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TWO ESSAYS ON INPUT SUBSTITUTION AND OPTIMAL DECISION MAKING IN CROP AND LIVESTOCK PRODUCTION SYSTEMS

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TWO ESSAYS ON INPUT SUBSTITUTION AND OPTIMAL DECISION MAKING IN CROP AND LIVESTOCK PRODUCTION SYSTEMS

THESIS

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in the
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By

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Lexington, Kentucky

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ABSTRACT OF THESIS

TWO ESSAYS ON INPUT SUBSTITUTION AND OPTIMAL DECISION MAKING IN CROP AND LIVESTOCK PRODUCTION SYSTEMS

The thesis presented consists of two essays that analyze input substitution and decision making in crop and livestock production systems. The first essay consists of a whole-farm analysis that sought to optimize feed mixes and enterprise combinations for an organic dairy operation in the Southeastern United States. This was accomplished through mathematical programming where whole-farm net returns were maximized, and total feed costs were minimized simultaneously for four milk production level cases. Additionally, the sensitivity of the system and break-even milk price were explored. Results suggest substitutability in ration components where an increase in supplemental feeds is justified by additional milk output and sales. The second essay utilizes econometric methods and hedonic modeling to explore factors that drive the price of row crop planters on the used machinery market. Factors relating to make, age, condition, planter specifications, sale type, spatial aspects, seasonality, and year of the sale were analyzed. Results suggest non-linear relationships for row number and age relative to price and interactions between variables make and age that imply varying depreciation depending on the manufacturer. An additional break-even analysis relating to pasture yields and planter purchase price was conducted to explore these primary concepts in further detail.

KEYWORDS: Input substitution, decision making, organic dairy, agricultural machinery, whole-farm analysis, hedonic modeling

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TWO ESSAYS ON INPUT SUBSTITUTION AND OPTIMAL DECISION MAKING IN CROP AND LIVESTOCK PRODUCTION SYSTEMS

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DEDICATION

To *my mom, dad, and brother*

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1. INTRODUCTION

Agriculture production has developed extensively over the past 50 years leading to larger farms, improved efficiency, higher yields, improved technology, and expanded mechanization. These factors, however, have increased the need for capital and have increased the risk for farming operations. Therefore, good farm management and decision making are essential for the long-term economic sustainability of farming operations. This requires producers to stay up to date on their knowledge, skills, consumer preferences, research findings, available technology, government policies, trade, and much more. To accomplish this, it is important that current resources from agricultural industry participants are available to aid decision making (Kay, Edwards, & Duffy, 2012).

This thesis puts forth two essays that analyze input substitution and optimal decision making for crop and livestock operations. This is explored at three levels: the individual input level, at the whole-farm level including input substitution, and at the input market level. This considers enterprise combinations, feed mixtures, and capital investments relative to machinery. Through this empirical process, a framework is laid for strategic and tactical planning at these three levels. Results are also presented that allow for informed decision-making not only by farmers, but other agricultural industry participants.

The first essay consists of a whole-farm analysis of an organic dairy operation which is an alternative production system consisting of low volume, high margin producers. The hypothetical farm is based on an organic dairy operation with a similar structure to those found in the Southeastern United States. Using mathematical programming, enterprise combinations and feed mixtures were explored for four milk production level cases. Classical economic optimization formulations relating to minimum cost feed mixtures, resource allocation, and product mix problems were applied with the primary objective to maximize whole-farm net returns while simultaneously minimizing total feed costs. Optimal ration composition, feed production, and feed purchases were determined on a seasonal basis to meet nutrient needs based on an assumed underlying lactation curve. Once the farm net return maximizing solution was determined, a post-optimal analysis was conducted that explored the sensitivity of results relating to milk price. In this analysis, a break-even milk price was also determined for the four cases.

The second essay explored buyer and seller decision making relative to row crop planters on the used machinery market. Econometric hedonic modeling was used to identify the primary factors that influence planter prices on the resale market. Three years of sale data were analyzed with variables for make, age, condition, planter specifications, sale types, sale location, the season of sale, and the year when the sale occurred. Secondary objectives explored potential non-linear relationships between explanatory variables and sale price as well as potential interactions between the variables make and age. Research provided insight into this unexplored market and the overall factors that drive its demand.

In continuation of the research questions and objectives addressed in chapters two and three, a third analysis was conducted and can be seen in Appendix 2 and Appendix 3. A break-even analysis was conducted to explore input substitution equivalency for alternative pasture mixes and planters of different makes. Appendix 2 analyzed four pasture mixtures to determine the necessary yield required for the adoption of that mixture into the optimal solution for the organic dairy model. Appendix 3 used regression results from the base model to predict purchase prices of three different planter makes. Additional assumptions and cost calculations were applied to determine the necessary break-even purchase price of a given planter where its total machinery costs were equal to that of an alternative option. These two supplemental analyses provide a conceptual bridge and alternative perspectives of the inputs explored in the two essays.

CHAPTER 2. OPTIMAL FORAGE AND SUPPLEMENT BALANCE FOR ORGANIC DAIRY FARMS IN THE SOUTHEASTERN UNITED STATES

2.1 Abstract

As financial issues prevail in the conventional dairy industry, organic production is a potential alternative; however, economic research is limited and the long-term economic sustainability of the system is debated. In this study, a whole-farm economic analysis was performed to explore and optimize enterprise and feed options on an organic dairy farm in the southeastern United States. Results demonstrated the substitutability of ration components, and for the scenario examined, increased milk sales justified the production and purchasing of additional supplemental feeds. Results also indicate the potential stability of break-even milk prices across varying production levels for organic dairies and the opportunity for organic hay to be a supplementary enterprise.

2.2 Introduction

Currently, in the United States agriculture industry, there is a struggle in the conventional dairy sector. This is especially true in the Southeastern United States where total dairy cow inventory has fallen from approximately 848,000 in 2000 to 451,000 in 2019 (LMIC, 2019). This stems from multiple issues including an oversupply of milk, a weak farm economy, changing consumer preferences, and other factors that overall have many producers contemplating the future of their operations. Their options are also limited with the potential for farm bankruptcy looming in the future, but one potential option that has arisen in recent years. This refers to the transition to organic milk production which has allowed operations to continue business who otherwise would have not been able to financially sustain (Mcginnis, 2019). The transition can be challenging however, as it is a long-term investment and a time-consuming process that can last up to three years. During the transition period and for a minimum of twelve months, animals must follow all guidelines under the USDA's National Organic Program (NOP) while the products cannot be marketed as organic during this period (Flack & McCrory, 2012). Even once established, this production system does have its associated risks though, and with a limited amount of research, its long-term economic sustainability is debated.

Organic milk sales had been increasing for multiple years prior to 2017 and record demand was set in 2014 that sparked expansion of organic dairy operations (Haddon, 2018). However, consumer preferences began to change in 2017 where demand shifted to dairy substitutes such as plant-based alternatives like almond milk. Estimates relating to the growth of demand for organic dairy products were inflated, resulting in an unexpected oversupply of organic milk. This also resulted in a hit to farm income that has producers re-evaluating their operations respecting continued production moving forward. With depressed prices and limited economic research relating to the optimization of organic dairies, especially in the southeastern United States, producers are seeking solutions to minimize their costs.

Whether discussing a conventional, grazing, or organic dairy, feed costs have a noticeable impact on farm income, potentially making up to 40-60% of total production costs (Goodling, 2016). Therefore, this research analyzed ration components and feed costs for an organic dairy operation in the southeastern United States, and determined the optimal forage system for the operation. This was best executed through a whole-farm system approach where linear programming was used to maximize net returns while simultaneously minimizing dairy herd feed costs. The overall objectives of this study were to: 1) Determine the optimal forage mixture and necessary feed supplementation for the various production levels in order to maximize net returns to the organic dairy operation; 2) Identify potential production issues and opportunities for the organic dairy system; and 3) Determine the sensitivity of returns relative to changes in milk production levels and varying output milk prices.

The scenario analyzed herein, and the corresponding applied linear programming model, was designed to reflect a typical organic dairy farm found in the Southeastern United States. Herd characteristics, production levels, and nutrient requirements were fixed, and feed options consisted of forages raised on farm and purchased supplemental feeds. The output products generating returns for the given scenario were milk and forages harvested for hay. Overall, this study lends economic insight into an alternative production system and facilitates optimizing its feeding strategy and operations.

2.3 Literature Review

Mathematical programming has commonly been applied in the past to analyze dairy operations and has been explored through models that focus on minimizing feed costs, whole-farm applications, and models that integrate both. This has been done in scenarios such as those relating to policy implications (Van Calker, Berentsen, De Boer, Giesen, & Huirne, 2004; Moraes, Wilen, Robinson, & Fadel, 2012) and multi-objective ration and enterprise applications (Lara & Romero, 1992). However, most of this research has been related to conventional or confinement dairy operations, and mathematical programming applications to organic dairy farms have not been thoroughly performed.

In general, an organic dairy farm is more comparable to that of a pasture-based operation due to the USDA organic standards and the pasture rule that must be followed for certification (Rinehart & Bailer, 2011). General economic analyses have been applied to pasture-based dairies for such things as comparing this system's profit to a conventional dairy (Gillespie & Nehring, 2014) and the effect that ration balance has on profit and feed efficiency (Tozer, Bargo, and Mueller, 2004). Methods similar to the ones used in this study have also been used to explore optimal forage mixtures and grazing systems for dairy cattle (McCall & Clark, 1999; Neal, Neal, & Fulkerson, 2007; Doole & Romera, 2013). Although this does provide useful insight and grounds for potential comparison, a pasture-based dairy and an organic dairy system have significant differences and so do their markets. Additionally, a majority of pasture related research has been conducted internationally or in the Northeastern and Midwestern United States where the climates and environments can vary greatly compared to the Southeastern United States.

