milk production reports and was inflated to 2021 using the CPI inflation calculator. All costs were multiplied by 1.3 given an average inflation rate of 3.58% per year between 2016 and 2021.

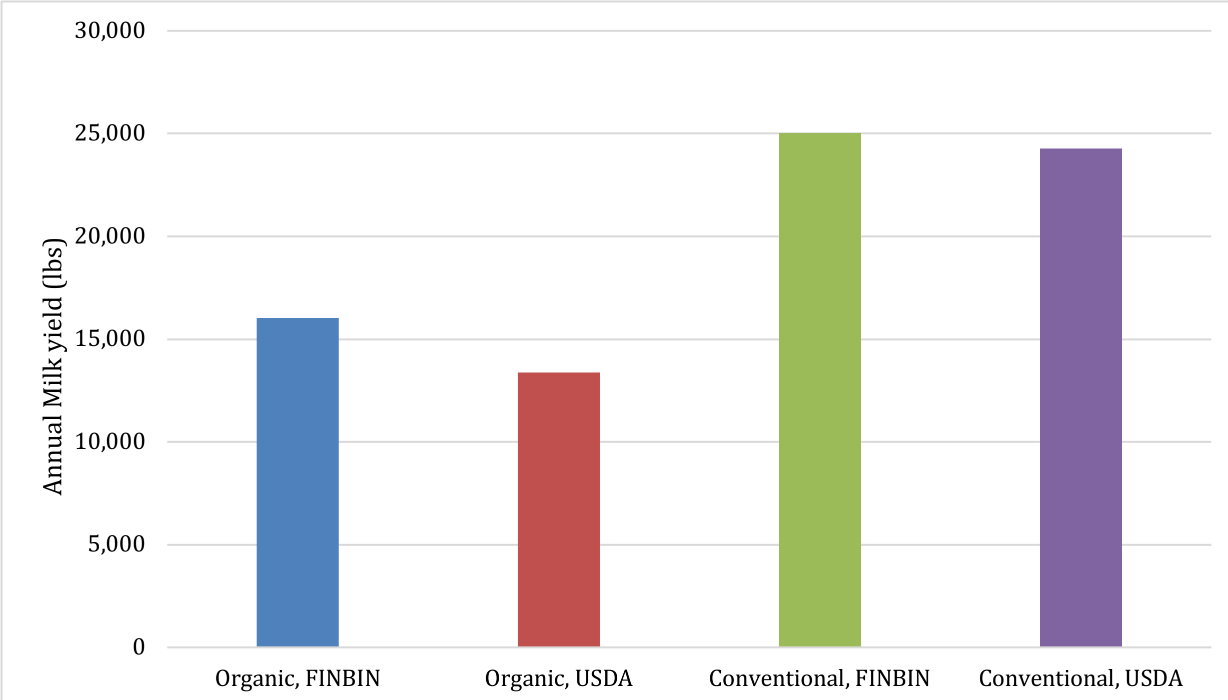

Figure 1: Average Annual Milk yield per Cow Comparison, for Organic and Conventional Milk in 2021.
Sources: FINBIN (2023) http://finbin.umn.edu,
USDA, (2016, a) https://www.ers.usda.gov/media/10023/milkall2016.xls ,
USDA, (2016, b)https://www.ers.usda.gov/media/10025/milkorg2016.xls

Though milk yield is lower for organic grazing cows, the 'organic' attribute of organic grazing milk enables producers to receive a significant price premium (Dimitri &Venezia, 2007). Using retail purchase data, Smith et al. (2009) found that organic price premiums for half-gallon whole organic milk were up to 68 percent above conventional whole milk prices, while skim organic milk prices were up to 109 percent above conventional skim milk prices. Figure 2 illustrates milk prices, which were consistently higher from 2008 to 2022 for organic milk than for conventional milk (USDA-AMS, 2023). Given that organic milk farmers incur higher production costs than conventional milk farmers, such as organic feed costs, certification costs and increased labor costs (MacDonald, 2020; McBride& Greene, 2010), organic dairy milk requires higher retail prices (Becker & Stone, 2020). In addition, consumers are willing to pay higher prices for the perceived health and environmental benefits associated with organic milk consumption and production (Smith et al., 2009; Yormirzoev et al., 2021).

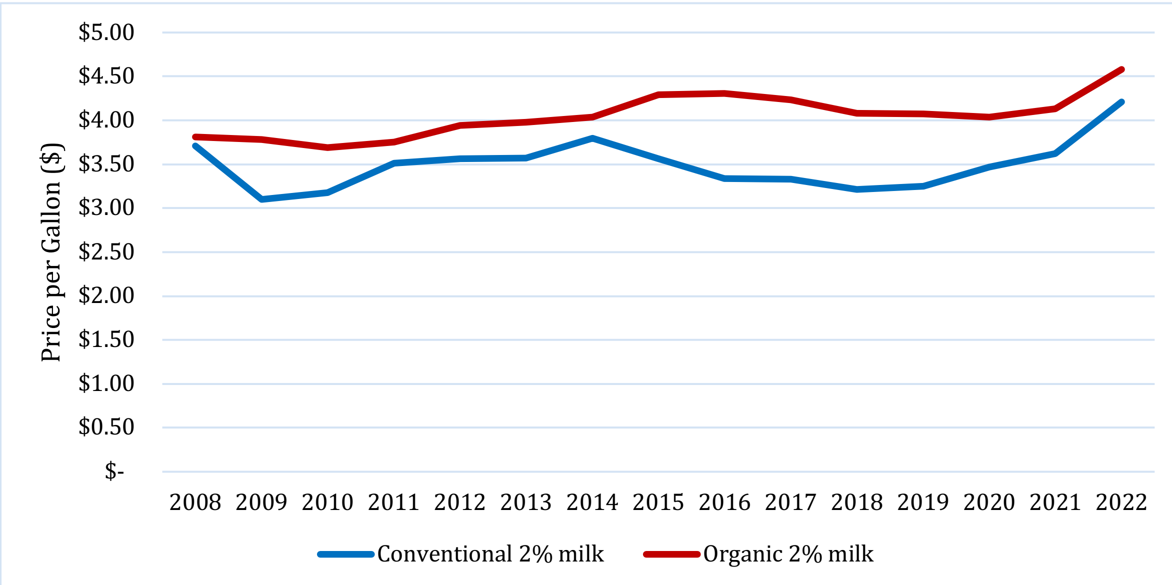


Figure 2: Comparison of 2% Conventional and 2% Organic Milk Prices Received, 2008-2022.
Source: USDA-AMS (2023) https://www.ams.usda.gov/mnreports/lsmdairycomp.pdf

The transition from conventional dairy production to organic grazing production does not simply have nutritional, yield and pricing implications. It is increasingly well documented that organic grazing dairy farms produce less greenhouse gas (**GHG**) emissions than conventional dairy farms (Biernat et al., 2020; Hanson et al., 1998). Bos et al. (2014) found that GHG emissions were up to 10 percent lower for organic dairy farms compared to conventional dairy farms. Conventional dairy producers utilize nitrogen fertilizers to grow crops to produce feed for their livestock. However, up to 50 percent of nitrogen from fertilizers is utilized by crops (The Royal Society, 2020), while the remaining nitrogen is released into the air in the form of GHG emissions (US EPA, 2022). Given that organic dairy farms do not rely on nitrogen fertilizers, their GHG emissions are substantially lower (Gomiero et al., 2011; Muller et al., 2017; Walling & Vaneeckhaute, 2020). Legume-enriched forages, pasture forages planted using legume seeds, have the ability to fix atmospheric nitrogen, reducing the need for synthetic fertilizers and decreasing emissions from fertilizer application (Brito & Khan, n.d.). Incorporating legume-enriched forages plays a strong part in reducing emissions from organic dairy production. Additionally, using legume-based forages can provide economic benefits to farmers through improved animal health, ultimately optimizing milk quality (Cooke, 2011).

### *LEGUME FORAGES*

Implementing legume forages as a feed source offers a multitude of economic and environmental benefits for dairy producers. From elevating feed nutritional content and optimizing milk nutritional value, to reducing the ecological footprint of dairy production, legume forages offer a way for producers to increase profit through enhanced milk quality, in a more environmentally sustainable way.

Incorporating legumes such as such as soybeans, red clover, white clover, alfalfa, and birds foot trefoil, enriches the nutritional value of feed. Legumes have high levels of energy content, compared to grass silages (Brito & Khan, n.d.), a crucial factor that enhances the diet and overall health of dairy cows. As a result, cows can convert nutrients from legumes into milk with increased levels of butterfat and protein, subsequently enhancing milk quality (Cooke, 2011) and enabling producers to maximize their potential for industry premiums.

In addition to the added value legumes provide to milk quality, legume forages are key to optimized levels of energy: protein **(E:P)** balance in milk (Ball et al., 2001). Dairy science studies (J. G. Linn, 1988; Brito & Khan; Weller et al., 2002 ) reveal that the quality of the forage grazed is directly correlated to the quality of the milk produced. Legumes increase the quality of forages compared to grass forages because of their nutritional benefits, as legumes have less fiber, but higher protein concentration than grass-based forages.

In addition to improving milk quality, legume forages are environmentally sustainable (Herrero et al., 2013). The use of legume forages substantially decreases the need for nitrogen fertilizer, reducing the general carbon footprint of dairy producers (Herrero et al., 2013). This is because legume-based forages support biological nitrogen fixation, an environmentally friendly source of fertilizer which improves soil fertility (Crews & Peoples, 2004). Nitrogen fixation refers to the process of converting atmospheric nitrogen into ammonia (Dixon & Kahn, 2004). A systems synthesis study was conducted to assess the impacts of changes in management on nitrogen losses, including incorporating the legume white clover as an alternative to nitrogen fertilizers. The results found that adding this legume into forages improved milk and soil quality, while reducing greenhouse gas emissions (Jarvis et al., 2012).

*PARTIAL BUDGETS*

The partial budgeting model is frequently used in dairy science literature to demonstrate the most profitable option for managerial purposes. Partial budget models are used to analyze the economic impact of management changes on producer profit. The analysis compares the current management practice implemented to an alternative one (Roth et al., 2002), such as a legume pasture-based system. In comparison to a whole farm budget, partial budgets evaluate the changes in cost and revenue with a proposed plan under a change in management (Kay et al., 1994).

A partial budget was used to evaluate the costs and net return of implementing a remote calving monitoring system within a simulated herd of 100 lactating cows, with an estimated increase in annual net return, from €37 positive to €90 per cow (Crociati et al., 2020). The approach has also been used to estimate the profitability of mixing Jersey milk in Holstein-

Friesian milk for cheese production. The outcome indicated that increasing inclusion-rates of Jersey milk by 25, 50, 75 and 100 percent resulted in profits of 3.41, 6.44, 8.57, and 11.18 pence per kilogram of milk annually, respectively (Bland et al., 2015).

The cumulative effects of farm management decisions regarding forage nutrient inputs influence farm profitability. By comparing managerial changes in feed strategies, such as increased legume forages compared to current forages, analysis can be conducted to identify changes in milk yield and economic profitability. Comparing dietary treatments with different supplements using partial budgets can determine which treatment will maximize the farm's profits, while minimizing its costs (Tozer et al., 2004). In studying the effect of supplementation on feed efficiency, Tozer et al. (2004) identified four dietary treatments and used partial budgeting to determine the treatment yielding the highest income over feed costs.

The partial budget model is a particularly effective tool utilized by dairy producers to make decisions regarding cow diets, based on their profitability. The approach has been used to compare net farm incomes of high-yielding Holstein cows fed either a TMR, a pasture-based diet, or a combination of both. The model showed that the TMR was most profitable, increasing revenue and decreasing costs as compared to the feedstuffs (Tozer et al., 2004). This approach has also been used to compare income over feed costs of high-yielding Holstein cows under a variety of dietary treatments. The treatments were low pasture allowance **(PA)** unsupplemented, low PA concentrate supplementation, high PA unsupplemented, and high PA concentrate supplementation. The partial budget established that the low PA concentrate supplementation treatment had the highest income over feed costs (Tozer et al., 2004), proving to be the most profitable option.