Although organic dairy management has been around for quite some time, research related to this production system has received heightened attention in more recent years as the market has expanded. A majority of the related economic research to this point has primarily looked at the expected costs, returns, and profitability of existing practices used in organic dairy production and how operations compare to their confinement or grass-based equivalents (Shadbolt et al., 2009; Kriegl, 2009; Tranel, 2017). This type of research has been conducted mostly in the upper Midwest and Northeast in such states as Wisconsin, Maine, New Hampshire, and others. These studies have also had primary focus on the role that ration composition and feeding strategies have on income and profit. A study from Wisconsin determined that feed strategies on organic dairy farms varied greatly from farm to farm, but feeding strategies, in general, were major factors in milk production level and income over feed costs (Hardie et al., 2014). Another study from New England demonstrated the economic advantage that forages can have in organic dairy feeding systems where grass-silage based diets were found to be superior in the study (Marston et al., 2011). Overall, general economic research relating to organic dairies has demonstrated the variability in farms production practices and feeding strategies especially between farms in different states (Kriegl, 2009). This has led to large variations in income over feed costs and profitability, while also emphasizing the need for unique and specific research applied to the southeastern U.S.

Whole-farm and feed ration modeling have been used in the past to simulate organic dairy farms primarily in European countries. This has been done through linear programming where a study from Belgium analyzed the economic potential for the conversion to organic farming. Another study from Norway used stochastic utility-efficient programming to incorporate risk and uncertainty on organic dairy farms (Kerselaers, 2007; Flaten & Lien, 2006). These studies continue to reinforce the variability in organic dairy operation's practices, costs and returns supporting the need for further economic research relating to decision making and optimization. Also, actual farm cost and financial data have become more available in more recent years, and when paired with current research, there is an opportunity for real-world modeling and application.

2.4 Mathematical Programming Model

A linear programming model was developed to represent an organic dairy operation at the whole-farm level while applying classical formulations relating to minimum cost feed mix, resource allocation, and product mix problems. The model was applied to four different scenarios that represented four different milk production levels with daily averages of 40, 45, 50, and 55 lbs. of milk per cow. The equations used, and the model in its entirety can be seen in Appendix A, wherein the objective function was to maximize net returns for a given production year and the necessary data to execute this is discussed in the next section. Overall, model decision activities constitute three general categories wherein the decision maker has options relating to what enterprises to produce, output products to sell, and feeds to include in the dairy ration by season (Table 2.1). Production activities include milk, alfalfa-grass mix hay, corn silage, sorghum-sudangrass, annual ryegrass, and four proposed pasture mixes consisting of both warm season species, cool-season species, annuals, and perennial grasses and legumes (Table 2.2). Herd number and production level were set for the dairy enterprise, but hay could be raised for on-farm use as well as being sold. Therefore, output products to generate returns were milk and baled hay.

On the contrary, the four pasture mixes, corn silage, sorghum-sudangrass, and annual ryegrass could only be raised for on-farm use as a feed source. Pasture mixes were used only for grazing, but the first cutting of sorghum-sudangrass and annual ryegrass could go to baleage while the second harvest went towards grazing, which is common practice in existing systems. Along with these forage sources, other supplements could be purchased for feed use and included: ground shelled corn, soybean meal, roasted soybeans, oats, barley, and wheat. Decision variables were primarily chosen by activities currently available or potentially feasible for organic dairy farms in the Southeastern United States.

Sets of constraints were modeled to reflect resource endowments and nutritional needs of the dairy herd. Overall, the constraints included land and labor availability, upper and lower limits for feed ration dry matter composition, livestock minimum nutritional requirements, feed balances, and marketing balances, as well as a constraint to fix herd size and milk production level. Two constraints related to land put a cap on the total number of acres that could be used for pasture and hay/cropland. Labor was represented on a monthly basis and broken into two categories: total labor and labor related to forage production. This was done to correctly assess both overall farm labor usage and the more constrained field machinery operations given machinery activities could only be accomplished on a suitable field day when the weather and field conditions were appropriate (Shockley & Mark, 2017). An example of this would be baling hay where hay moisture level must be considered, while the operation of milking can and should be conducted daily regardless of weather conditions. Balance constraints for the model guaranteed that all agricultural products produced were either sold or consumed by livestock; therefore, considerations related to storage were not implemented into the model.

A majority of the constraints that were applied were related to livestock nutrition and feed ration composition on a seasonal basis that reflected the cow's lactation stage and milk production level (Figure 2.1). This included the minimum total pounds of dry matter that must be consumed by the herd on a given day, as well as the maximum pounds of dry matter that a given feed ingredient could make up in the ration. These individual upper limits were set for specific concentrates including ground shelled corn, roasted soybeans, oats, barley, and wheat (NRC,2001). As forages are the foundation of a ruminant animal's nutrition, constraints were employed to ensure that upper and lower limits were met regarding forage, neutral detergent fiber (NDF), and acid detergent fiber (ADF) dry matter intake. Regarding nutrition, constraints guaranteed nutrient requirements such as crude protein (CP) and net energy for lactation (NeL) were met at their minimum limit for a given milk production level. Protein and energy were modeled as they are common deficiencies in pasture-based systems that can result in a potentially large reduction in milk yield (Muller, 2016). A minimum requirement was also set for dry hay consumption to allow for proper ruminant digestion (Linn, n.d.). Finally, a constraint was implemented to enforce "the pasture rule" that is required by the USDA for organic ruminant livestock production (Reinhart & Baier, 2011). This rule specifies that animals must graze a minimum of 120 days out of the year and at least 30% of dry matter intake, during the grazing period, must come from pasture. Therefore, this rule is potentially a strong determinant in organic dairy feed ration composition and overall whole-farm net returns. To focus on the primary objectives relating to cows and milk production it was also assumed in the model that calves were sold post birth and heifers were bought back when they reached a breeding age of approximately 24 months. To run the model and determine results AIMMS software was used (AIMMS B.V., 2017).

2.5 Data and Assumptions

Research questions, objectives, and the hypothesis for this study stemmed from field research currently being conducted on five organic dairy farms in Kentucky (four farms) and Tennessee (one farm). The project seeks to determine optimal forage combinations that promote good herd health, milk production, and economic returns for organic dairy farms in the Southeastern United States (USDA C, 2018). Data from the project relating to the four proposed forage mixtures (Table 2.2), forage yield, forage quality, milk yield, milk components, production practices, and general farm characteristics were applied to the model for this study. In general, the farm being modeled consisted of characteristics and factors that were common across the five producer farms to best represent a typical organic dairy operation in the Southeastern region. It was also assumed that the hypothetical farm was an established and fully functioning organic dairy farm and factors related to the transition period of organic production were not considered in this study. The hypothetical farm structure, resource endowments, and optional decision activities can be seen in table 2.2.

In linear programming or mathematical programming in general, the optimal solution reflects the numerical values of variables as determined by the model, and is therefore endogenous. To determine this solution, it first requires exogenous data from outside the model that makes up the technical, objective function, and right-hand side coefficients. Information, and the assumptions associated with the data, were sourced from recent on-farm research, previous scientific literature, university publications, and private industry sources for the model being used. Land and labor right-hand side values were determined through producer surveys of the farmers currently participating in research efforts (USDA C, 2018). It was assumed that the farm had two full-time employees who work 2,500 hours each on an annual basis and suitable field days were assumed to be at the 50th percentile representing "median" weather. A labor rate of $13.50 was assumed and the technical coefficients associated with labor for the production decision variables were based on field capacity calculations for various machines and general requirements determined through enterprise budgeting (Hanna, 2016). The total available land for production was 125 acres with 100 suited for pasture and the remaining 25 allocated for hay or crop production.

Production yields for the forage enterprises were based on current research, extension publications, and historical averages for the state and region with an assumed yield penalty for organic production that ranged from 5-20% depending on the crop. Corn silage had the largest organic yield penalty of 20%, and sorghum-sudangrass, annual ryegrass, and alfalfa-grass hay had penalties of 15%, 5%, and 5% respectively (Lee et al., 2007). For forages that could be grazed, an assumed utilization rate of 65% was applied to the total yield to reflect rotational grazing under intensive management (Amaral-Phillips, Hemken, Henning, & Turner, 1997). The fixed and variable costs of forage production were determined through enterprise budgeting (Appendix 2) and represented on a per acre basis (Halich, 2018; USDA C, 2019). Total costs, available yields, and nutrient composition of both produced and purchased feeds can be seen in table 4. All forage yields and nutrient composition were represented on a seasonal basis.

The assumed milk production levels were based on producer farm averages as well as benchmark numbers that are appropriate for the organic dairy industry (Miller, 2017). Using dairy production benchmarks from the University of Georgia, a seasonal distribution was created for the 365-day average milk production that resulted in four points along the lactation curve (Stewart et al., 2017). Therefore, four milk production levels and the relevant nutrient requirements were considered within the four overall scenarios. The lactation curve for the four milk production scenarios can be seen in Figure 2.1. The herd size was set at 50 cows with an assumed calving date of October 1st and 300 total days in milk (65-day dry period). The cows were assumed to be medium-large framed (Holstein-

Cross) with an average milk fat percentage of 3.5. Both the technical coefficients and the right-hand side values relating to dairy cows and feed nutrient composition were based on University extension research and those provided by the National Research Council (Linn, n.d.; NRC 2001). These nutrient requirements were based on general assumptions relating to cow characteristics, milk production level, milk composition, and stage of lactation.

As mentioned previously, the objective function coefficients related to production activities were determined through budgeting and cost analysis methods. The total costs, of those that were considered, on a yearly per head basis for the 40 lb., 45 lb., 50 lb. and 55 lb. were $2,402.10, $2,436.99, $2,471.86, and $2,504.32 respectively (Appendix 2). These values were determined through on-farm research and university extension publications and encompassed all costs besides those relating to feed and management (USDA C, 2019; Tranel, 2017). Feed costs were not included as they were determined by the model as part of the optimal solution. The university extension costs then were adjusted based on the milk production level and model assumptions. Price information for purchased feeds was received from Kentucky Organic Farm and Feed Inc. which is a primary supplier of organic dairy farms in western Kentucky and should be representative of organic feed prices in the Southeast region (2018). Milk price was determined through Organic Valley Dairy Benchmarks, which provided an average pay price over recent years, and an assumed base price of $30.00 per hundredweight was applied to the model (Miller, 2017). Finally, the output price of hay was $70.00 per ton which was assumed based on the USDA's "National Organic Grain and Feedstuffs Bi-Weekly Report" as well as expected premium's for organic hay compared to that of conventional hay on the local market (USDA B, 2018). Further information related to the objective coefficients can also be seen in Table 2.3.

2.6 Results and Discussion

A whole-farm linear programming model was developed and solved for a southeastern United States organic dairy operation and its feed ration components. Four milk production levels were examined which included daily per head averages of 40, 45, 50 and 55 pounds. The 45-pound level was the base for the analysis, and a change in production level prompted a change in the hand side coefficients relating to nutrient requirements, technical coefficients relating to labor and yield, and the objective function coefficient relating to the enterprise's total cost. The change in objective function values, net returns, and other relevant results for the different milk levels can be seen in Table 2.4. Although a 5-pound increase in milk production per head may sound modest at first, the results of the model indicate that at the whole farm level it can have a large impact on net returns and decision variable choices.

At the milk production level of 40 pounds, the expected net returns for the whole-farm scenario were approximately $42,212. At the 45, 50, 50-pound levels, expected net returns increased to approximately $64,622, $86,340, and $100,117, respectively. Therefore, as the average milk production increased by five pounds the net returns increased, but at a decreasing rate. More specifically, an increase in milk production from 40 to 45-pounds increased whole-farm net returns by 53%, from 45 to 50 net returns increased 34%, and from 50 to 55 net returns increased only 16%. This is a factor of the relative change in feed cost to meet the higher nutrient needs of an increased milk production level and reflects diminishing marginal returns for the hypothetical farm. As production level changed, total feed costs increased at an increasing rate where from the

40 to 45-pound level feed costs increased 6%, from 45 to 50 feed costs increased 7%, and from 50 to 55 feed costs increased 13%. This potentially relates to the input substitutability of feed sources to meet nutrient needs and an increase in the total quantity of feed demanded. Overall, the revenues and total costs of the four scenarios suggest that marginal revenue is greater than marginal cost and that a higher production level may, in fact, be optimal; however, that is beyond the scope of this current research. Therefore, the fact that the linear programming model does not truly maximize net returns should be noted and is a factor of fixed milk production levels and fixed herd size.

Enterprise and feed mix combinations across the four scenarios were similar in general with differences relating primarily to the quantity produced or fed. Across all scenarios, the cool season pasture mix was found to be economically superior to the other pasture mixtures. Other production activities for the scenarios included raising alfalfa-grass hay and corn silage. The economic preference for the cool season mixture was a result of lower total costs that stem from being composed totally of perennials where a majority of costs (i.e. seed costs and machinery costs related to planting) were distributed or prorated over the stands useful life of four years. Lower total costs of the cool season mixture was also a factor of requiring dramatically less machinery operations compared to mixtures composed of annuals, where seeding can be required as often as two times annually for the other mixtures. The yield of the cool season mix was also comparable to the others, and through statistical testing, this mix was found to be statistically higher in nutrient quality (USDA C, 2019). On average across the four scenarios, approximately 78 acres of cool-season pasture mix was produced and, interestingly, there was slack relating to total pastureland where not all the acres were utilized. A couple factors potentially explain this with the primary being that additional supplement feeds were needed to meet minimum nutrient requirements. This was especially true for the energy constraint, which was binding for all seasons across the four scenarios, which was consistent with previous research (Mueller, 2016). Another factor underlying this result is herd size relative to the total acreage available. On average, the stocking rate across the four scenarios was approximately 1.5 acres per cow and results suggest that there could be a potential benefit in increasing the herd number based on the scenario modeled herein.

In the optimal solutions, pasture was found to compose at most 98% of the ration dry matter, which was during the summer and fall seasons at the lowest production level scenario. It is worth noting that based on the assumed lactation cycle this is when the cow's dry period occurs as well as part of early or "fresh" lactation where dry matter intake and nutrient needs are relatively low (Chiba, 2014). In the spring when milk production was still relatively high, pasture made up on average 91% of total dry matter across the four scenarios. This was still relatively high when compared to the diet of a conventional dairy cow, but also suggests in this case that pasture unto itself is insufficient in meeting nutrient needs (Chase, n.d.). This relates back to the energy constraint being binding, as well as the production of corn silage and the need for other concentrated feeds such as shelled corn in the diet.

Corn silage was the second most consumed feedstuff on an annual quantity basis, but was consumed only in the winter months. This was a factor of its classification as a forage, because the fiber component maintains proper digestion when pasture is not present. This also showed that corn silage was a good energy source for the cost of production ($0.27/Mcal), which was reflected by its inclusion in the optimal solution.

Shelled corn was fed as an energy supplement as well in other months when pasture was present. Overall, feed cost across the scenarios made up approximately 60% of total variable costs, which was on the high end for dairy production systems in general, but not surprising based off the typically higher costs of organic production. These higher costs of organic feed production are typically factors of increased use of labor and capital, as well as a factor of typically lower yields compared to conventional production (AMRC, 2019) As production level increased across the four scenarios, additional acres were used for corn silage production. Also, since hay/cropland acreage was being utilized at its maximum in all scenarios, this resulted in less hay being sold off-farm as production level increased. The resulting shadow price for the hay/cropland constraint was approximately $26 across the scenarios, which was lower than typical cash rents for the area (approximately $45 for improved pasture) and does not justify the expansion of acreage for these operations (Halich, Kindred, and Pulliam, 2018).

The constraints relating to total labor and field sensitive labor endowments were non-binding across all seasons in the four scenarios. In addition to the 50% percentile assumed relative to suitable field days, a 30% percentile was tested which resulted in no change in the optimal solution and continued slack relative to labor.

In Table 6 and Figure 2, the results for the third objective and from the sensitivity analysis relative to milk price are presented. The break-even milk prices for the 40, 45, 50, and 55-pound level were $19.56, $20.23, $21.87, and $24.00, respectively. This suggests that, compared to the base price of $30, prices could drop between 20 and 35% depending on the production level and producers could still cover specified costs (excluding management costs). What occurs in the future is unknown, but for the given scenario and model this margin suggests a degree of safety or stability in the current position. Relative to the divergent shape of the lines in Figure 2, this demonstrates that not all costs were variable across the scenarios.

2.7 Conclusions

Linear programming was used in a whole-farm economic analysis of an organic dairy operation in the southeastern United States. Four milk production levels were analyzed and with incremental increases of 5 pounds of milk per head/day expected net returns increased at a decreasing rate. Enterprise and ration composition remained constant, but varied in the quantity produced and fed. As expected, higher milk production required additional feed supplementation. Higher levels required more silage to be utilized which decreased hay production due to resource limitations, but a feasible solution was determined, and net returns continued to increase. This and other factors demonstrated that, up to this point, the marginal revenue still exceeds the marginal costs for the organic dairy enterprise and the optimal milk production level has potentially not been reached. Furthermore, findings potentially suggest that grazing maximization does not necessarily mean profit maximization for the scenarios in that a higher milk production level can justify supplemental feeding for the conditions modeled. Additionally, the study showed that organic hay production was a beneficial and supplementary enterprise to organic dairy production and it could potentially assist producer's profits.

Potential model expansion will be explored in the future, as there are shortcomings in this current version. Data was compiled from a multitude of sources and relied on several assumptions, but as current research continues, the model and data will be revisited.

Ideally, the herd size and milk production levels would not be fixed. This would allow for the optimal number of head, based on available resources, to be determined as well as the optimal milk production level to be determined as a factor of the inputs. Additionally, previous research has identified potential economies of size relationships related to herd number; therefore, a non-fixed herd size could give insight into whether this remains true in Southeastern U.S. production systems. (McBride & Greene, 2009). Adding factors relating to the transition period from conventional dairy production to organic would also be beneficial for future research and more accurately represent the system over a multitude of years.

Overall, the organic dairy system could offer a potential opportunity to conventional producers, but further research must be done to test the sustainability of this type of system and market. Through this study and research conducted going forward, recommendations can be made to actual operations and farmers. This will allow them to optimize their operations based on their available resources thereby potentially increasing operation efficiencies and mitigating potential risk.

2.8 Chapter 2 Tables and Figures

Table 2.1 Organic Dairy Model Components and Assumptions

Location:	Southeastern United States		*Primary Enterprise:*	Organic Dariy
			Secondary Enterpise:	Organic Hay (Alfalfa-Grass Mix)
Acres:	*Pasture*	100		
	Crops/Hay	25	*Dairy Enterprise Size:*	50 Head
			Breed :	Medium-Large Cows
Labor (Full time eqiv.):	2 Employees		Production Levels:	40 lbs. 45 lbs. 50 lbs. 55 lbs.
Total Avail. Labor Year:	5,000 hours			
Produced Feed Options:	Pasture Mix (WRC)		*Purchased Feed Options:*	Corn (Shelled, Ground)
	Pasture Mix (WCC)			Soybean Meal
	Pasture Mix (CS)			Roasted Soybeans
	Pasture Mix (WTR)			Oats
	Sorghum-Sudangrass			Barley
	Annual Ryegrass			Wheat
	Alfalfa-Grass Hay			Alfalfa Hay
	Corn Silage			

Notes: Assumed two cuttings/grazings, first harvest goes to baleage with second being grazed. Medium-large cows are more specifically assumed to be Holstein Crosses with a Body weight approximately 1,300 lbs. Rolling Herd Averages for the herd across a callender year assuming milking period of 305 days Units: milk lbs./head/day

Table 2.2 Proposed Forage Mixture for Organic Dairy in the Southeastern U.S.