In addition to its use for dairy management practices, the model expands to decision making practices in other areas of agriculture. Partial budgets have been used to compare the annual economic return of four cover crops used on Midwest row crop farms. The cover crops compared included cover crops terminated with herbicides followed by corn for grain, cover crops terminated with herbicides followed by soybeans, cover crops terminated with herbicides in a corn-soybean rotation, and winter-kill cover crops. Using survey data from farm operators managing cover crops, the partial budget results established that cover crops terminated with herbicides followed by soybeans and cover crops winter-killed generated the most economic return (Plastina et al., 2018). The model was also in another agricultural study to assess the economic outcomes of three levels of nitrogen-fertilizer use on a sorghum farm in Egypt. Level 1 was the base treatment, 100 kg N/Feddan, level 2 was 200 kg N/Feddan, and level 3 was 300 kg N/Feddan.[2] The partial budget results indicated that level 2 generated the most profit, with a marginal rate of return of 961 percent (Soha, 2014), showing that the most profitable amount of nitrogen-fertilizer is 200 kg N/Feddan.

While the partial budget model is a widely used tool for assessing revenue and cost differences based on changes in management practices, the model has a few limitations. The model is a static analysis that only considers one time period, typically one calendar year. Model output should be analyzed with this consideration in mind, else failure to do so could skew information regarding profits, misguiding dairy producer decisions regarding management changes (Hady & Lloyd, 1994). Additionally, partial budgets don't account for the time value of money (Rutgers Cooperative Extension, 2014). While the model accounts for the difference in

[2] A Feddan is an Egyptian measurement unit of area, which equals 1.038 acres (Merriam Webster Dictionary). N/Feddan represents nitrogen-fertilizer application per feddan.

the current value of cash received and expended, it does not account for its value in the future. A study conducted using the partial budget model to estimate the economic impact of  herds switching from blanket dry cow therapy to culture-guided selective dry cow therapy, encountered this limitation (Rowe et al., 2021). The modeled budgets in the study were found to be pertinent only to the current time at which the budget was built, as there was no account for the financial cost of decreased control of contagious mastitis. Most importantly, partial budget models are limited by their resulting estimates of profit changes, not absolute profit changes. While the approach excels at assisting in making management practice decisions, the outcome is only an estimate of the possible economic impacts of the proposed changes, not an assurance (Tigner, 2018).

*MONTE CARLO SIMULATION*

Monte Carlo simulation is a forecasting simulation method that relies on repeated random sampling to compute results for uncertain scenarios (Raychaudhuri, 2008). By using random sampling based on a range of input values, Monte Carlo simulation predicts a probability distribution of possible outcomes, which account for the uncertainty of real-life scenarios (Zio, 2013). The simulation repeats the process of computing results thousands of times, using a different set of random numbers within the input values to produce a large number of possible outcomes (Bonate, 2001).

Monte Carlo simulations are frequently used in research to help predict a potential range of costs for certain variables, showing the implications of cost variability on profit. Specifically, Monte Carlo simulations aim to address the static nature of models, such as the partial budget model, which provide a fixed analysis considering a single time period. Within the context of agricultural research, a study aiming to assess the variability of rice farming practices used Monte Carlo simulations to compare traditional rice farming with the System of Rice Intensification, a farming method that aims to increase yield while decreasing resources (SRI International Network and Resources Center, n.d.). The simulation results showed that using System of Rice Intensification had a positive profit range greater than traditional rice farming, encouraging the use of this ecological method of farming (Kadigi et al., 2020). The simulation method has also been used in the context of animal science to estimate the variability in costs associated with dairy diseases in the United States. The costs of the diseases were divided into seven categories: culling, labor, discarded milk, extended days open, milk loss, on-farm death, and vet expenses. Each cost category was simulated to produce a possible range of costs. The simulation results showed that the estimated cost ranges that were highest and varied the most were milk loss and vet expenses (Liang et al., 2017). A Monte Carlo Simulation was also used to assess how concentrate costs, milk price and silage quality affect a dairy farm's profitability. The simulation indicated that milk price had the most variable range of potential outcomes of the three factors and had the greatest impact on the farm's net profit (Shalloo et al., 2004). Similarly, within the context of this research, Monte Carlo simulations are used to help predict potential cost ranges for uncertain variables, addressing the static nature of the partial budget models.

## III. METHODS

### *PARTIAL BUDGETS*

Management changes affect the profitability of a dairy farm by changing the costs incurred and the revenue generated. A switch from a current management practice to an alternative one can cause changes in revenues and costs, which are captured by the partial budget model as illustrated in Figure 3.

Dairy producers often make management decisions based on net profit change, the difference between revenue generated and total costs incurred. Revenue consists of the sale of products, which include milk sold, culled cows, and sold calves. Total costs consist of operating expenses and ownership expenses for dairy production. Operating costs include the costs associated with producing a product. Ownership costs are associated with owning and maintaining property and machinery to produce milk. The linear equation of the partial budget model demonstrates net profit changes based on differences in costs and revenues occurring from management changes. The change in profit is defined as

$$(1)\ \Delta\pi = (\ R_{\alpha t} + C_{\lambda t}\ ) - (R_{\lambda t} + C_{\alpha t})$$

where the expected change in profit, $\Delta\pi$, is a function of the sum of $R_{\alpha t}$ , revenues under the alternative plan, and $C_{\lambda t}$ costs under the current plan, minus the sum of $R_{\lambda t}$, revenues under the current plan and $C_{\alpha t}$ , costs under the alternative plan. In this formula, $\alpha$ represents the alternative plan and $\lambda$ represents the current plan, over an annual time period, $t$.

| The Partial Budget Model | |
|---|---|
| | |
| A. Additional Revenues | B. Reduced Revenues |
| | |
| C. Reduced Costs | D. Additional Costs |
| | |
| E. Total gain= A+C | F. Total loss = B+D |
| | |
| Net profit change = E - F | |

Figure 3: The Partial Budget Model Structure

The partial budget model analyzes changes in costs and revenues under a proposed management plan. This analysis allows farmers to make informed decisions about implementing alternative practices, such as legume-enriched pasture-based systems. The model considers the components under the current management practice and the alternative one to provide insight into the possible impacts of implementing management changes on net profit.

*Revenues*

The two revenue components of the model are reduced revenues and additional revenues. Reduced revenue is the revenue generated under the existing system that will no longer be incurred or will be reduced after the implementation of an alternative management practice. After the management change is implemented, a reduction in yield may occur, decreasing the amount of goods available for sale, causing revenue losses. Alternatively, the change may compromise the quality of produced goods, generating income losses. In the context of this research, revenues are generated from milk, calf, and cull sales.

Additional revenues account for the revenue streams that are generated under the proposed management method (Dalsted & Gutierrez, 1990). There are two contributing factors for changes in revenue due to the implementation of a new plan in this research: changes in milk yield and changes in milk prices received, due to changes in milk quality. The expansion of an enterprise often leads to an increase in milk yield, thereby increasing the amount of goods available for sale and increasing revenue (Tigner, 2018). Additionally, alternate management practices may enable producers to capitalize on industry premiums, thereby enabling them to sell their products at higher prices.

### *Costs*

In addition to accounting for revenue changes, the partial budget model evaluates the impacts of changes in management methods on costs. Increases and decreases in costs are incorporated into the partial budget model to provide analysis of potential impacts of implementing proposed management practices on expenses.

Reduced costs are the costs under the existing system that will no longer be incurred after the implementation of the alternative management practice. Costs that may experience a reduction include labor requirements and material inputs into production (Dhoubhadel & Stockton, 2010). Reduced costs result from lower input costs, eliminating an enterprise, or reducing its size.

Additional costs are defined as costs generated under an alternative management practice that did not exist under the current plan. There are many determinants of changes in cost under an alternative plan, such as the need for additional labor, the necessity for higher quality inputs, or depreciation. Cumulatively, these factors may all contribute to increases in costs.

*MONTE CARLO SIMULATION*

For this research, Monte Carlo simulation was used to assess the potential cost ranges for management labor, seed, and labor costs. These costs were analyzed due to their deterministic effect on profit. Management labor, seed, and labor costs exhibit strong variability between organic dairy milk production and organic grazing dairy production. Organic milk production has higher seed costs compared to organic grazing milk production. Organic milk producers must cultivate feed crops for their cows, while organic grazing producers rely more on forages for feed, which decreases the quantity of seed needed to cultivate feed crops (Hardie et al., 2014). In addition, relying less on feed crops may involve less manual and management labor for organic legume-grazing milk production in contrast with organic milk production. Given the variances in these costs for organic and organic grazing milk production, using Monte Carlo simulation to assess the cost fluctuation between them and determine the possible cost ranges is crucial to determining production effects on profit. The Monte Carlo simulations are used to provide a sensitivity analysis of the cost structure of the dairy herds within the context of this research.

## IV. DATA

FINBIN, a farm financial database, was the primary data source for this research (www.finbin.umn.edu). Supplementary data sources include the West Central Research and Outreach Center (WCROC), a part of the University of Minnesota's College of Food, Agricultural and Natural Resource Sciences, which oversees the management of cropland and research plots (www.wcroc.cfans.umn.edu), the University of New Hampshire (UNH), the United States Department of Agriculture Agricultural Marketing Service (AMS), and Iowa State University. The FINBIN database aggregates farm data from thousands of farmers and ranchers using FINPACK, a software tool utilized by farmers for financial and credit analysis (www.finpack.umn.edu). The database offers financial information for farm producers, educators, and professionals in the field of agriculture (www.cffm.umn.edu). With a focus on farms in Midwestern states, FINBIN generates publicly available financial summaries in an aggregate form, spanning from 1998 through 2022. By utilizing FINBIN, individuals can filter data by including "special sorts" to generate reports, show average outcomes of a particular type of farm or evaluate their own farm's performance against a comparable group

The FINBIN data used in this study were comprised of four livestock enterprise budget reports, which include the 2021 average costs and revenues of milk production aligning with the feeding trials conducted for this study. Two of the budgets pertain to organic grazing milk production, generated using the "special sort" for organic farms that use a rotational grazing feeding method (Appendix A and B), while the other two budgets pertain to organic milk production, which relies more heavily on TMR (Appendix C and D). The two organic grazing milk production budgets were used to account for the implementation of legume-grass grazing pastures in this study. For these two organic grazing budgets (Appendix A and B), data was summarized from 26 organic dairy farms in Minnesota, with an average herd size of 88 cows. The enterprise budgets pertaining to organic dairy farms that use rotational grazing are measured both per cwt (hundredweight) and per cow.[3] These two units of measure are used to assess milk revenue as a component of the partial budget (Appendix A), and assess the costs and revenues associated with milk production within the partial budget (Appendix B), respectively. For this study, the costs, and revenues from Appendix A and/or B are allocated to the additional revenues and additional costs sections within the partial budget models, known as the alternative management plan. The alternative plan in this study is defined as organic legume-grazing dairy cows, as they rely on legume-grass pastures as their primary feed source during the grazing season, and secondarily on supplementary feed sources.

To account for the current management plan in this study, which is considered under the reduced costs and revenues portions of the partial budget, the two other enterprise budgets pertaining to organic dairy cows, excluding the rotational grazing "special sort" in FINBIN, were presented (Appendix C and D). Within the context of this research, the current plan is defined as organic dairy cows relying on TMR as their primary feed source, and secondarily on grass pastures. This data generated from FINBIN was summarized from 23 organic dairy farms in Minnesota, with a collective average herd size of 92 cows. Like the organic grazing dairy cow enterprise budgets, one budget is measured in cwt livestock units (Appendix C), while one is measured in per cow units (Appendix D). Incorporating the data obtained from the enterprise budgets for organic cows and organic legume-grazing cows in the partial budget model allowed

[3] Cwt is a unit of measurement, equal to 100 pounds (Merriam Webster Dictionary), which serves as the pricing mechanism for milk sales, as milk is sold on a cwt basis in the dairy industry.

for a complete comparative analysis of the differences in costs, revenues, and net profit between both management methods.

In addition to FINBIN data, seed cost data from the feeding trials conducted at UNH and at the WCROC were foundational to this research. Seed costs included in the partial budget model include orchard grass and red clover for the UNH and meadow fescue, orchard grass, red clover, and alfalfa for the WCROC. These seed costs are accounted for in the additional costs portion of the partial budget models, as they represent the cost of the seed necessary for establishing the legume-grass pastures on which cows will graze.