Mixture	Mix Name	Abbrev.	Species	Scientific Name	Classification	Life Cycle
A	**Warm Red Clover**	**WRC**	Annual Ryegrass	*Lolium multiflorum*	Cool Season Grass	Annual
			Red Clover	*Trifolium pratense*	Cool Season Legume	Perennial
			Crabgrass	*Digitaria ciliaris*	Warm Season Grass	Annual
			Annual Lespedeza	*Kummerowia striata*	Warm Season Legume	Annual
B	**Warm Crimson Clover**	**WCC**	Annual Ryegrass	*Lolium multiflorum*	Cool Season Grass	Annual
			Crimson Clover	*Trifolium inarnatum*	Cool Season Legume	Annual
			Sorghum-Sudangrass	*Sorghum bicolor x S. bicolor var. sudanense*	Warm Season Grass	Annual
			CowPea	*Vigna unguiculata*	Warm Season Grass	Annual
C	**Cool Season**	**CS**	Alfalfa	*Medicago Sativa*	Cool Season Legume	Perennial
			Red Clover	*Trifolium pratense*	Cool Season Legume	Perennial
			Orchardgrass	*Dactylis glomerata*	Cool Season Grass	Perennial
			Tall Fescue	*Festuca arundinacea*	Cool Season Grass	Perennial
D	**Warm Turnip and Rape**	**WTR**	Forage Turnip	*Brassica rapa*	Cool Season Brassica	Annual
			Forage Rape	Brassica napus	Cool Season Brassica	Annual
			Spring Oats	*Avena sativa* L.	Cool Season Grass	Annual
			Annual Ryegrass	*Lolium multiflorum*	Cool Season Grass	Annual
			Sorghum-sudangrass	*Sorghum bicolor x S. bicolor var. sudanense*	Warm Season Grass	Annual
			Cowpea	*Vigna unguiculata*	Warm Season Grass	Annual

Table 2.3 Costs, Yields, and Nutrient Composition of Available Feedstuffs

Produced Forages		Yield (Tons DM/Acre)	Total Cost ($/acre)	Dry Matter	NDF	ADF	CP	Net Energy
Pasture Mix (WRC)		4.50	$314.40	22%	46%	31%	20%	0.69
Pasture Mix (WCC)		5.00	$375.79	22%	47%	30%	18%	0.69
Pasture Mix (CS)		4.50	$196.20	22%	45%	30%	20%	0.71
Pasture Mix (WTR)		4.50	$385.72	22%	48%	32%	17%	0.68
Alfalfa-Grass Mix Hay		4.00	$237.97	90%	49%	36%	17%	0.64
Corn Silage		4.80	$645.09	35%	46%	28%	8%	0.70
Sorghum-Sudangrass	*Baleage*	2.80	$589.77	45%	68%	42%	11%	0.56
	Pasture	1.20	-	22%	55%	35%	17%	0.57
Annual Ryegrass	*Baleage*	2.00	$470.09	45%	58%	37%	16%	0.59
	Pasture	0.50	-	22%	50%	31%	18%	0.67

Purchased Feeds		Purchase Price ($/ton)	Dry Matter	NDF	ADF	CP	Net Energy
Corn (Ground, Shelled)	-	$426.00	89%	9%	3%	9%	0.92
Soybean Meal	-	$837.00	91%	12%	10%	50%	0.97
Roasted Soybeans	-	$807.65	88%	13%	15%	43%	0.96
Oats	-	$450.00	89%	32%	15%	13%	0.80
Barley	-	$480.00	89%	26%	21%	12%	0.84
Wheat	-	$451.00	89%	13%	4%	14%	0.90
Alalfa Hay	-	$333.00	90%	42%	34%	18%	0.90

Notes: Source: NRC "Nutrient Requirements of Dairy Cattle: Seventh Revised Edition" 2001 NDF = Neautral Detergent Fiber, ADF = Acid Detergent Fiber, CP = Crude Protein. Net Engery refers to net energy for lactation and is measured in Mcal/lb

Table 2.4 Optimal Solutions and Whole-Farm Net Returns

		Average Milk Production Levels (lbs./Head/Day)			
		40 lbs.	**45 lbs.**	**50 lbs.**	**55 lbs.**
	Exp. Net Returns	$42,212.40	$64,622.30	$86,340.90	$100,117.00
Produce (Acres)	Pasture (CS Mix)	76.04	77.72	78.63	78.53
	Alfalfa-Grass Hay	10.09	9.76	9.42	9.24
	Corn Silage	14.91	15.25	15.58	15.76
Sell	Milk (CWT/Herd)	7,041.50	7,940.50	8,839.50	9,588.50
	Alfalfa-Grass Hay (Tons)	30.55	29.27	28.03	27.33
Feed (Tons/DM)	Pasture (CS Mix)	995.36	1,017.40	1,029.28	1,028.02
	Alfalfa-Grass Hay	7.60	7.60	7.60	7.60
	Alfalfa Hay	22.80	22.80	22.80	22.80
	Corn Silage	192.16	196.57	200.79	203.17
	Shelled Corn	38.85	44.15	51.44	67.79

Table 2.5 Break-even Milk Price at Varying Production Levels

Milk Production Level	Breakeven Milk Price
40 lbs.	$24.00
45 lbs.	$21.87
50 lbs.	$20.23
55 lbs.	$18.56

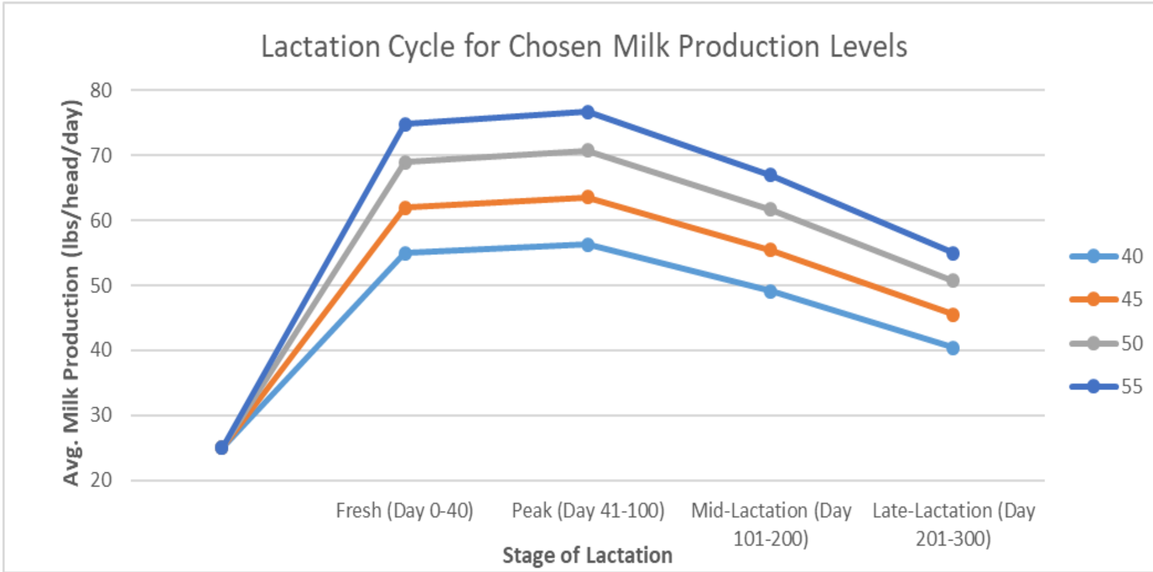

Figure 2.1 Lactation Cycle for Chosen Milk Production Levels

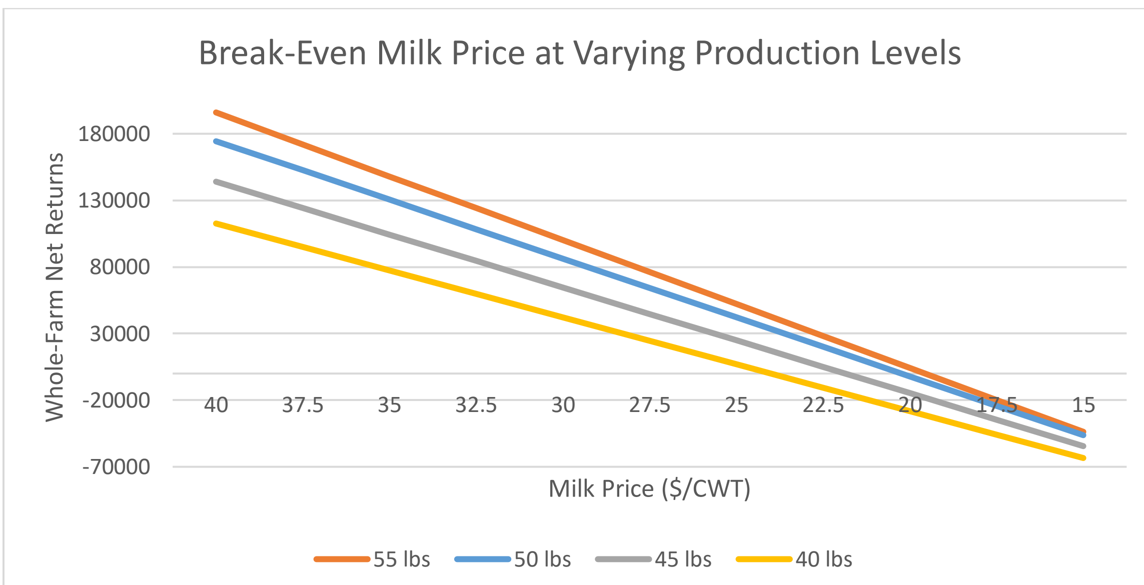

Figure 2.2 Break-even Milk Price at Varying Production Levels

CHAPTER 3. PLANNING FOR PLANTING: A HEDONIC ANALYSIS OF AGRICULTURAL PLANTER PRICES

3.1 Abstract

A model is developed to explore the primary factors that influence the resale price of agricultural planters on the used machinery market. Using a hedonic analysis, coefficient estimates were determined for price factors that included machinery make, age, condition, specifications, sale type, sale location, season, and the year when the sale occurred. A majority of the variables considered were found to be significant, and a non-linear relationship between planter re-sale price and the number of planter row units was found. Results also suggest that there is a potential interaction effect between planter make and age where depreciation varies by the make of the planter. Findings support the complexity and heterogeneous nature of agricultural planters where the sale price is a result of the summation of individual characteristic values.

3.2 Introduction

In row crop production, it is hard to argue that there is a more important piece of machinery than the planter. Without the planter, there is no crop to spray, irrigate, or combine. Additionally, the timing of when the planter is used, its efficiency, and its utilization of available technology have a dramatic effect on yield from the moment the seed is placed in the ground (De Bruin & Pederson, 2008; Van Roekel & Coulter, 2011). With a goal of achieving the maximum attainable yield, it is essential that the planter reaches the field at the optimal time to deliver properly spaced seeds leading to healthy plant populations (Nafziger, 1994). Therefore, there is a lot of pressure placed on farm profitability during planting, in turn leading to increased producer demand for quality and reliable planting equipment for their operations.

Due to their large role in production agriculture (Figure 3.1-3.3) and the scale/size of row crop production, research and development has led to major advancements in planter technology over recent years (USDA A, 2018; Schnitkey A & B, 2004). Like other equipment in agriculture, planters have trended toward larger machines with row-numbers ranging from 1 to 48 units that can cover 120 feet with a single pass. However, with innovative technology and increased planter size has come higher sale prices. When this is paired with the fact that machinery expenses make up approximately 40% of total crop expenses, additional pressure has been added to the purchasing decision (Ibendahl, 2015). The machines have also become highly customizable giving producers the ability to specialize the machines for their given operation. This also makes buying a planter on the resale market a difficult decision, as a planter is not a one-size fits all machine for every crop farm. Customizable components include frames, drive systems, row units, seed delivery systems, row cleaners, fertilizer and pesticide options, and many more (Wehrspann, 2010). Overall, this customization has led to highly differentiated products on the used machinery market with a potentially large number of planter specific, economic, seasonal, and spatial factors that drive a wide range of prices. Therefore, lending itself to a hedonic framework.

Fairly extensive research has been done in the past related to the factors that influence machinery and vehicle prices. This application has commonly been done on cars/automobiles (Boyd & Mellman, 1980), as well as a few studies relating to agricultural machinery such as tractors (Diekmann, Roe, & Batte, 2008). However, the factors relating to agricultural planting equipment prices have not been analyzed in detail. Therefore, the extent of physical machinery components, as well as the extent of outside factors such as commodity prices or sale location have not been explored in relation to planter prices. The form of these potential relationships is also unknown where there is potential for nonlinear relationships relating to the variables.

Additionally, popular press articles and private industry research have recently noted shortcomings in available information and data relating to agricultural planter markets (Mowitz, 2018). This is causing potential market inefficiencies where consumers do not have full knowledge or confidence in what is for sale, thereby potentially hurting sale price due to the associated risk involved. Overall, technological advancements, improved agronomic knowledge, lack of relevant scientific literature, and complaints within the market are only a few justifications for further economic research relating to agricultural planter re-sale prices.

The research presented in this work sought to address the issues mentioned above to lay the framework for additional research and to benefit both the buyers and sellers in the market. Fundamental planter components, economic factors, spatial aspects, seasonality factors, type of sale, and other variables will be explored in their relation to the sale price of used planters. The overall objectives for this study were to 1) identify the primary factors that impact planter sale price on the resale market; 2) explore potential non-linear relationships in the variables to better understand the hedonic surfaces; 3) determine if there is an interaction amongst the independent variables make and age that would suggest that depreciation varies between different makes for planters.

3.3 Literature Review

Hedonic demand theory and analysis dates back to 1974 and since its development has been applied in a wide range of industries (Rosen, 1974). In the agriculture industry specifically, it has been applied to such things as land (Roka & Pamquist, 1997), commodities (Ethridge & Davis, 1982), and machinery. Its application to agricultural machinery has allowed for supported price adjustments, forecasting, and the creation or improvement of price indexes.

Before the development of hedonic analysis, factors affecting machinery prices were still explored under different theoretical and empirical models. An early and noteworthy study looked at adjusting tractor prices based on changes in quality and generated price indexes based on this information (Fettig, 1963). The study found that two specification variables (horsepower, diesel or gasoline engine) were responsible for 88-96% of the variance in tractor price. Overall, the findings demonstrated the strong role that quality changes have and that modifying price indexes for them can be a challenge. Another study using duality theory explored the effect that interest rates have on agricultural machinery investment (Leblanc & Hrubovcak, 1985). The results of the study confirmed that interest rates affect price adjustments. Additionally, it was found that input/output price ratios role in adjustments were larger than that of interest rates. These studies are classic examples of research relating to agricultural machinery prices, and a majority of the findings have remained true with the development of machinery over time.

The substantial changes in the agriculture industry and extensive technological improvements over time have created the need for current research relating to machinery markets in recent years. To fulfill this need, hedonic analysis has been applied in a few different cases. A study that is very relevant to the research conducted for this paper explored the effect that adoption of online auctions had on the used machinery market (Diekmann, Roe, & Batte, 2008). Specifically, it studied the difference in marketing tractors on the internet/eBay versus in-person auctions. The goals of the study were: 1) if the two outlets resulted in similar average prices, determine what factors drive the seller to the two outlets, 2) determine if sellers were intentionally going to the outlet that offered the higher potential sales revenue. Variables that were studied included machinery specifications (make, age, hours of use, horsepower, 4WD, etc.), location factors, and the timing of when the sale occurred. The results found that sales on eBay resulted in lower average sales prices in general, and if the tractor was valued at more than $20,000, in-person auctions offered higher potential revenue. Overall, significant results relating to hours of use, age, make, sale timing, and the location were found which have important potential implications for this study and influenced which variables were included in the models.

Two other relevant studies were conducted in recent years that explored economic, financial, and political factors role in machinery sales and its overall effect on U.S agricultural productivity. Osbourne and Saghaian researched the effect of these outside factors on machinery expenditures for the period spanning 1960-2010 (2013). They attempted to explain demand through variables that included interest rates, commodity prices/cash receipts, lagged machinery expenditures, input prices, and net farm income. Significant results were found for machinery expenditures (positive), net farm income (positive), purchased inputs (positive), and interest rates (negative). Cash receipts relating to commodity prices were not found to be significant. Therefore, it was concluded that its influence on expenditures is minimal. The other relevant literature applied quality-adjusted tractor prices to a productivity analysis of agricultural output growth for the period of 1950-2011 (Wang, Schimmelpfennig, & Ball, 2013). The research found hedonic prices lower than the Bureau of Labor Statistics tractor index used by the USDA. This demonstrated an increased technical change in farm tractors and when these hedonic prices were applied, the average annual total factor productivity (TFP) decreased. Therefore, demonstrating the importance of accurate machinery quality characteristics in forming indexes and in their application.

By examining previous literature, shortcomings and opportunities have been pinpointed that have led to the research and information presented in this paper. The hedonic approach has been commonly applied in the past, but its use in relation to non-tractor agricultural machinery has not been explored. Additionally, the heterogeneous nature of planters in general, and their wide range of sale prices, aligns well with the theory of hedonic demand (Kristensen, 1984). Previous literature has also revealed the need for the continuation of hedonic research relating to agricultural machinery to ensure accuracy in utilized indexes. These factors, paired with the complaints in the industry about inconsistent data collection and consumer knowledge continue to support research relating to machinery markets (Mowitz, 2018).

3.4 Data

Data relating to finalized sales was collected from a multitude of auction companies and machinery dealers for sales occurring from 2016 to the middle of 2018. The results were then compiled in Machinery Pete's "Auction Price Data" database where they were sourced for this research (Machinery Pete, 2018). The data set initially consisted of 2,818 observations and included information for the final sale price, make, model, manufacturing year, hours of use, condition, sale date, sale type, city and state of sale, and a specs column where auctioneers entered information they deemed relevant. Extensive data cleaning was required, and total observations were reduced to 847 observations in the process. This required the removal of all observations that did not include the manufacturing year, make of the machinery, two observations that were listed as "Other" sale type, and the variable for hours due to a very limited number of observations with this information included.

Additionally, there were gaps in the data relating to the total number of rows the machine could cover or the spacing on the rows where only one or the other was included in the sales description. Therefore, necessary data for either row number or row spacing was sourced from online sale catalogs and machinery operator manuals for approximately 290 observations. The resulting pooled data sample remains extensive with descriptive observations for sales occurring across 31 states (Figure 4) and the prominent United States production areas; therefore, it is deemed a good representation of the overall planter population on the resale market.

The data posed some initial challenges related to inconsistencies in the specifications provided where some observations were highly descriptive with information relating to seed systems, meters, drive systems, fold types, monitors, and more. Other observations were provided with no specifications relating to the planter, which limited the number of components that could be studied. This is relevant, as one would hypothesize that the presence or absence of certain features could potentially affect the final sale price. Lastly, the lack of a variable relating to acres covered, hours of use, etc. is unfortunate with other studies finding significant results relating to this depreciation factor (Cross & Perry, 1995). Therefore, the effect of use and wear on the planter observations is now represented by age since manufacturing and the subjective condition measurements of excellent, good, or fair.

As mentioned above, the final data set consisted of 847 total observations broken down into primarily dummy variables with continuous variables for sale price and age. Descriptive statistics for the pooled data can be seen in Table 3.1 and group means for row number, and individual makes can be seen in Table 3.2 and 3.3. To best support the main objective relating to the identification of the primary factors that influence planter re-sale price, variables relating to the manufacturer, age, condition, planter structure, sale type, seasonality, and macroeconomic factors (captured by dummy variables for sale year) were included in the models.

3.5 Econometric Models

Three models with slightly different components were developed for this analysis and were based on the hedonic theoretical framework that was presented by Sherwin Rosen (1974). In his work, he put forth the hypothesis that "goods are valued for their utility-bearing attributes or characteristics" and defined hedonic prices as "the implicit prices of attributes and revealed to economic agents from observed prices of differentiated products and the specific amounts of the characteristics associated with them." Therefore, planters are differentiated goods, and in this case, their sale price is equal to the value obtained from each individual characteristic it contains.

For the regression analysis, the general form of the agricultural planter price function and the base model is as follows (Diekmann, Roe, & Batte, 2008):

$$\ln(P_i) = k + \beta_j x_i + u_i$$

In the equation, i represents the planter corresponding to an observation, P_i is the predicted hedonic price for the planter i , k is the price intercept, β_j is a row vector representing the implicit marginal values for the varying planter characteristics, x_i is a column vector of the characteristics of the planter, and finally u_i are the errors where some are purely random, but have an influence on a given planters price. To control for skewness and potential outliers in the dependent variable price, a logarithmic transformation was applied to the price. The variable age was also transformed under the hypothesis that a quadratic relationship might exist between age and final sale price. Additionally, row number was broken into four groupings (Table 2) to test for a non-linear relationship between the row number explanatory variable and sale price. These groupings were determined by plotting the residuals pertaining to the variable row number. The pattern of the residuals suggested natural breaks at the row numbers 12, 16, and 24 with linearity between the breaks. Finally, the model was run under robust standard errors to handle heteroskedastic issues that were found in the data set.