Pasture renovation costs were calculated based on an Iowa State University Extension and Outreach publication, "Estimated Costs of Pasture and Hay Production" (ISU Extension and Outreach, n.d.). This publication provides insight into pasture renovation costs for different legume pasture improvement systems. Pasture renovation refers to the revitalization of a pasture by replacing a third of the existing pasture, every three to five years, with a desired forage species into the current plant stands (Barnhart, 1995). In the context of this study, pasture renovation, done with a legume-grass seeding, is necessary only for organic legume-grazing dairy farms. This was accounted for in additional costs in the partial budget model.

The required pasture acreage for legume forage production is contingent on herd size. Total pasture acreage needed plays a crucial role in determining the acreage needed for renovation, which, in turn, has a direct impact on overall seed costs. To calculate the number of acres needed for organic grazing (Appendix A and B) and organic milk production (Appendix C and D), we operate under the common assumption of two acres needed per cow (University of Massachusetts Extension, n.d.; Ishler, 2020; Cothren, 2023). Therefore, for a herd size of 88

(Appendix A and B), 174 acres are needed. One third of this acreage, 58 acres, will be used to plant seed for legume forage production, which will be used for grazing. For a herd size of 92 (Appendix C and D), 184 acres are needed.

*SCENARIOS*

For this research, three scenarios involving adopting legume forages as feed are evaluated as alternative approaches to the current management plan, which involves organic dairy production with 53 percent TMR use. Scenario A considers data from the feeding trials conducted at UNH as the alternative plan compared to organic dairy production, scenario B considers data from the feeding trials at the WCROC as the alternative plan compared to organic dairy production, Lastly, scenario C uses Monte Carlo simulated cost values, considering costs across both UNH and WCROC, for management labor, seed, and labor costs as an alternative to the current management plan.

Table 1 provides a comprehensive summary of the revenues and costs for each item integrated in the partial budget models for all three organic grazing alternative scenarios and the current organic scenario. Data sources for each item of the organic grazing alternative scenarios are described in further detail in the remainder of this table, including the associated appendix source for reference.

Table 1: Partial Budget Financial Assumptions

| Item | Organic - Current Scenario ($/unit) [4] | Organic Grazing – Alternative Scenarios ($/unit)[5] | Source | Organic Grazing-FINBIN Appendix source |
|---|---|---|---|---|
| Milk Price ($/cwt) | 28.62 | 28.03 | FINBIN | Appendix A |
| Cull Revenue ($/cow) | 295.16 | 284.36 | FINBIN | Appendix B |
| Calf Revenue ($/cow) | 243.00 | 243.00 | Calculated in formula 3 | NA |
| *Operating Costs* | | | | |
| Labor ($/cow) | 123.43 | 113.89 | FINBIN | Appendix B |
| Fuel, Lube and Electricity ($/cow) | 83.05 | 80.09 | FINBIN | Appendix B |
| Feedstuffs ($/cow) | 2,324.42 | 2,093.74 | FINBIN | Appendix B |
| Hired Labor ($/cow) | 120.98 | 118.31 | FINBIN | Appendix B |
| Grass Seed ($/acre) | 101.90 | 101.90 | FINBIN | Appendix A |
| Legume-Grass Seed ($/acre) | NA | 95.70 | UNH (Scenario A) | NA |
| | | 94.84 | WCROC (Scenario B) | NA |
| | | 97.87 | Monte Carlo Simulated Value (Scenario C) | NA |
| Repairs ($/cow) | 196.35 | 190.68 | FINBIN | Appendix B |
| Bedding and Litter ($/cow) | 65.93 | 63.07 | FINBIN | Appendix B |
| *Ownership Costs* | | | | |
| Management Labor ($/cow) | 372.20 | 364.81 | FINBIN | Appendix B |
| Depreciation ($/cow) | 202.99 | 200.61 | FINBIN | Appendix A |
| Interest ($/cow) | 98.64 | 93.22 | FINBIN | Appendix B |
| Pasture Renovation ($/acre) | NA | 287.85 | ISU | NA |

[4] Organic dairy milk production data is sourced from FINBIN, at the exception of calf revenue (Appendix C and D).
[5] Organic grazing dairy milk production data is sourced from FINBIN, at the exception of calf revenue, legume-grass seed, and pasture renovation (Appendix A and B)

*REVENUES*

Three sources of revenue are accounted for in the partial budget model: milk revenue, calf revenue, and cull revenue. Milk revenue is calculated as the price received multiplied by the milk yield. In 2021, organic dairy farms in Minnesota yielded 16,014 pounds of milk per cow on average, selling milk for $28.62/cwt. Organic legume-grazing dairy farms produced less on average at 15,840 pounds per cow. They also had a lower selling price of $28.03/cwt. Therefore, milk revenue per cow for non-legume-grazing organic dairy farms was greater than organic grazing dairy farms in 2021 (Appendix A and C).

Some dairy farmers sell bull calves shortly after birth, keeping only heifers to increase their herd. Calf revenue is generated from the sale of these young bull calves. Data regarding calf weight and calf price in $/cwt was collected from the USDA-AMS National Dairy Comprehensive Report. Organic dairy farms sold an average of 47 calves in 2021 (Appendix D), earning $243 per calf sold, while organic grazing dairy farms sold an average of 49 calves annually (Appendix B), also priced at $243 per calf sold. The $243 selling price for calves was calculated based on the following two equations. First, average weight in pounds was first converted to cwt. Then the weight in cwt is used with the price per cwt data to get the selling price.

$$(2)\ Weight\ in\ cwt = Average\ weight\ in\ lbs/100$$

The average weight of bull calves at 15 days old is 105 pounds (USDA-AMS, 2023), therefore the weight in cwt was 1.05. Price per calf was then calculated as

$$(3)\ Price\ per\ calf = Price\ per\ cwt/\ Weight\ in\ Cwt$$

With a cwt calf price of $254.72 (USDA-AMS, 2023), divided by the weight in cwt of 1.05, the price per calf is $243.

Cull revenue is generated from selling culled cows from the livestock operation. Culling cows involves removing them from the dairy production operation as a result of issues affecting milk productivity, such as infertility, age, health issues or lameness. Organic dairy farms obtained $295.16 per cow from cull sales in 2021, while organic grazing dairy farms earned $284.36 per cow (Appendix B and D).[6]

*COSTS*

The partial budget model under consideration considers two categories of costs: operating costs and ownership costs. Operating costs incur only as a result of production (Van Tassel et al., 2020). Operating costs include costs associated with the inputs needed for production. These inputs may include seed, labor, feed, and fuel. Unlike operating costs, ownership costs are costs that producers incur, regardless of whether a commodity is produced or not (Van Tassel et al., 2020). These costs encompass depreciation of various assets such as buildings, machinery, and equipment. Ownership costs also include fees associated with the assets owned, such as utilities and interest. Regardless of the quantity of goods produced, or if production occurs, these costs must be paid solely due to the ownership of assets. Figure 4 illustrates the categorization of costs into operating and ownership costs for this research study.

[6] The cull revenue was reported in the FINBIN reports. It is calculated by averaging cull revenue values from farmers that contribute data to FINBIN, which may include cull sales equal to $0, resulting in a lower-than-expected cull revenue in this analysis. For data consistency, the values reported from FINBIN are used for the primary analysis. Guidelines FINBIN data collection can be accessed at https://www.cffm.umn.edu/wp-content/uploads/2022/11/MN-Closeout-Manual-2022.pdf

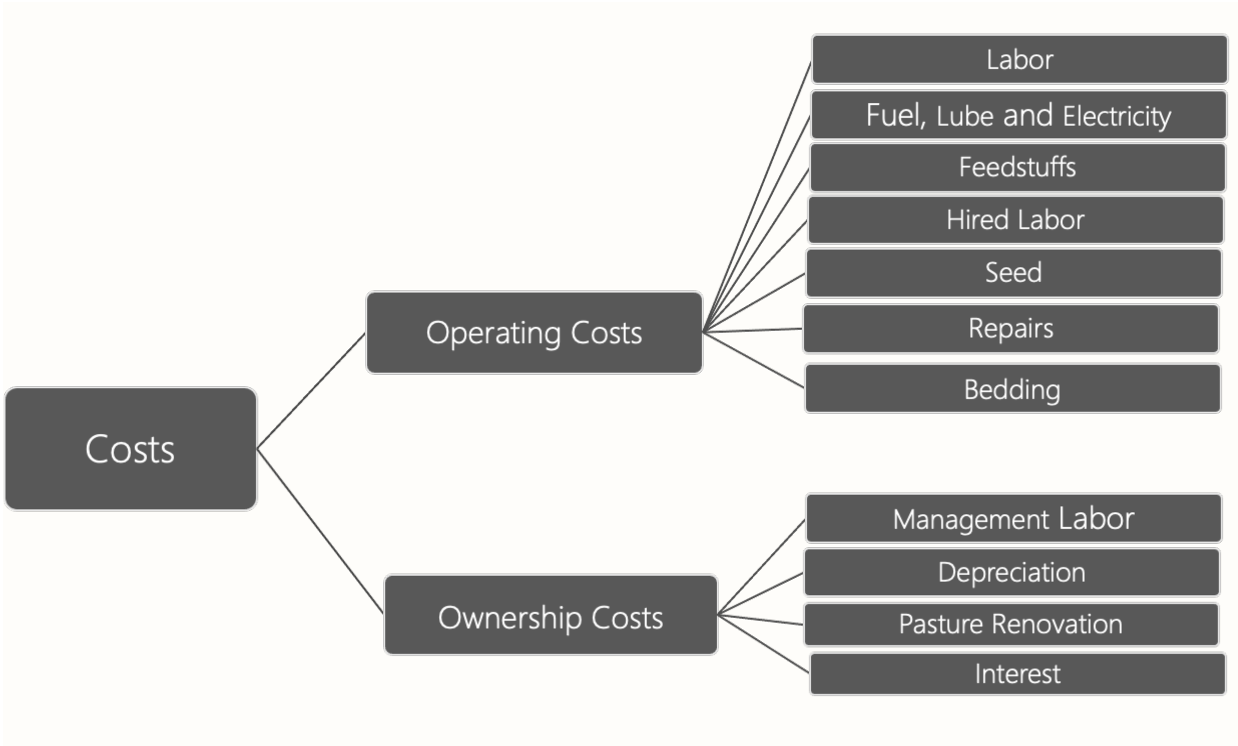


Figure 4: Categorization of Operating and Ownership Costs in Organic Dairy Farming

*Operating Costs*

The operating costs included in the partial budget model are labor, fuel, lube and electricity, feedstuffs, hired labor, seed, bedding, and repairs. Cost data for labor, fuel, lube and electricity, feedstuffs, hired labor, bedding, and repairs were collected from FINBIN (www.finbin.umn.edu). Seed costs were sourced from the feeding trials at UNH and the WCROC. Labor costs are incurred from compensating workers for daily tasks needed for farm operations, such as operating machinery, milking, feeding, and caring for animals. In 2021, the average labor cost per cow for organic dairy farms was $123.34, while organic grazing dairy farms exhibited lower average labor costs at $113.89 per cow (Appendix B and D). This illustrates that, on average, organic dairy farms implementing a rotational grazing system had lower costs associated with per cow labor inputs.

Fuel, lube, and electricity are necessary inputs for machinery and equipment operation. On average, organic dairy farms paid $83.05 per cow for fuel, lube, and electricity, while organic grazing dairy farms had slightly lower fuel, lube, and electricity expenses at $80.09 per cow (Appendix B and D). Feedstuffs refer to the cost of animal feed, which includes grains and concentrates such as minerals, protein, vitamins, and other additives. As discussed in the literature review, feed types are what differentiate organic dairy farms from organic grazing dairy farms. Organic dairy farms paid an average of $2,324 per cow on feedstuffs, while organic grazing dairy farms paid a lower cost of $2,093 per cow (Appendix B and D). Hired labor denotes the employment of labor from external sources outside of the farm operation and occurs when there is need for specialized skills or seasonal, short-term labor. Organic dairy farms paid $120.98 per cow for hired labor in 2021, but organic grazing dairy farms paid slightly less, $118.31 per cow (Appendix B and D).

Seed costs pertain to the expenses associated with the seed planted to establish pastures and each farm type had 188 acres of grazed pasture. In 2021, organic dairy farms incurred a seed cost of $101.90 per acre to maintain their 184 acres of grass pasture. Legume-grazing organic dairy farms had 58 acres of renovated pastures and 118 acres of non-renovated pasture, given that it is recommended to renovate a third of the total pasture to allow for grazing of the remaining acreage (OSU, n.d.). Seed costs for red clover and orchard grass planted on 58 acres of legume-grass pasture renovated land at UNH, scenario A, totaled to $95.70 per acre. Seed costs planted on 58 acres of legume-grass pasture renovated land at the WCROC, scenario B, for meadow fescue, orchard grass, red clover and alfalfa totaled to $94.84 per acre. The remaining 118 pasture acres, that were not renovated, cost $101.90 per acre for both scenarios A (UNH) and B (WCROC).

Repair costs are incurred from repairing assets, such as machinery, equipment, and buildings. Repairs may include replacing broken or missing machinery parts and repairing damage. Organic dairy farms spent $196.35 per cow on average on repairs, while organic grazing dairy farms spent $190.68 per cow on average on repairs (Appendix B and D). Bedding refers to the costs associated with providing bedding materials for cows, such as straw, wood shavings, hay, corn stocks and sawdust. On organic dairy farms, bedding costs were $65.93 per cow on average, while bedding costs were $63.07 per cow for organic grazing dairy farms (Appendix B and D).

As evidenced by the data, comparing operating costs for organic and organic legume-grazing milk production in 2021, average operating costs appeared to be lower overall for organic dairy farms implementing a rotational grazing system.

*Ownership Costs*

The ownership costs accounted for in the partial budget model consist of management labor, depreciation, pasture renovation and interest. Management labor is the labor involved in managing a farm’s operations. The costs cover the compensation of the individuals responsible for overseeing farm operations. Organic dairy farms had average management labor costs of $372.20 per cow, while average management costs were $357.23 for organic grazing dairy farms, showing that the average cost of management labor for farms that do not use a rotational grazing system is higher.

Depreciation accounts for the decline in an asset's value over time. Assets such as tractors, mowers, seeders, and trucks, which are used over multiple years, have a lower resale value than the initial price paid for the asset.

The reduction in the asset value from its initial value to its current value is called depreciation. The depreciation costs for organic dairy farms was $202.99 per cow, on average, while depreciation costs for organic grazing dairy farms was $200.61. Thus, losses due to depreciation were slightly higher for farms not utilizing a rotational grazing system.

Pasture renovation is the process of renewing a proportion of pasture, 58 of 176 acres for this research, by removing the existing pasture and reseeding with a desired forage species into the present plant stands. While essential when reseeding with a new forage, pasture renovation is a costly endeavor. Pasture renovation with legume-grass mixture seeding for organic grazing dairy farms was $287.85 per acre.

Interest is the cost of borrowing funds to purchase assets. When a loan is taken out to make a purchase, interest must be paid on the borrowed amount of money. Farmers may pay interest on purchased assets such as buildings, land, and machinery. For organic dairy farms, the average interest was $98.64 per cow, while organic grazing dairy farms had a lower average interest cost of $93.22 per cow.

## V. RESULTS

Microsoft Excel ™, Version 16.66.1 (Microsoft Office Excel, 2022) was used to create partial budget models and compute costs, revenues, and net profit changes. RStudio ™, Version 2022.12.0+353 (Posit, 2022) was used to conduct Monte Carlo simulations and generate histograms of cost outcome distributions.

### *PARTIAL BUDGETS*

After identifying the costs and revenues under the current management plan and the costs and revenues for each scenario under the alternative management plan, the net change in profit was calculated. The current management plan involves organic dairy production relying primarily on TMR as a feed source. Three scenarios are considered under the alternative management plan. Scenario A considers the feeding trials conducted at UNH, scenario B considers the feeding trials conducted at WCROC, and scenario C uses Monte Carlo simulated cost values for management labor, seed, and labor costs compared to the current management plan. Net profit for all scenarios is calculated using Equation 1. A positive net profit indicates that the alternative management method is profitable.

Table 2 shows the total gain associated with scenario A, establishing legume-grass grazing pastures at UNH, is $776,482 and the total loss from forfeiting the current plan, relying primarily on TMR as a source of feed, is $785,854. The net profit when total loss is subtracted from total gain is -$9,371. This indicates that implementing scenario A causes the net change in profit to be negative and is not financially advantageous. The negative net change in profit is driven by lower milk yield from the legume-grazing feeding trials at UNH (scenario A).

This production change resulted in less revenue generated than under the current management plan. The reduced yield in scenario A can be attributed to a slightly smaller herd size of 88, compared to the herd size under the current plan, 92, and differences in milk price (Appendix C and D). Additionally, the current management plan involves a higher feed intake of TMR in comparison to scenario A, which contributes to higher milk production per cow under the current management plan. In addition, the investment associated with pasture renovation makes scenario A more costly than the current plan.

Table 3 identifies the total gain associated with scenario B  ($776,492), and the total loss from forfeiting the current management practice ($785,804). Net profit totals to be -$9,322, showing that implementing scenario B causes negative profit, and is not financially profitable. However, the loss in scenario B is lower than that of scenario A by $49. Similar to scenario A, the negative net change in profit in this scenario is also due to lower revenue from reduced milk yield, given that the current management plan provides cows higher TMR intake in comparison to cows in scenario A, which rely more on grazing legume-grass pastures during the grazing season. Therefore, scenario B has lower milk production than under the current plan. The investment of pasture renovation costs also contributes to the negative net change in profit.

Table 2: Summary Partial Budget for Scenario A: UNH Feeding Trials, Year 1, 2021

| **Additional Revenue – Scenario A** | **Quantity** | **$/unit** | **Total ($)** | **Reduced Revenue-Current Plan** | **Quantity** | **$/unit** | **Total ($)** |
|---|---|---|---|---|---|---|---|
| Milk Revenue | | | | Milk Revenue | | | |
| Milk Price ($/cwt) | | 28.03 | | Milk Price ($/cwt) | | 28.62 | |
| Yield | 15,840 | | *Total Milk Sales*: | Yield | 16,014 | | *Total Milk Sales*: |
| Cows | 88 | | 390,715 | Cows | 92 | | 421,655 |
| Cull Revenue ($/cow) | 88 | 284.36 | 25,023 | Cull Revenue ($/cow) | 92 | 295.16 | 27,154 |
| Calf Revenue ($/cow) | 49 | 243.00 | 11,907 | Calf Revenue ($/cow) | 47 | 243.00 | 11,421 |
| Total Additional Revenue | | | 427,646 | Total Reduced Revenue | | | 460,230 |
| **Reduced Costs – Current Plan** | | | | **Additional Costs – Scenario A** | | | |
| *Operating Costs* | | | | *Operating Costs* | | | |
| Labor ($/cow) | 92 | 123.34 | 11,347 | Labor ($/cow) | 88 | 113.89 | 10,022 |
| Fuel, Lube and Electricity ($/cow) | 92 | 83.05 | 7,640 | Fuel, Lube and Electricity ($/cow) | 88 | 80.09 | 7,047 |
| Feedstuffs ($/cow) | 92 | 2,324.4 | 213,846 | Feedstuffs ($/cow) | 88 | 2,093.7 | 184,249 |
| Hired Labor ($/cow) | 92 | 120.98 | 11,130 | Hired Labor ($/cow) | 88 | 118.31 | 10,411 |
| Grass Pasture Seed ($/acre) | 184 | 101.90 | 18,064 | Grass Pasture Seed ($/acre) | 118 | 101.90 | 12,024 |
| Repairs ($/cow) | 92 | 196.35 | 18,064 | Legume-Grass Pasture Seed ($/acre) | 58 | 95.70 | 5,550 |
| Bedding and Litter ($/cow) | 92 | 65.93 | 6,065 | Repairs ($/cow) | 88 | 190.68 | 16,779 |
| *Ownership Costs* | | | | Bedding and Litter ($/cow) | 88 | 63.07 | 5,550 |
| Management Labor ($/cow) | 92 | 372.20 | 34,242 | *Ownership Costs* | | | |
| Depreciation ($/cow) | 92 | 202.99 | 18,675 | Management Labor | 88 | 357.23 | 31,436 |
| Interest ($/cow) | 92 | 98.64 | 9,074 | Depreciation ($/cow) | 88 | 200.61 | 17,653 |
| | | | | Interest ($/cow) | 88 | 93.22 | 8,203 |
| | | | | Pasture Renovation ($/acre) | 58 | 287.85 | 16,695 |
| Total Reduced Costs | | | 348,836 | Total Additional Costs | | | 325,624 |
| Total Gain | | | 776,482 | Total Loss | | | 785,854 |
| **Net Profit Change** | | | **-$9,371** | | | | |

Table 3: Summary Partial Budget for Scenario B: WCROC Feeding Trials, Year 1, 2021

| **Additional Revenue – Scenario B** | **Quantity** | **$/unit** | **Total ($)** | **Reduced Revenue-Current Plan** | **Quantity** | **$/unit** | **Total ($)** |
|---|---|---|---|---|---|---|---|
| Milk Revenue | | | | Milk Revenue | | | |
| Milk Price ($/cwt) | | 28.03 | | Milk Price ($/cwt) | | 28.62 | |
| Yield | 15,840 | | *Total Milk Sales*: | Yield | 16,014 | | *Total Milk Sales:* |
| Cows | 88 | | 390,715 | Cows | 92 | | 421,655 |
| Cull Revenue ($/cow) | 88 | 284.36 | 25,023 | Cull Revenue ($/cow) | 92 | 295.16 | 27,154 |
| Calf Revenue ($/cow) | 49 | 243.00 | 11,907 | Calf Revenue ($/cow) | 47 | 243.00 | 11,421 |
| Total Additional Revenue | | | 427,646 | Total Reduced Revenue | | | 460,230 |
| **Reduced Costs – Current Plan** | | | | **Additional Costs – Scenario B** | | | |
| *Operating Costs* | | | | *Operating Costs* | | | |
| Labor ($/cow) | 92 | 123.34 | 11,347 | Labor ($/cow) | 88 | 113.89 | 10,022 |
| Fuel, Lube and Electricity ($/cow) | 92 | 83.05 | 7,640 | Fuel, Lube and Electricity ($/cow) | 88 | 80.09 | 7,047 |
| Feedstuffs ($/cow) | 92 | 2,324.42 | 213,846 | Feedstuffs ($/cow) | 88 | 2,093.74 | 184,249 |
| Hired Labor ($/cow) | 92 | 120.98 | 11,130 | Hired Labor ($/cow) | 88 | 118.31 | 10,411 |
| Grass Pasture Seed ($/acre) | 118 | 101.90 | 18,749 | Grass Pasture Seed ($/acre) | 118 | 101.90 | 12,024 |
| Repairs ($/cow) | 92 | 196.35 | 18,064 | Legume-Grass Pasture Seed ($/acre) | 58 | 94.84 | 5,500 |
| Bedding and Litter ($/cow) | 92 | 65.93 | 6,065 | Repairs ($/cow) | 88 | 190.68 | 16,779 |
| *Ownership Costs* | | | | Bedding and Litter ($/cow) | 88 | 63.07 | 5,550 |
| Management Labor ($/cow) | 92 | 372.20 | 34,242 | *Ownership Costs* | | | |
| Depreciation ($/cow) | 92 | 202.99 | 18,675 | Management Labor ($/cow) | 88 | 357.23 | 31,436 |
| Interest ($/cow) | 92 | 98.64 | 9,074 | Depreciation ($/cow) | 88 | 200.61 | 17,653 |
| | | | | Interest ($/cow) | 88 | 93.22 | 8,203 |
| | | | | Pasture Renovation($/acre) | 58 | 287.85 | 16,695 |
| Total Reduced Costs | | | 348,836 | Total Additional Costs | | | 325,574 |
| Total Gain | | | 776,492 | Total Loss | | | 785,804 |
| **Net Profit Change** | | | **-$9,322** | | | | |

Legume-grass pasture renovation, the process of rejuvenating a pasture by introducing a legume-grass seeding mixture into existing plant stands, has an expected life of three to five years. (Barnhart, 1995). In fact, pastures are the most well-established during the second- and third-year following renovation (ISU, n.d.). In Tables 2 and 3, the two alternative management plan scenarios consider the initial establishment of a legume pasture on 58 acres in its first year. Since pasture renovation will not be needed in near future years, pasture renovation costs were excluded from the partial budgets in Tables 4 and 5 to account for the potential profits generated by scenarios A and B in a subsequent year after the initial pasture establishment investment, year 2.