Based on economic and agronomic principles as well as market trends, expectations can be made about the relationship between the explanatory variables and sale price in the base model. When compared to the variable "Other" makes (grouping of White, Great Plains, Monosem, Peaque, IHC, and Wil-Rich), coefficients for John Deere, Case IH, and Kinze are expected to be highly significant with positive coefficients as seen with previous research related to tractors. Age and age^2 are also expected to have highly significant roles and have negative coefficients as seen in prior literature (Diekmann, Roe, & Batte, 2008). Excellent and good condition are expected to have positive coefficients when compared to the variable for fair condition. If the planter has a split row structure, it is expected to have a positive coefficient due to the increased number of planter components, structural complexity, and increased demand from crop producers in recent years (Mowitz, 2017). The coefficient for a planter with a twin-row structure is expected to be negative as these types of planters are not highly demanded and their use is almost primarily in the Southern U.S. The base for split and twin-row configurations was a variable consisting of planters with "conventional" row-unit configurations.

Row spacing and row number are two variables that represent the impact of a planter's size on its sale price. If a planter's row spacing is 30" it is expected to have a positive coefficient when compared to the base of <30" as 30" is the common row spacing in corn production today. The variable for row spacing > 30" is expected to be negative due to these spacing's no longer being a common practice where yield is not maximized (Lambert & Lowenberg-Deboer, 2003). Regarding row numbers, the coefficient across all groupings is expected to be positive when compared to the base of having 10 or fewer rows. As the groupings increase to a higher row number range the marginal contribution to sale price is expected to increase as well compared to the other groupings.

The base sale type in this study was dealer sales and all other sale types are expected to have positive coefficients. This is primarily anticipated because of the competitive nature of the other auction platforms. Spatial factors are analyzed through variables for the four regions, and when compared to the Midwest all other regions are expected to be negative.

This is expected to derive primarily from the Midwest being the prominent growing area for corn and soybeans where there is larger demand and competition for planters. The coefficients for winter, summer, and fall are expected to be positive due to spring planting workload and historical trends (Mowitz, 2018). Dummy variables for years were included in the model with an attempt to capture the impact of macroeconomic factors at an aggregate level. This method makes predicting the relevant sign more difficult when compared to other variables, but it is expected that the dummy variables for 2017 and 2018 would be positive compared to the base of 2016. The reasoning behind this comes primarily from the continuation of a depressed farm economy where more producers are switching from buying new to used; therefore, increasing demand and final sale prices (Gustafson, Barry, & Sonka, 1988).

To explore the potential interaction between the variables, make and age, and to analyze the difference in hedonic surfaces for individual makes, the base model was slightly modified. The interaction model was developed and applied to all 847 observations, but the model for makes was ran in three iterations where the specific observations for John Deere (497), Case IH (112), and Kinze (179) were all run separately. Compared to the variables included in the base model, all the same variables besides for age and age squared were included in the interaction model with the addition of the interaction terms and procedures for the interaction model remained the same as the base. For the models applied to individual makes, dummy variables representing makes were dropped, no interactions were included, and all other components remained the same as the base model.

3.6 Results and Discussion

Hedonic modeling and STATA software was used to analyze agricultural planter's final sale prices on the used machinery market (StataCorp, 2017). In figure 6, a box and whisker plot was used to demonstrate the distribution of sale prices for all observations as well as for the three primary machinery makes. The x's in the boxes represent the means, the horizontal line within the boxes is the median, the top, and bottom of the boxes reflect the 75th and 25th percentile value respectively, the whiskers represent the upper and lower extreme values, and finally, the dots outside the extremes represent the outliers. The mean price across all sale observations was $39,626.19 which was less than the mean value for the market leader John Deere ($43,413.29), but larger than the means for all other makes. Overall, Figure 6 visually demonstrates the potential role that makes can have in relation to the resale price, and regression estimations were found to statistically support this as well.

In Table 4, the results and estimated coefficients for the base hedonic model are displayed. The first column lists the variable with the second column containing the corresponding estimated coefficient, its level of significance, and in parenthesis is the robust standard error. Overall, the model was found to be a good fit for the cross-sectional data with an R^2 value of 0.81 representing that 81% of the variation in planter re-sale prices was explained by the model. The model was tested for potential multicollinearity (variance inflation factor) and specification error (link test) and the results suggested no violation of assumptions. A majority of the variables were found to be statistically significant as well. Statistically significant results for variables at the 1% level included: John Deere, Kinze, age, age^2, condition excellent, condition good, split row configuration, all row number groupings, 30” row spacing, >30” row spacing, winter season, and the 2018 sale year.

Additionally, at the 5% level the variable for the fall season was found to be significant and at the 10% level the make Case IH was significant. This demonstrates that some of the major factors that affect planter re-sale price are related to make, age, condition, size, and planter configuration. These results also support that there are non-linear relationships between price and age where planters’ values are decreasing with age at a decreasing rate. Results also support a stepwise relationship between price and row numbers. This relationship can be seen in Figure 7, and through paired t-tests for difference between means, it was determined that the impact of row number on price was relative to the size grouping (t = -2.44, p = 0.008; t = 2.893, p = 0.002; t = 5.37, P = < 0.001). These results also suggest that the marginal impact of an additional row-unit is higher for larger planters. This could be influenced by planters being more technologically advanced at a larger size paired with the decision by producers to upsize, creating more demand for larger planters.

A majority of the expected relationships between the variables was confirmed with the exception of those pertaining to row spacing. Results suggest that when compared to planters with row spacings <30”, 30” and >30” row spacings have a negative effect on a planter’s value. This is potentially driven by the fact that when row spacings are narrower, there is more steel and technology in a given area compared to a planter at the same width that has 30” or >30” rows. Another potential explanation is recent agronomic research showing potential yield benefits from narrow row spacings compared to 30” which is increasing producer demand for these types of planters (Lambert & Lowenberg-Deboer, 2003).

The results for the interaction model can be seen in Table 4 where the fit and significant variables were comparable to the results of the base model. The inclusion of the interaction terms relating to make and age is supported by the results where all four interaction variables (JDAge, CIHAge, KinAge, & OthAge) were highly significant at the 1% level. It was also determined that JDAge, CIHAge, and KinAge are all significantly different from one another ($t = 17.14$, $p < 0.001$; $t = 11.15$, $p < 0.001$; $t = 5.52$, $p < 0.001$). This could not be said for these three interactions in relation to OthAge which could be a result of data limitations from a small sample size for the variable OthAge. Overall, these results suggest varying depreciation exists among planters of different makes and these findings are consistent with previous research relating to other types of agricultural machinery (Perry & Nixon, 1991; Cross & Perry, 1995). More specifically, results suggest that Case IH planter values are most negatively impacted by age when compared to John Deere and Kinze. Somewhat surprisingly, Kinzes retained their value better over time compared to John Deere, which could potentially be a factor of John Deere planters having higher values at the time of manufacturing. This could also be a result of the technology employed on the planters where it could be argued that Kinzes may be “simpler” than John Deeres historically; therefore, John Deeres experience more rapid obsolescence relative to Kinze. This could also be compounded by a potential niche market existing for these older or “simpler” Kinze planters. Overall, when the interaction terms were included the dummy variable for Kinze became non-significant while Case IH improved to the 5% significance level and John Deere's coefficient remained basically the same.

When the model was run for the individual makes John Deere, Case IH, and Kinze, it proved to be a good fit for the sub-samples as well (Table 5). The highest R^2 value was found for John Deere (R^2 = 0.85, Case IH = 0.85, Kinze = 0.81) which could be driven by John Deere having the most observations compared to other makes. If this is representative of the true ratio of John Deere planters on the market compared to other makes, it could also suggest that buyers have comparable knowledge of the perceived value of the machine; therefore, limiting the range of price fluctuations. It could also simply be a factor of potential brand loyalty where John Deere is viewed superior by a majority of crop producers.

Similar variables were found to be significant across the three makes which included those relating to age, condition, planter configuration, specifications, and the 2018 sale year. Interestingly, the twin-row variable was significant for both John Deere and Kinze, but their coefficients were opposite. This could be related to areas of focus in research and development by the manufactures relative to the markets they are potentially targeting. Another interesting and important finding from the individual regressions for different makes relates to the age and age^2 variables where the results potentially suggest that there is variable depreciation based on the make (Figure 3.8). These findings are also consistent with results determined by the interactions model where the impact of age on sale-price is dependent on the make of the planter. Age was significant at the 1% level for all three makes, and age^2 was significant at the 1% level for John Deere and Case IH and at the 10% level for Kinze. Their coefficients suggest a quadratic relationship where John Deere and Case IH lose value at a decreasing rate while surprisingly Kinze loses value at an increasing rate. Another potential explanation for this variable depreciation relates to demand and brand loyalty, where a recent survey revealed that of the producers surveyed 75% confirmed that they are brand loyal (Kanicki, 2017). Therefore, demand could be higher for certain brands, which assist in the retention of the machines value over time.

3.7 Conclusion

The structure of farming operations has changed dramatically in the past few decades which has led to drastic changes in the machines that are necessary to carry out their operations in an efficient manner. Agriculture machinery, in general, has trended towards larger sizes with more technologically advanced components. This remains especially true for the planters which vary greatly in size, structure, and other characteristics. The research presented here sought to explore these factors, as well as others, in their relation to planter's resale prices on the used machinery market. There is a lack of knowledge relative to this market which leads to a common question that has been proposed in the agriculture industry, "Why does a crop planter cost so much?" This is a seemingly simple question with a complex answer and findings from this research provide some insight into this question as well as insight into non-linearities and interactions between factors that would influence planter values.

Hedonic modeling was used in three applications that provided different perspectives on factors that influence planter values on the resale market. Significant and mostly consistent results were found across the five estimations which supports that hedonic approach and the specified empirical models were appropriate methods for the questions of interest. Results suggest that the primary factors that impact planter re-sale prices are make, age, condition, planter configuration, row number, and row spacing. Other factors that showed a significant impact in some cases relate to seasonality and sale year. Surprisingly, sale types and sale location were not found to have a significant role that was consistent across the varying models in this study. This could be a potential result of distribution issues in the data relating to these variable categories. Another potential limitation in this current research includes the data set only covered three sale years which limits the ability to capture time trends and macroeconomic factors accurately. Future research will be conducted to explore sale types at a deeper depth with the hope of it providing further insight into buyer and seller decision making.