Table 4 shows the total gain associated with scenario A in year 2, after pasture renovation, is $1,058,758, the total loss from forgoing the current plan is $1,051,094 and the net profit is $7,664. Table 5 establishes that the total gain for scenario B in year 2, is $1,064,142, the total loss incurred is $1,037,458, and the net profit totals to be $26,683. Across both scenarios in year 2, profit increased significantly without pasture renovation costs. The positive net change in profit in both scenarios, in year 2, is due to ownership and operating costs being lower under scenarios A and B, without pasture renovation, than under the current plan.

Considering that in the second year, seed is unnecessary, since legume-pastures have already been established, and there is no need to pasture renovate, it is unsurprising that both scenarios A and B have the same profit outcome in Tables 4 and 5. This stems from the fact that the only distinguishing factor between both scenarios are their seed costs, sourced from UNH in scenario A and WCROC in scenario B, which become irrelevant in the second year.

Table 4: Summary Partial Budget for Scenario A: UNH Feeding Trials, Year 2

| **Additional Revenue – Scenario A** | **Quantity** | **$/unit** | **Total ($)** | **Reduced Revenue- Current Plan** | **Quantity** | **$/unit** | **Total ($)** |
|---|---|---|---|---|---|---|---|
| Milk Revenue | | | | Milk Revenue | | | |
| Milk Price ($/cwt) | | 28.03 | | Milk Price ($/cwt) | | 28.62 | |
| Yield | 15,840 | | *Total Milk Sales:* | Yield | 16,014 | | *Total Milk Sales:* |
| Cows | 88 | | 390,715 | Cows | 92 | | 421,655 |
| Cull Revenue ($/cow) | 88 | 284.36 | 25,023 | Cull Revenue ($/cow) | 92 | 295.16 | 27,154 |
| Calf Revenue ($/cow) | 49 | 243.00 | 11,907 | Calf Revenue ($/cow) | 47 | 243.00 | 11,421 |
| Total Additional Revenue | | | 427,646 | Total Reduced Revenue | | | 460,230 |
| **Reduced Costs – Current Plan** | | | | **Additional Costs – Scenario A** | | | |
| *Operating Costs* | | | | *Operating Costs* | | | |
| Labor ($/cow) | 92 | 123.34 | 11,347 | Labor ($/cow) | 88 | 113.89 | 10,022 |
| Fuel, Lube and Electricity ($/cow) | 92 | 83.05 | 7,640 | Fuel, Lube and Electricity ($/cow) | 88 | 80.09 | 7,047 |
| Feedstuffs ($/cow) | 92 | 2,324.42 | 213,846 | Feedstuffs ($/cow) | 88 | 2,093.74 | 184,249 |
| Hired Labor ($/cow) | 92 | 120.98 | 11,130 | Hired Labor ($/cow) | 88 | 118.31 | 10,411 |
| Repairs ($/cow) | 92 | 196.35 | 18,064 | Repairs ($/cow) | 88 | 190.68 | 16,779 |
| Bedding and Litter ($/cow) | 92 | 65.93 | 6,065 | Bedding and Litter ($/cow) | 88 | 63.07 | 5,500 |
| *Ownership Costs* | | | | *Ownership Costs* | | | |
| Management Labor ($/cow) | 92 | 372.20 | 34,242 | Management Labor ($/cow) | 88 | 357.23 | 31,436 |
| Depreciation ($/cow) | 92 | 202.99 | 18,675 | Depreciation ($/cow) | 88 | 200.61 | 17,653 |
| Interest ($/cow) | 92 | 98.64 | 9,074 | Interest ($/cow) | 88 | 93.22 | 8,203 |
| Total Reduced Costs | | | 330,086 | Total Additional Costs | | | 291,353 |
| Total Gain | | | 757,733 | Total Loss | | | 751,584 |
| **Net Profit Change** | | | **$6,148.59** | | | | |

Table 5: Summary Partial Budget for Scenario B: WCROC Feeding Trials, Year 2

| **Additional Revenue – Scenario B** | **Quantity** | **$/unit** | **Total ($)** | **Reduced Revenue-Current Plan** | **Quantity** | **$/unit** | **Total ($)** |
|---|---|---|---|---|---|---|---|
| Milk Revenue | | | | Milk Revenue | | | |
| Milk Price ($/cwt) | | 28.03 | | Milk Price ($/cwt) | | 28.62 | |
| Yield | 15,840 | | *Total Milk Sales*: | Yield | 16,014 | | *Total Milk Sales*: |
| Cows | 88 | | 390,715 | Cows | 92 | | 421,655 |
| Cull Revenue ($/cow) | 88 | 284.36 | 25,023 | Cull Revenue ($/cow) | 92 | 295.16 | 27,154 |
| Calf Revenue ($/cow) | 49 | 243.00 | 11,907 | Calf Revenue ($/cow) | 47 | 243.00 | 11,421 |
| Total Additional Revenue | | | 427,646 | Total Reduced Revenue | | | 460,230 |
| **Reduced Costs – Current Plan** | | | | **Additional Costs – Scenario B** | | | |
| *Operating Costs* | | | | *Operating Costs* | | | |
| Labor ($/cow) | 92 | 123.34 | 11,347 | Labor ($/cow) | 88 | 113.89 | 10,022 |
| Fuel, Lube and Electricity ($/cow) | 92 | 83.05 | 7,640 | Fuel, Lube and Electricity $/cow | 88 | 80.09 | 7,047 |
| Feedstuffs ($/cow) | 92 | 2,324.42 | 213,846 | Feedstuffs ($/cow) | 88 | 2,093.74 | 184,249 |
| Hired Labor ($/cow) | 92 | 120.98 | 11,130 | Hired Labor ($/cow) | 88 | 118.31 | 10,411 |
| Repairs ($/cow) | 92 | 196.35 | 18,064 | Repairs ($/cow) | 88 | 190.68 | 16,779 |
| Bedding and Litter ($/cow) | 92 | 65.93 | 6,065 | Bedding and Litter ($/cow) | 88 | 63.07 | 5,500 |
| *Ownership Costs* | | | | *Ownership Costs* | | | |
| Management Labor ($/cow) | 92 | 372.20 | 34,242 | Management Labor ($/cow) | 88 | 357.23 | 31,436 |
| Depreciation ($/cow) | 92 | 202.99 | 18,675 | Depreciation ($/cow) | 88 | 200.61 | 17,653 |
| Interest ($/cow) | 92 | 98.64 | 9,074 | Interest ($/cow) | 88 | 93.22 | 8,203 |
| Total Reduced Costs | | | 330,086 | Total Additional Costs | | | 291,353 |
| Total Gain | | | 757,733 | Total Loss | | | 751,584 |
| **Net Profit Change** | | | **$6,148.59** | | | | |

*MONTE CARLO SIMUALTIONS*

To help address the static nature of the partial budget model, which provides an analysis considering a single time period, Monte Carlo simulations were used to help predict potential cost ranges for certain volatile costs within the model. Management labor, seed and labor costs were analyzed, using Monte Carlo simulation, given their variability between organic dairy milk production and organic legume-grazing milk production. Leveraging Monte Carlo simulation in this context is crucial to determining the effects that these volatile costs have on profit.

Figures 5-7 are histograms showing the probability distributions of the estimated management labor, seed and labor cost outcomes generated using Monte Carlo simulation. These histogram graphs show the probability of costs being in certain ranges, based on management labor, seed, and labor cost data from FINBIN ( http://finbin.umn.edu ) used for this study. Costs are represented by being grouped into bins within the probability distribution, where the tallest bins, or peaks indicate a higher probability that costs will be within a certain range. Figures 5 and 7 show relatively normal distributions, indicating that costs near the mean value have a higher probability of occurring than costs far lower or higher than the mean value. Figure 6 shows a slightly right-skewed distribution indicating that lower costs have a higher probability of occurring than higher costs on the y-axis. All costs were simulated with a minimum total cost value of $0, given costs cannot be negative.

Figure 5 shows the probability distribution of Monte Carlo simulated values for management labor costs. These simulations are based on input costs of $372.20 per cow for organic milk production with TMR use and $357.23 per cow for organic grazing milk production. The peak in the distribution shown in Figure 5 indicates that most simulated values for management labor costs were between $360 and $380 per cow, with a mean estimated value of $364.40 per cow. This distribution revealed a wide range of costs, spanning from $161.94 per cow to $569.90 per cow.

Input costs for the Monte Carlo simulation for seed costs were $101.90 per acre for grass pasture seed, $95.70 per acre for legume-grass seed at UNH, and $94.70 per acre for legume-grass seed at the WCROC. In Figure 6, observing the probability of simulated values for seed costs, the most probable simulated values ranged between $80 and $100 per acre, with a mean estimated value of $98.50 per acre. The simulated values showed that seed costs had a large potential cost range, between $0 per acre and $327.77 per acre.

Figure 7 shows the probability distribution of Monte Carlo simulated values for labor costs. The simulated values are based on input costs of $123.34 per cow for organic milk production relying primarily on TMR use and $113.89 per cow for organic grazing milk production. The most simulated values for labor costs were between $100 and $140 per cow, with a mean estimated value of $118.34 per cow. Labor costs simulated values have a wide cost range, between $0 per cow and $306.99 per cow.

While the distributions in each histogram exhibit a different spread, all of the estimated value spreads are wide, indicating that there is a large range of possible cost outcomes for all simulated costs, and therefore greater potential for volatility.

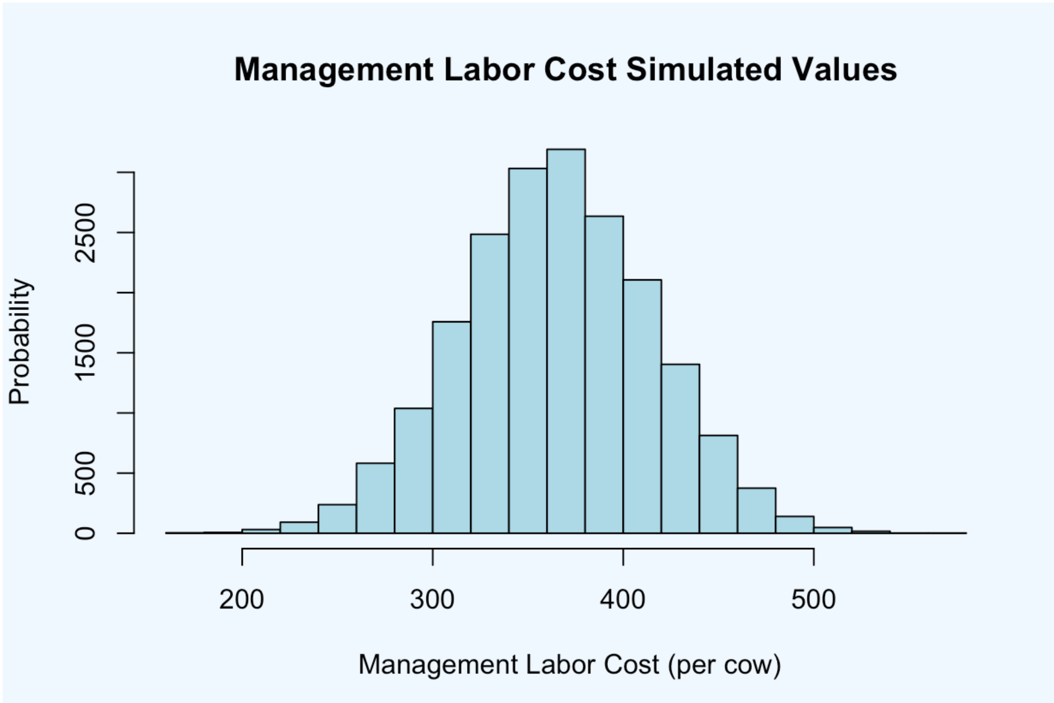

Figure 5: Management Labor Cost per Cow Estimate Distribution, Monte Carlo Simulation