The other main findings of these research relate to interactive effects between variables upon expected planter price. It was determined that the variables price and age have a quadratic relation for planters where in most cases the price is decreasing at a decreasing rate with an increase in planter age. Natural breaks were found relating to the row number, where the impact of this variable on price was dependent on the range of row numbers covered in a given group. More specifically breaks were determined at row numbers 12, 16, and 24, where graphically the relationship takes on a stepwise shape. Finally, through a model with a focus on interaction terms, it was determined that there is a significant interaction between the variables make and age. Therefore, the impact of age on sale price depends on the make of the planter, and for John Deere, Case IH, and Kinze their impact was found to be statistically different from one another. These findings suggest that Kinzes tends to relatively hold their value with age, while CASE IH depreciates at a faster rate than the other two primary makes. Further research will need to be conducted in the future relative to variable depreciation on planters and the relationship between depreciation and make.

The significant results from this research have potential implications and applications in the agriculture industry. These results are beneficial for both the buyers and sellers in the used machinery market as there is currently a lack of knowledge about the market. This allows participants to make more educated decisions and an overall increase in market efficiency. It also could potentially assist agriculture producers when they are considering buying equipment new. It will allow them to potentially think more long term about capital investments in machinery and make educated decisions relative to replacement choices. This research also addresses the issue of shortcomings in planter descriptions especially relating to add-ons and specifications (Mowitz, 2018). These components make planters customized for specific types of operations and could potentially be significant factors in the final sales price. In conclusion, the research conducted here offers highly encouraging results that are the base for future research related to agriculture machinery prices on the used machinery market for planters, tractors, and combines.

3.8 Chapter 3 Tables and Figures

Table 3.1 Planter Data Distribution and Summary Statistics

Variable	Definition	Number of Observations	Range	Mean	Stand. Deviat.	Variance
Independent						
Price	Final Sale Price ($)	847	1,800.00 - 224,000.00	39,626.19	33,084.61	6.493E+10
Dependent						
Make						
JohnDeere	= 1 if John Deere is the make	497	0 - 1	0.59	0.49	0.24
CaseIH	= 1 if Case IH is the make	112	0 - 1	0.13	0.33	0.11
Kinze	= 1 if Kinze is the make	179	0 - 1	0.21	0.41	0.17
Other	= 1 if make is not John Deere, Case IH, or Kinze	60	0 - 1	0.07	0.25	0.07
Usage Factors						
Age	Total years since manufacturing	847	1- 42	11.04	6.82	46.52
Cond_Exc	= 1 if condition is excellent	73	0 - 1	0.09	0.28	0.08
Cond_Good	= 1 if condition is good	749	0 - 1	0.88	0.32	0.10
Cond_Fair	= 1 if condition is Fair	25	0 - 1	0.03	0.17	0.03
Specifications						
Conv_Row	= 1 if planter has a conventional structure	631	0 - 1	0.74	0.42	0.18
Split_Row	= 1 if planter has a split row structure	209	0 - 1	0.25	0.43	0.19
Twin_Row	= 1 if planter has twin row spacing & structure	7	0 - 1	0.01	0.10	0.01
Row0to10	= 1 if planters total number of row units is 10 or less	109	0 - 1	0.13	0.34	0.11
Row12to16	= 1 if planters total number of row units is 12 to 16	247	0 - 1	0.29	0.45	0.21
Row18to22	= 1 if planters total number of row units is 18 to 22	304	0 - 1	0.36	0.48	0.23
Row24Plus	= 1 if planters total number of row units is 24 or more	187	0 - 1	0.22	0.42	0.17
CRS_Nar	= 1 if row spacing for corn is 30"	49	0 - 1	0.06	0.23	0.05
CRS_30	= 1 if row spacing for corn is < 30"	776	0 - 1	0.92	0.28	0.08
CRS_Wide	= 1 if row spacing for corn is > 30"	22	0 - 1	0.03	0.16	0.03
Sale Type						
Sale_Onl	= 1 if the sale occurred online	178	0 - 1	0.21	0.41	0.17
Sale_Cons	= 1 if the sale was for consignmnet	326	0 - 1	0.38	0.49	0.24
Sale_Farm	= 1 if the sale occurred on farm	279	0 - 1	0.33	0.47	0.22
Sale_Deal	= 1 if the sale occurred at a dealership	64	0 - 1	0.08	0.26	0.07
Region of Sale						
Reg_Nor	= 1 if the sale was in the Northern Region	10	0 - 1	0.01	0.11	0.01
Reg_Mid	= 1 if the sale was in the Midwest Region	788	0 - 1	0.93	0.25	0.06
Reg_Sou	= 1 if the sale was in the Southern Region	34	0 - 1	0.04	0.20	0.04
Reg_West	= 1 if the sale was in the Western Region	15	0 - 1	0.02	0.13	0.02
Season of Sale						
Wint	= 1 if the sale occurred in the winter season	309	0 - 1	0.36	0.48	0.23
Spring	= 1 if the sale occurred in the Spring season	341	0 - 1	0.40	0.49	0.24
Summ	= 1 if the sale occurred in the summer season	120	0 - 1	0.14	0.35	0.12
Fall	= 1 if the sale occurred in the fall season	77	0 - 1	0.09	0.29	0.08
Year of Sale						
Year_16	= 1 if the sale occurred in the 2016 sale year	331	0 - 1	0.24	0.49	0.24
Year_17	= 1 if the sale occurred in the 2017 sale year	364	0 - 1	0.43	0.50	0.25
Year_18	= 1 if the sale occurred in the 2018 sale year	152	0 - 1	0.18	0.38	0.15

Table 3.2 Group Means for Row Number Groupings

Variable	Row Number 0 - 10	12 - 14	16 - 22	22+
Independent				
Price	17,396.51	28,712.25	39,263.31	67,589.25
Dependent				
Make				
JohnDeere	0.47	0.58	0.57	0.7
CaseIH	0.12	0.11	0.15	0.14
Kinze	0.33	0.23	0.23	0.09
Other	0.08	0.08	0.06	0.07
Usage Factors				
Age	15.00	12.59	10.21	8.02
Cond_Exc	0.07	0.06	0.07	0.16
Cond_Good	0.84	0.90	0.92	0.83
Cond_Fair	0.08	0.04	0.01	0.01
Specifications				
Conv_Row	0.65	0.73	0.64	0.98
Split_Row	0.35	0.25	0.36	0.01
Twin_Row	-	0.02	0.01	0.01
CRS_Nar	0.01	0.02	0.01	0.22
CRS_30	0.88	0.94	0.99	0.78
CRS_Wide	0.11	0.04	-	-
Sale Type				
Sale_Onl	0.21	0.25	0.19	0.19
Sale_Cons	0.46	0.33	0.42	0.35
Sale_Farm	0.29	0.35	0.30	0.37
Sale_Deal	0.04	0.07	0.08	0.1
Region of Sale				
Reg_Nor	0.06	-	0.01	-
Reg_Mid	0.89	0.91	0.93	0.98
Reg_Sou	0.03	0.07	0.04	0.01
Reg_West	0.02	0.02	0.02	0.01
Season of Sale				
Wint	0.31	0.41	0.41	0.27
Spring	0.46	0.34	0.40	0.45
Summ	0.17	0.17	0.10	0.15
Fall	0.06	0.08	0.09	0.13
Year of Sale				
Year_16	0.42	0.34	0.40	0.42
Year_17	0.39	0.49	0.39	0.44
Year_18	0.19	0.17	0.21	0.14

Notes: Group 0-10 consisted of row numbers 2,4,6,8,10. Group 12-14 consisted of only 12 row planters, 16-22 consisted of 16 and 18, and 22+ consisted of 24, 30, 32, 36, 47, 48. Total obersvations for 0-10, 12-14, 16-22, and 22+ were 109, 247, 304, and 187, respectively. The mean row number for the groups were 7.14, 12.00, 16.01, and 26.21

Table 3.3 Group Means for Varying Makes

Variable	John Deere	Case IH	Kinze	Other
Independent				
Price	43,414.29	36,671.12	34,903.93	27,773.58
Dependent				
Usage Factors				
Age	11.52	8.56	11.60	10.02
Cond_Exc	0.10	0.07	0.06	0.1
Cond_Good	0.87	0.90	0.92	0.87
Cond_Fair	0.03	0.03	0.02	0.03
Specifications				
Conv_Row	0.83	0.89	0.40	0.75
Split_Row	0.16	0.11	0.59	0.18
Twin_Row	0.01	-	0.01	0.07
Row0to10	0.10	0.12	0.15	0.15
Row12to16	0.29	0.25	0.33	0.33
Row18to22	0.35	0.40	0.28	0.28
Row24Plus	0.26	0.23	0.23	0.23
CRS_Nar	0.07	0.03	0.01	0.12
CRS_30	0.90	0.93	0.97	0.87
CRS_Wide	0.03	0.04	0.02	0.02
Sale Type				
Sale_Onl	0.22	0.28	0.13	0.22
Sale_Cons	0.33	0.38	0.51	0.45
Sale_Farm	0.34	0.30	0.32	0.32
Sale_Deal	0.10	0.04	0.04	0.02
Region of Sale				
Reg_Nor	0.92	0.94	0.96	0.03
Reg_Mid	0.01	-	0.02	0.9
Reg_Sou	0.05	0.03	0.02	0.07
Reg_West	0.02	0.04	-	-
Season of Sale				
Wint	0.37	0.41	0.33	0.35
Spring	0.41	0.32	0.42	0.47
Summ	0.13	0.12	0.19	0.17
Fall	0.10	0.15	0.06	0.02
Year of Sale				
Year_16	0.39	0.33	0.41	0.45
Year_17	0.42	0.54	0.40	0.38
Year_18	0.19	0.13	0.19	0.17

Notes: Number of Observations (n): John Deere (497), Case IH (112), Kinze (178), Other Makes (60). Other observations include: White, Great Plains, Monosem, Peaque, IHC, Wil-Rich