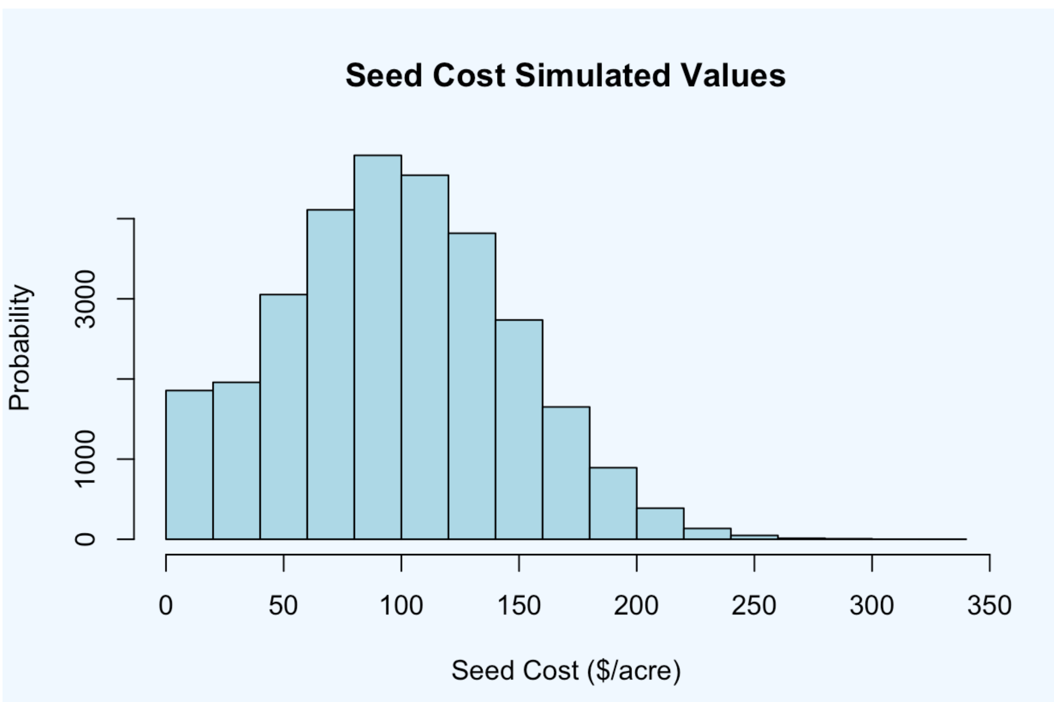

Figure 6: Monte Carlo Simulation Seed Cost per Acre Estimate Distribution

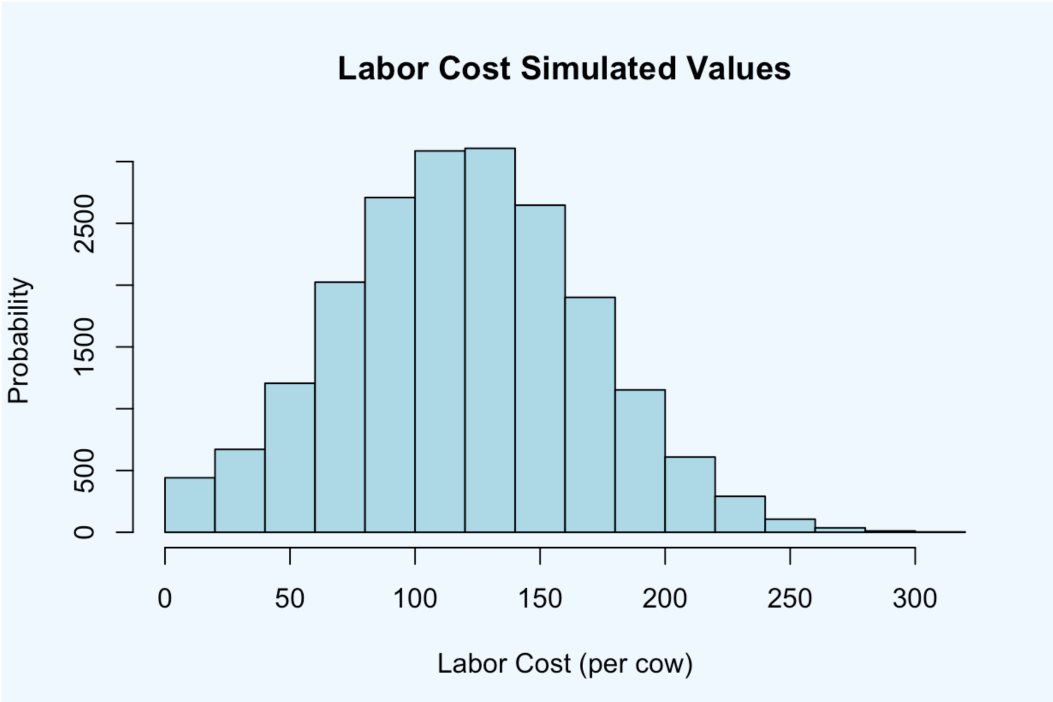

Figure 7: Monte Carlo Simulation Labor Cost per Cow Estimate Distribution

To address the variability in all three costs observed through the Monte Carlo simulations, the mean simulated values for management labor, seed, and labor costs were incorporated in the partial budget for the alternative plan (organic legume-grazing forages) and compared to the current plan, organic milk production relying primarily on TMR use. Table 8 shows the partial budget model using Monte Carlo simulated cost values, scenario C. The total gain associated with scenario C is $776,482 and the total loss from forgoing the current plan is $787,039. Including the Monte Carlo simulated values into the alternative plan, net profit is -$10,556, showing that scenario C is not financially advantageous because of the high cost of pasture renovation.

Table 6: Summary Partial Budget for Scenario C: Monte Carlo Simulated Values, Year 1, 2021

| **Additional Revenue – Scenario C** | **Quantity** | **$/unit** | **Total ($)** | **Reduced Revenue- Current Plan** | **Quantity** | **$/unit** | **Total ($)** |
|---|---|---|---|---|---|---|---|
| Milk Revenue | | | | Milk Revenue | | | |
| Milk Price ($/cwt) | | 28.03 | | Milk Price ($/cwt) | | 28.62 | |
| Yield | 15,840 | | *Total Milk Sales:* | Yield | 16,014 | | *Total Milk Sales*: |
| Cows | 88 | | 390,715 | Cows | 92 | | 421,655 |
| Cull Revenue ($/cow) | 88 | 284.36 | 25,023 | Cull Revenue ($/cow) | 92 | 295.16 | 27,154 |
| Calf Revenue ($/cow) | 49 | 243.00 | 11,907 | Calf Revenue ($/cow) | 47 | 243.00 | 11,421 |
| Total Additional Revenue | | | 427,646 | Total Reduced Revenue | | | 460,230 |
| **Reduced Costs - Current Plan** | | | | **Additional Costs – Scenario C** | | | |
| *Operating Costs* | | | | *Operating Costs* | | | |
| Labor ($/cow) | 92 | 123.34 | 11,347 | **Labor ($/cow)** | **88** | **118.34** | **10,403** |
| Fuel, Lube and Electricity ($/cow) | 92 | 83.05 | 7,640 | Fuel, Lube and Electricity ($/cow) | 88 | 80.09 | 7,047 |
| Feedstuffs ($/cow) | 92 | 2,324.4 | 213,846 | Feedstuffs ($/cow) | 88 | 2,093.7 | 184,249 |
| Hired Labor ($/cow) | 92 | 120.98 | 11,130 | Hired Labor $/cow) | 88 | 118.31 | 10,411 |
| Grass Pasture Seed ($/acre) | 184 | 101.90 | 18,749 | Grass Pasture Seed ($/acre) | 118 | 101.90 | 12,024 |
| Repairs ($/cow) | 92 | 196.35 | 18,064 | **Legume-Grass Pasture Seed ($/acre)** | **58** | **98.50** | **5,712** |
| Bedding and Litter ($/cow) | 92 | 65.93 | 6,065 | Repairs ($/cow) | 88 | 190.68 | 16,779 |
| *Ownership Costs* | | | | Bedding and Litter ($/cow) | 88 | 63.07 | 5,500 |
| Management Labor ($/cow) | 92 | 372.20 | 34,242 | *Ownership Costs* | | | |
| Depreciation ($/cow) | 92 | 202.99 | 18,675 | **Management Labor ($/cow)** | **88** | **364.40** | **32,103** |
| Interest ($/cow) | 92 | 98.64 | 9,074 | Depreciation ($/cow) | 88 | 200.61 | 17,653 |
| | | | | Interest ($/cow) | 88 | 93.22 | 8,203 |
| | | | | Pasture Renovation ($/acre) | 58 | 287.85 | 16,695 |
| Total Reduced Costs | | | 348,836 | Total Additional Costs | | | 326,808 |
| Total Gain | | | 776,482 | Total Loss | | | 787,039 |
| **Net Profit Change** | | | **-$10,556** | | | | |

*SENSITIVITY ANALYSIS*

While partial budgets show how profit changes when costs and revenues are added and eliminated, they do not identify specific key risk factors, such as price volatility, which can affect profit outcomes. A sensitivity analysis was performed for all partial budgets within this study. This served as a framework to visualize the risk of uncertainty in pasture care, milk prices, seed costs, and cull revenue on profit, considering these three four have a large influence on profit. By addressing different scenarios, such as five-year low, average, and high milk prices, the sensitivity analysis identifies best and worst-case scenarios in price volatility and management changes.

The impacts of changes in pasture renovation, milk price, seed costs and cull revenue on the current management plan and in scenarios A, B and C were assessed through the sensitivity analysis presented in Table 7. The net profit from each of the partial budget analysis scenarios is presented in the first row of Table 7. The profit values in the rows below show the changes from the sensitivity analysis which include increases or decreases in profit based on the scenario, such as a negative change in profit from a decrease in milk price. The first sensitivity analysis removes pasture renovation costs, after the initial pasture renovation investment, given that pasture renovation is needed only every three to five years. For the first sensitivity analysis scenario, removing pasture renovation costs increased profit by 178.1% for scenario A, 179.1% for scenario B, 1 and 158.1% for scenario C, showing that removing pasture renovation costs from the partial budget model leads to increased net profit. Substituting the milk price in each budget scenario for the five-year average milk price of $29.01/cwt caused profit to increase by 5.1% in the current scenario, 145.7% in scenario A, 146.5% in scenario B, and 129.4% in scenario C.

However, substituting the milk price in each budget scenario for the five-year low milk price of $27.79/cwt caused net change in profit to decrease in each scenario by 11% in the current scenario, 35.7% in scenario A, 35.8% in scenario B and 31.6% in scenario C. Price volatility can be detrimental to profit. On the contrary, substituting the milk price in each budget for the five-year high milk price of $29.70/cwt increased profit in every scenario. Profit increased by 14.2% for the current scenario, 248.3% in scenario A, 249.7% in scenario B, and 220.5% in scenario C, proving that the risk of volatility in milk prices can also be beneficial to profit. Then, substituting seed costs of $97.87/acre for the Monte Carlo simulated value in Figure 7 caused profit to increase by 0.6% under the current scenario, while profit decreased for all alternative scenarios by 1.3% for scenario A and 1.8% for scenario B. Finally, doubling the value for cull revenue increased profit under the current scenario by 22.6%, while net profit change decreased in all alternative scenarios, by 1.5% in scenario A, .9% in scenario B, and 1.3% in scenario C.

Table 7: Sensitivity Analysis: Impact of Cost and Revenue Changes on Partial Budget Scenarios

| Scenario | Assumption | Current Plan | Scenario A | Scenario B | Scenario C |
|---|---|---|---|---|---|
| **Net Change in Profit** | | 111,394 | -9,371 | -9,322 | -10,556 |
| **No Pasture Renovation** | | N/A | 7,323 | 7,373 | 6,139 |
| **Milk Price $29.01/cwt** | **5-Year average** | 117,140 | 4,288 | 4,338 | 3,104 |
| **Milk Price $27.79/cwt** | **5-Year low** | 99,166 | -12,717 | -12,667 | -13,901 |
| **Milk Price $29.70/cwt** | **5-Year High** | 127,305 | 13,906 | 13,956 | 12,722 |
| **Seed Cost $97.87/acre** | **Monte Carlo Simulated** | 112,150 | -9,497 | -9,497 | N/A |
| **Cull Revenue $568/cow** | **Doubled Cull Revenue** | 136,595 | -9,512 | -9,462 | -10,697 |

*BREAKEVEN ANALYSIS*

In year 1, scenarios A and B do not breakeven, that is, their losses are always greater than their profits. Net profit is -$-9,371 in scenario A and -$9,322 in scenario B. The breakeven milk price and milk yield were also computed in year 2, the second year after implementing legume forages in cow diets. Breakeven analysis in year 2 highlights the shift in profit and the financial flexibility farmers have once the cost of pasture renovation is no longer a factor. In year 2, net profit is $40,182 in scenario A and B. In both scenarios in year 1, profit is negative, so milk price or milk yield would need to rise to increase profit by $9,371 in scenario A, and $9,322 in scenario B to breakeven. In year 2, milk price and milk yield could decrease, and producers would still breakeven in both scenarios, given profit is positive.

In year 1, milk price would have to increase from $28.03 to $28.71 per cwt in scenario A and would need to increase $28.03 to $28.70 per cwt in scenario B for producers to breakeven. In contrast, milk price could decrease from $28.03 to $25.15 per cwt in both scenarios A and B in year 2, and producers could still breakeven, proving that farmers have much more financial flexibility without pasture renovation costs.

Considering the influence of milk yield on profit, in year 1, milk yield would have to increase from 15,840 pounds per cow to 16,220 pounds per cow in scenario A and increase from 15,840 pounds per cow to 16,218 pounds per cow in scenario B for producers to breakeven. However, in year 2, the breakeven milk yield is 14,211 pounds per cow in scenarios A and B, showing once again that not incurring the high cost of pasture renovation in year 2 allows farmers more financial leeway.

Table 8: Breakeven Needed for Milk Price and Milk Yield

| Scenario | Year | Base Milk Price ($/cwt) | Breakeven Milk Price Needed ($/cwt) | Base Milk Yield (lbs/cow) | Breakeven Milk Yield Needed (lbs/cow) |
|---|---|---|---|---|---|
| **A - UNH** | 1 | $28.03 | $28.71 | 15,840 | 16,220 |
| **B - WCROC** | 1 | $28.03 | $28.70 | 15,840 | 16,218 |
| **A - UNH** | 2 | $28.03 | $25.15 | 15,840 | 14,211 |
| **B - WCROC** | 2 | $28.03 | $25.15 | 15,840 | 14,211 |

### *SUGGESTIONS FOR FUTURE RESEARCH*

As previously discussed, a limitation of the partial budget model lies in its static nature, focusing on a single time period, specifically one calendar year in the context of this research. The proposed forage system of renovating a pasture with legume seeds entails a multi-year investment, as pasture renovation occurs only every three to five years. Consequently, a multi-year net present value analysis could provide more precise insights into the multi-year impacts this management change could have on profits. For this study, conducting such an analysis was not feasible due to the availability of only one year's worth of seed data from the UNH and WCORC feeding trials and financial data compiled using a secondary source (FINBIN).

## VI. Discussion

This research study assessed changes in profit across three scenarios implementing legume-grass grazing forages as an alternative feeding method to non-grazing cows in year 1, 2021 and in year 2, a subsequent year after legume-pasture establishment. The results showed that each scenario affected revenue, costs, and profit differently.

Sources of revenue incorporated in the study included milk, cull, and calf revenue. Management changes had a substantial impact on revenue. Implementing legume-grass forages in all three scenarios led to reduced revenue. Milk yield, sourced from FINBIN (http://finbin.umn.edu), was lower when integrated into each partial budget model in all scenarios, compared to the current plan, given that organic cows under the current plan have a higher proportion of TMR feed in their diet, which provides them energy to maximize milk production (Santa et al., 2022; Tozer et al., 2004). In addition, cull revenue was lower for all three alternative scenarios. This is likely because organic grazing dairy farms prioritize establishing forage pastures and their cows' health over increasing milk yield, therefore their cows remain in the herd longer. The cull revenue for scenarios A and B compared to the cull revenue under the current plan highlights the differing management priorities between both feeding methods.

Operating costs were lower for all alternative management plans, scenarios A-C, in comparison to the current management plan. Considering the current management approach, the herd relied more on supplemental nutrition for feed rather than on pastures. In addition, the herd size was slightly larger compared to scenarios A-C, necessitating a higher quantity of feed. Consequently, feed costs under this approach were 10% higher than feed costs under scenarios

A-C. The current management plan also incurred greater labor costs due to additional feeding efforts required, given that cows were relying less on pastures as a source of feed. Balanced TMR diets lead to maximized milk production, but they also translate to higher labor intensity in comparison to cows grazing legume pastures. Though grazed dairy cows receive a concentrate-based ration during winter, they are quickly transitioned to pasture grazing in the spring and for the rest of the grazing season, while cows that do not rely on a rotational grazing system, such as in the current management plan, continue to receive TMR feed (Schären et al., 2016). Thus, it is inevitable that per cow labor costs are greater under the current management plan.

Across scenarios A-C, ownership costs were higher compared to the current management plan, due to the financial investment required for pasture renovation in year 1. The high initial cost associated with pasture renovation often deters producers from implementing legume-grass pastures, even though the renovation yields improved forage yield and quality in the future (OSU, n.d.). When pasture renovation costs were removed in Tables 4 and 5 to account for profit in year 2, ownership costs were higher for the current management plan than for scenarios A and B. This is likely due to the fact that cows that rely primarily on TMR as a source of feed, as opposed to grazing pastures, require more planning and management efforts related to feed storage and infrastructure (Amaral-Phillips et al., 2002). TMR requires blending feed components using dedicated mixing equipment and specialized storage structures. Nutritional planning and monitoring are crucial to ensure cows receive a balanced diet that optimizes milk production (Ishler & Rosemond, 2023). These additional management efforts are reflected in increased management labor costs for the current scenario in year 2, leading to higher ownership costs for the current management plan in comparison to scenarios A and B.

Considering the cost variations between organic dairy production and organic grazing dairy production, Monte Carlo Simulations were used to evaluate possible cost ranges for management labor, seed, and labor costs. This approach addressed the static nature of the partial budget model, which offers a fixed analysis for a single time period. It is also used to account for the potential impact of cost volatility on profit. Figures 5, 6, and 7 depicted probability distributions derived from Monte Carlo simulated values for management labor, seed, and labor costs. These distributions exhibited wide spreads of estimated values for each cost simulated. The difference between the lowest and highest possible management labor cost was $404 per cow, while the difference between the lowest and highest estimated seed cost was $294 per cow, and the difference between the lowest and highest estimated labor cost was $331 per cow. The outcomes from these simulations emphasize the potential for volatility in these costs and, therefore, their potential to impact profit. This solidifies the importance for producers to cautiously consider the potential shifts in management labor, seed and labor costs when making decisions. The variance in these costs could lead to financial strain, affecting overall profitability.

The primary objective for the partial budget models used in this study was to assess the potential net profit changes through the adoption of a legume-forages as a source of feed for organic dairy grazing cows. Tables 2 and 3 showed that in the first year of implementation (year 1), scenarios A and B exhibited diminished profit due to reduced revenue from lower milk yield and lower cull revenue, along with higher costs, due to pasture renovation. However, in the year after pasture renovation (year 2), Tables 4 and 5, changes in profit were positive for both scenarios. Legume-grazing cows incurred lower costs compared to non-grazing cows, proving that using legume-forages as a source of feed during the grazing season can be profitable in year 2, despite generating less revenue. The sensitivity analysis in Table 8 also confirmed the impact of pasture renovation cost on profit. Once pasture renovation costs were removed the analysis, profit increased substantially for scenarios A and B.

Additionally, the sensitivity analysis showed the influence that milk price has on profit. Integrating either the 5-year average milk price of ($29.01/cwt) or the 5-year high milk price ($29.70/cwt) into each scenario, resulted in net a net positive profit for all scenarios. In contrast, when the 5-year low milk price of $27.79/cwt was integrated into each scenario, all scenarios had net negative profit, except the current plan. Evidently, increases in milk price led to increases in revenue in all scenarios. Monte Carlo simulated seed costs resulted in negative net profit for scenarios A-C, given that the simulated seed costs were higher than the actual seed costs in each scenario. However, the simulated seed cost increased profit under the current plan, as the simulated seed cost was lower than the actual seed cost under the current plan.

## VII. Conclusion

Changes in demand, feed prices and milk prices present new challenges for organic dairy farmers. Consequently, organic dairy farmers are exploring alternative feeding methods and feed compositions to mitigate feed costs and improve milk quality to capitalize on industry premiums. A possible solution involves incorporating legumes into pasture rotations as an alternative feed source. This solution has the potential to enhance milk content and augment profit for dairy farmers, while decreasing feed costs, given that cows grazing on legume pastures require less supplemental feed.

In this research study, a comparative analysis was performed using partial budgets to evaluate the profit associated with incorporating legumes in forages as a feed source for organic dairy cows. This approach was explored in three different scenarios, as an alternative to the current management plan, organic dairy cows relying primarily on TMR as a feed source.

Leveraging partial budget models allowed for a comprehensive analysis of changes in revenues, costs, and their effects on profitability resulting from the implementation of a legume-grass feed method. Results showed that in the first year (year 1), all alternative scenarios suffered profit losses due to the high cost of pasture renovation, a necessity in the first year of implementing this new feeding plan. However, in year 2, the year after pasture renovation was completed, all scenarios exhibited net positive profit, and their costs were lower compared to the current management plan. Therefore, farmers must cautiously evaluate the profitability tradeoff and determine whether they are willing to suffer substantial profit losses in the first year of implementation to increase profits in the years following.

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## Appendix A - Organic Grazing Dairy Cow Enterprise Budget, Measured in Cwt

**Livestock Enterprise Analysis**
**(Farms Sorted By Years)**

**Dairy -- Average Per Cwt. Of Milk**

| | Avg. Of All Farms | 2021 |
|---|---|---|
| Number of farms | 26 | 26 |
| Milk sold | 27.64 | 27.64 |
| Dairy Calves sold | 0.31 | 0.31 |
| Transferred out | 0.35 | 0.35 |
| Cull sales | 1.80 | 1.80 |
| Insurance income | 0.06 | 0.06 |
| Government payments | 1.95 | 1.95 |
| Other income | 0.48 | 0.48 |
| Purchased | -0.19 | -0.19 |
| Transferred in | -0.49 | -0.49 |
| Inventory change | 0.31 | 0.31 |
| Dairy repl cost | -4.30 | -4.30 |
| Gross margin | 27.90 | 27.90 |
| **Direct Expenses** | | |
| Protein Vit Minerals | 1.83 | 1.83 |
| Corn, Organic | 2.62 | 2.62 |
| Corn Silage, Organic | 1.81 | 1.81 |
| Hay, Alfalfa, Organic | 2.73 | 2.73 |
| Pasture, Organic | 0.63 | 0.63 |
| Haylage, Alfalfa Organic | 0.72 | 0.72 |
| Other feed stuffs | 2.87 | 2.87 |
| Breeding fees | 0.16 | 0.16 |
| Supplies | 0.95 | 0.95 |
| Fuel & oil | 0.51 | 0.51 |
| Repairs | 1.20 | 1.20 |
| Hired labor | 0.72 | 0.72 |
| Utilities | 0.55 | 0.55 |
| Hauling and trucking | 0.68 | 0.68 |
| Marketing | 0.33 | 0.33 |
| Bedding | 0.40 | 0.40 |
| Miscellaneous | 0.94 | 0.94 |
| Total direct expenses | 19.66 | 19.66 |
| Return over direct expense | 8.24 | 8.24 |
| **Overhead Expenses** | | |
| Hired labor | 0.75 | 0.75 |
| Building leases | 0.48 | 0.48 |
| Farm insurance | 0.38 | 0.38 |
| Interest | 0.59 | 0.59 |
| Mach & bldg depreciation | 1.27 | 1.27 |
| Miscellaneous | 0.69 | 0.69 |
| Total overhead expenses | 4.16 | 4.16 |
| Total dir & ovhd expenses | 23.82 | 23.82 |
| Net return | 4.09 | 4.09 |
| Labor & management charge | 2.26 | 2.26 |
| Net return over lbr & mgt | 1.83 | 1.83 |
| **Cost of Production Per Cwt. Of Milk** | | |
| Total direct expense per unit | 19.66 | 19.66 |
| Total dir& ovhd expense per unit | 23.82 | 23.82 |
| With other revenue adjustments | 23.88 | 23.88 |
| With labor and management | 26.13 | 26.13 |
| Est. labor hours per unit | 0.24 | 0.24 |
| **Other Information** | | |
| Number of cows | 87.8 | 87.8 |
| Milk produced per cow | 15,840 | 15,840 |
| Lbs of protein & fat per cow | 1,134 | 1,134 |
| Culling percentage | 25.2 | 25.2 |
| Turnover rate | 31.0 | 31.0 |
| Cows per milking unit | 10 | 10 |
| Feed cost per cwt. of milk | 13.22 | 13.22 |
| Feed cost per cow | 2,093.74 | 2,093.74 |
| Hired labor per cow | 232.20 | 232.20 |
| Avg. milk price per cwt. | 28.03 | 28.03 |
| Milk price / feed margin | 14.81 | 14.81 |

## Appendix B - Organic Grazing Dairy Cow Enterprise Budget, Measured per Cow

**_Livestock Enterprise Analysis_**
**_(Farms Sorted By Years)_**

**_Dairy -- Average Per Cow_**

| | Avg. Of All Farms | 2021 |
|---|---|---|
| Number of farms | 26 | 26 |
| Milk sold | 4,377.70 | 4,377.70 |
| Dairy Calves sold | 49.37 | 49.37 |
| Transferred out | 54.68 | 54.68 |
| Cull sales | 284.36 | 284.36 |
| Insurance income | 9.82 | 9.82 |
| Government payments | 308.14 | 308.14 |
| Other income | 75.29 | 75.29 |
| Purchased | -30.11 | -30.11 |
| Transferred in | -77.89 | -77.89 |
| Inventory change | 49.83 | 49.83 |
| Dairy repl cost | -681.37 | -681.37 |
| Gross margin | 4,419.82 | 4,419.82 |
| **Direct Expenses** | | |
| Protein Vit Minerals | 290.01 | 290.01 |
| Corn, Organic | 415.70 | 415.70 |
| Corn Silage, Organic | 286.85 | 286.85 |
| Hay, Alfalfa, Organic | 432.37 | 432.37 |
| Pasture, Organic | 100.27 | 100.27 |
| Haylage, Alfalfa Organic | 114.42 | 114.42 |
| Other feed stuffs | 454.12 | 454.12 |
| Breeding fees | 26.08 | 26.08 |
| Supplies | 151.16 | 151.16 |
| Fuel & oil | 80.09 | 80.09 |
| Repairs | 190.68 | 190.68 |
| Hired labor | 113.89 | 113.89 |
| Utilities | 86.49 | 86.49 |
| Hauling and trucking | 107.39 | 107.39 |
| Marketing | 52.89 | 52.89 |
| Bedding | 63.07 | 63.07 |
| Miscellaneous | 148.48 | 148.48 |
| Total direct expenses | 3,113.97 | 3,113.97 |
| Return over direct expense | 1,305.85 | 1,305.85 |
| **Overhead Expenses** | | |
| Hired labor | 118.31 | 118.31 |
| Building leases | 76.57 | 76.57 |
| Farm insurance | 60.75 | 60.75 |
| Interest | 93.22 | 93.22 |
| Mach & bldg depreciation | 200.61 | 200.61 |
| Miscellaneous | 109.10 | 109.10 |
| Total overhead expenses | 658.56 | 658.56 |
| Total dir & ovhd expenses | 3,772.53 | 3,772.53 |
| Net return | 647.29 | 647.29 |
| Labor & management charge | 357.23 | 357.23 |
| Net return over lbr & mgt | 290.06 | 290.06 |
| **Cost of Production Per Cwt. Of Milk** | | |
| Total direct expense per unit | 19.66 | 19.66 |
| Total dir& ovhd expense per unit | 23.82 | 23.82 |
| With other revenue adjustments | 23.88 | 23.88 |
| With labor and management | 26.13 | 26.13 |
| Est. labor hours per unit | 37.54 | 37.54 |
| **Other Information** | | |
| Number of cows | 87.8 | 87.8 |
| Milk produced per cow | 15,840 | 15,840 |
| Lbs of protein & fat per cow | 1,134 | 1,134 |
| Culling percentage | 25.2 | 25.2 |
| Turnover rate | 31.0 | 31.0 |
| Cows per milking unit | 10 | 10 |
| Feed cost per cwt. of milk | 13.22 | 13.22 |
| Feed cost per cow | 2,093.74 | 2,093.74 |
| Hired labor per cow | 232.20 | 232.20 |
| Avg. milk price per cwt. | 28.03 | 28.03 |
| Milk price / feed margin | 14.81 | 14.81 |

## Appendix C - Organic Dairy Cow Enterprise Budget, Measured in Cwt

**Livestock Enterprise Analysis**
**(Farms Sorted By Years)**

**Dairy -- Average Per Cwt. Of Milk**

| | Avg. Of All Farms | 2021 |
|---|---|---|
| Number of farms | 23 | 23 |
| Milk sold | 28.20 | 28.20 |
| Dairy Calves sold | 0.29 | 0.29 |
| Transferred out | 0.37 | 0.37 |
| Cull sales | 1.84 | 1.84 |
| Insurance income | 0.07 | 0.07 |
| Government payments | 1.97 | 1.97 |
| Other income | 0.48 | 0.48 |
| Purchased | -0.20 | -0.20 |
| Transferred in | -0.53 | -0.53 |
| Inventory change | 0.37 | 0.37 |
| Dairy repl cost | -4.36 | -4.36 |
| Gross margin | 28.50 | 28.50 |
| **Direct Expenses** | | |
| Protein Vit Minerals | 1.85 | 1.85 |
| Corn, Organic | 2.81 | 2.81 |
| Corn Silage, Organic | 1.94 | 1.94 |
| Hay, Alfalfa, Organic | 2.92 | 2.92 |
| Pasture, Organic | 0.68 | 0.68 |
| Haylage, Alfalfa Organic | 0.77 | 0.77 |
| Other feed stuffs | 2.58 | 2.58 |
| Breeding fees | 0.17 | 0.17 |
| Supplies | 0.97 | 0.97 |
| Fuel & oil | 0.52 | 0.52 |
| Repairs | 1.23 | 1.23 |
| Hired labor | 0.77 | 0.77 |
| Utilities | 0.57 | 0.57 |
| Hauling and trucking | 0.70 | 0.70 |
| Marketing | 0.35 | 0.35 |
| Bedding | 0.41 | 0.41 |
| Miscellaneous | 0.98 | 0.98 |
| Total direct expenses | 20.21 | 20.21 |
| Return over direct expense | 8.29 | 8.29 |
| **Overhead Expenses** | | |
| Hired labor | 0.76 | 0.76 |
| Building leases | 0.52 | 0.52 |
| Farm insurance | 0.39 | 0.39 |
| Interest | 0.62 | 0.62 |
| Mach & bldg depreciation | 1.27 | 1.27 |
| Miscellaneous | 0.68 | 0.68 |
| Total overhead expenses | 4.22 | 4.22 |
| Total dir & ovhd expenses | 24.43 | 24.43 |
| Net return | 4.07 | 4.07 |
| Labor & management charge | 2.32 | 2.32 |
| Net return over lbr & mgt | 1.74 | 1.74 |
| **Cost of Production Per Cwt. Of Milk** | | |
| Total direct expense per unit | 20.21 | 20.21 |
| Total dir& ovhd expense per unit | 24.43 | 24.43 |
| With other revenue adjustments | 24.47 | 24.47 |
| With labor and management | 26.80 | 26.80 |
| Est. labor hours per unit | 0.24 | 0.24 |
| **Other Information** | | |
| Number of cows | 91.7 | 91.7 |
| Milk produced per cow | 16,014 | 16,014 |
| Lbs of protein & fat per cow | 1,138 | 1,138 |
| Culling percentage | 25.8 | 25.8 |
| Turnover rate | 31.2 | 31.2 |
| Cows per milking unit | 10 | 10 |
| Feed cost per cwt. of milk | 13.55 | 13.55 |
| Feed cost per cow | 2,170.09 | 2,170.09 |
| Hired labor per cow | 244.32 | 244.32 |
| Avg. milk price per cwt. | 28.62 | 28.62 |
| Milk price / feed margin | 15.07 | 15.07 |

## Appendix D - Organic Dairy Cow Enterprise Budget, Measured per Cow

**Livestock Enterprise Analysis**
**(Farms Sorted By Years)**

**Dairy -- Average Per Cow**

| | Avg. Of All Farms | 2021 |
|---|---|---|
| Number of farms | 23 | 23 |
| Milk sold | 4,515.57 | 4,515.57 |
| Dairy Calves sold | 47.00 | 47.00 |
| Transferred out | 59.22 | 59.22 |
| Cull sales | 295.16 | 295.16 |
| Insurance income | 10.63 | 10.63 |
| Government payments | 315.06 | 315.06 |
| Other income | 77.39 | 77.39 |
| Purchased | -32.61 | -32.61 |
| Transferred in | -84.12 | -84.12 |
| Inventory change | 59.23 | 59.23 |
| Dairy repl net cost | -698.20 | -698.20 |
| Gross margin | 4,564.33 | 4,564.33 |
| **Direct Expenses** | | |
| Protein Vit Minerals | 295.68 | 295.68 |
| Corn, Organic | 450.19 | 450.19 |
| Corn Silage, Organic | 310.66 | 310.66 |
| Hay, Alfalfa, Organic | 468.25 | 468.25 |
| Pasture, Organic | 108.59 | 108.59 |
| Haylage, Alfalfa Organic | 123.92 | 123.92 |
| Other feed stuffs | 412.81 | 412.81 |
| Breeding fees | 26.61 | 26.61 |
| Supplies | 154.70 | 154.70 |
| Fuel & oil | 83.05 | 83.05 |
| Repairs | 196.35 | 196.35 |
| Hired labor | 123.34 | 123.34 |
| Utilities | 91.17 | 91.17 |
| Hauling and trucking | 112.66 | 112.66 |
| Bedding | 65.93 | 65.93 |
| Miscellaneous | 213.27 | 213.27 |
| Total direct expenses | 3,237.17 | 3,237.17 |
| Return over direct expense | 1,327.16 | 1,327.16 |
| **Overhead Expenses** | | |
| Hired labor | 120.98 | 120.98 |
| Building leases | 82.74 | 82.74 |
| Farm insurance | 62.29 | 62.29 |
| Interest | 98.64 | 98.64 |
| Mach & bldg depreciation | 202.99 | 202.99 |
| Miscellaneous | 108.16 | 108.16 |
| Total overhead expenses | 675.79 | 675.79 |
| Total dir & ovhd expenses | 3,912.97 | 3,912.97 |
| Net return | 651.37 | 651.37 |
| Labor & management charge | 372.20 | 372.20 |
| Net return over lbr & mgt | 279.17 | 279.17 |
| **Cost of Production Per Cwt. Of Milk** | | |
| Total direct expense per unit | 20.21 | 20.21 |
| Total dir& ovhd expense per unit | 24.43 | 24.43 |
| With other revenue adjustments | 24.47 | 24.47 |
| With labor and management | 26.80 | 26.80 |
| Est. labor hours per unit | 38.73 | 38.73 |
| **Other Information** | | |
| Number of cows | 91.7 | 91.7 |
| Milk produced per cow | 16,014 | 16,014 |
| Lb. of milk sold per FTE | 1,140,651 | 1,140,651 |
| Culling percentage | 25.8 | 25.8 |
| Turnover rate | 31.2 | 31.2 |
| Cow death loss percent | 4.2 | 4.2 |
| Cows per milking unit | 10 | 10 |
| Feed cost per cwt. of milk | 13.55 | 13.55 |
| Feed cost per cow | 2,170.09 | 2,170.09 |
| Hired labor per cow | 244.32 | 244.32 |
| Avg. milk price per cwt. | 28.62 | 28.62 |
| Milk price / feed margin | 15.07 | 15.07 |