Table 3.4 Hedonic Regression Results for Base Model

R^2 = 0.8086		**Base Model** ln (Price)
	Constant	9.99*** (0.295)
Make		
	JohnDeere	0.432*** (0.060)
	CaseIH	0.116* (0.070)
	Kinze	0.444*** (0.067)
Condition		
	Age	-0.120*** (0.007)
	Age^2	0.001*** (0.000)
	Cond_Exc	0.471*** (0.122)
	Cond_Good	0.343*** (0.112)
Specifications		
	Split_Row	0.414*** (0.033)
	Twin_Row	0.233 (0.207)
	Row12to16	0.323*** (0.052)
	Row18to22	0.469*** (0.052)
	Row24Plus	0.872*** (0.062)
	CRS_30	-0.200*** (0.071)
	CRS_Wide	-0.300** (0.145)
Sale Type		
	Sale_Onl	0.022 (0.054)
	Sale_Cons	-0.078 (0.051)
	Sale_Farm	0.045 (0.051)
Region of sale		
	Reg_Mid	0.203 (0.215)
	Reg_Sou	-0.033 (0.227)
	Reg_West	0.222 (0.266)
Season of Sale		
	Wint	0.130*** (0.033)
	Summ	0.067 (0.046)
	Fall	0.107** (0.054)
Sale Year		
	Year_17	0.049 (0.039)
	Year_18	0.240*** (0.043)

Note: The first number represents the coeficient and the shadow values of the independent variables. The number in the parentheseses represents the robust standard errors. (***) = significance at the 1% level, (**) = sifnificance at the 5% level, and (*) = Significance at the 10% level. The base variable for makes was other makes which included white, Great Plains, Monosem, Peaque, IHC, and Wil-Rich. The bases for row number, row spacing, sale types, regions, seasons, and sale year were Row0to12, CRS_Nar, Sale_Deal, Reg_Nor, Spring, and Year_2016, respectively. Total observation was 847.

Table 3.5 Hedonic Regression Results for Interaction Model

R^2 = 0.809	**Base Model With Interaction** ln (Price)
Constant	9.937*** (0.328)
Make and Age Interaction	
JDAge	-0.089*** (0.004)
CIHAge	-0.119*** (0.009)
KinAge	-0.070*** (0.005)
OthAge	-0.094*** (0.011)
Make	
JohnDeere	0.396*** (0.134)
CaseIH	0.323** (0.146)
Kinze	0.166 (0.141)
Condition	
Cond_Exc	0.492*** (0.123)
Cond_Good	0.304*** (0.113)
Specifications	
Split_Row	0.413*** (0.033)
Twin_Row	0.234 (0.200)
Row12to16	0.269*** (0.052)
Row18to22	0.402*** (0.052)
Row24Plus	0.794*** (0.064)
CRS_30	-0.203*** (0.074)
CRS_Wide	-0.300** (0.147)
Sale Type	
Sale_Onl	0.030 (0.052)
Sale_Cons	-0.081* (0.049)
Sale_Farm	0.045 (0.049)
Region of sale	
Reg_Mid	0.245 (0.200)
Reg_Sou	0.009 (0.213)
Reg_West	0.298 (0.260)
Season of Sale	
Wint	0.137*** (0.032)
Summ	0.068 (0.046)
Fall	0.103** (0.053)
Sale Year	
Year_17	0.046 (0.038)
Year_18	0.216*** (0.043)

Note: The first number represents the coeficient and the shadow values of the independent variables. The number in the parentheseses represents the robust standard errors. Compared to base model, variables for age and age2 were not included in this model. (***) = significance at the 1% level, (**) = sifnificance at the 5% level, and (*) = Significance at the 10% level. The bases for row number, row spacing, sale types, regions, seasons, and sale year were Row0to12, CRS_Nar, Sale_Deal, Reg_Nor, Spring, and Year_2016, respectively. Total observation was 847.

Table 3.6 Hedonic Regression Results for Individual Manufacturers

	John Deere	Case IH	Kinze
	ln (Price)	ln (Price)	ln (Price)
R^2	0.8486	0.8549	0.8053
Constant	10.408*** (0.197)	10.898*** (0.557)	12.049*** (0.299)
Use Factors			
Age	-0.125*** (0.008)	-0.226*** (0.038)	-0.051*** (0.016)
Age^2	0.001*** (0.000)	0.005*** (0.002)	-0.001* (0.001)
Cond_Exc	0.598*** (0.132	0.417** (0.197)	-0.661*** (0.249)
Cond_Good	0.433*** (0.119)	0.364** (0.170)	-0.616** (0.239)
Specifications			
Split_Row	0.348*** (0.045)	0.587*** (0.117)	0.436*** (0.071)
Twin_Row	-0.404** (0.196)	-	0.585*** (0.087)
Row12to16	0.301*** (0.076)	0.318** (0.160)	0.375*** (0.079)
Row18to22	0.551*** (0.079)	0.648*** (0.154)	0.234*** (0.078)
Row24Plus	0.908*** (0.087)	1.04*** (0.161)	0.338*** (0.130)
CRS_30	-0.227*** (0.082)	-0.314 (0.204)	-0.356** (0.140)
CRS_Wide	-0.127 (0.208)	-0.614** (0.244)	-1.089** (0.229)
Sale Type			
Sale_Onl	0.015 (0.064)	0.030 (0.139)	-0.086 (0.137)
Sale_Cons	-0.038 (0.060)	-0.096 (0.134)	-0.327*** (0.120)
Sale_Farm	0.075 (0.060)	-0.140 (0.143)	-0.199 (0.126)
Region of sale			
Reg_Mid	0.138 (0.104)	-0.035 (0.303)	-0.344** (0.158)
Reg_Sou	-0.069 (0.136)	-	-0.585*** (0.182)
Reg_West	0.171 (0.230)	-0.234 (0.351)	-
Season of Sale			
Wint	0.127*** (0.040)	0.006 (0.116)	0.112* (0.063)
Summ	-0.085 (0.063)	-0.058 (0.104)	0.185** (0.074)
Fall	0.068 (0.068)	0.215 (0.138)	0.045 (0.089)
Sale Year			
Year_17	0.102** (0.050)	0.126 (0.122)	-0.001 (0.065)
Year_18	0.234*** (0.054)	0.429*** (0.151)	0.128* (0.077)

Note: The first number represents the coeficient and the shadow values of the independent variables. The number in the parentheseses represents the robust standard errors. Model is same as the base model with the exclusion of dummy variables for makes. (***) = significance at the 1% level, (**) = sifnificance at the 5% level, and (*) = Significance at the 10% level. The bases for row number, row spacing, sale types, regions, seasons, and sale year were Row0to12, CRS_Nar, Sale_Deal, Reg_Nor, Spring, and Year_2016, respectively. Total observation were 497 John Deeres, 112 Case IH, and 179 Kinzes.

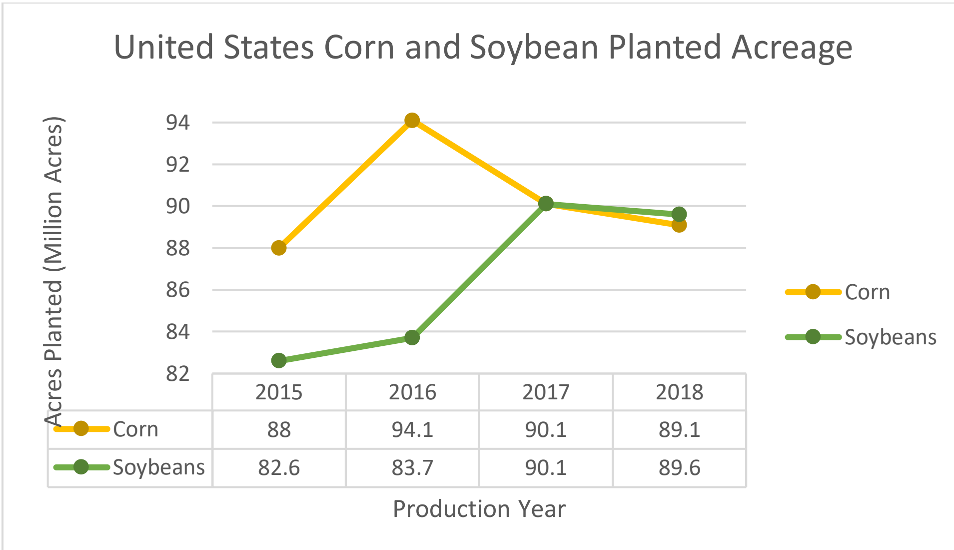

Figure 3.1 United States Corn and Soybean Planted Acreage

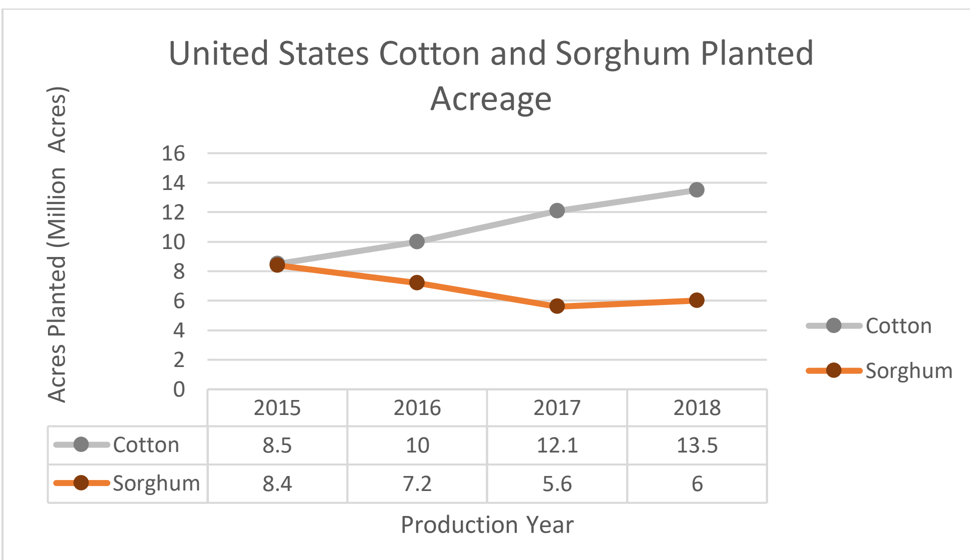

Figure 3.2 United States Cotton and Sorghum Production

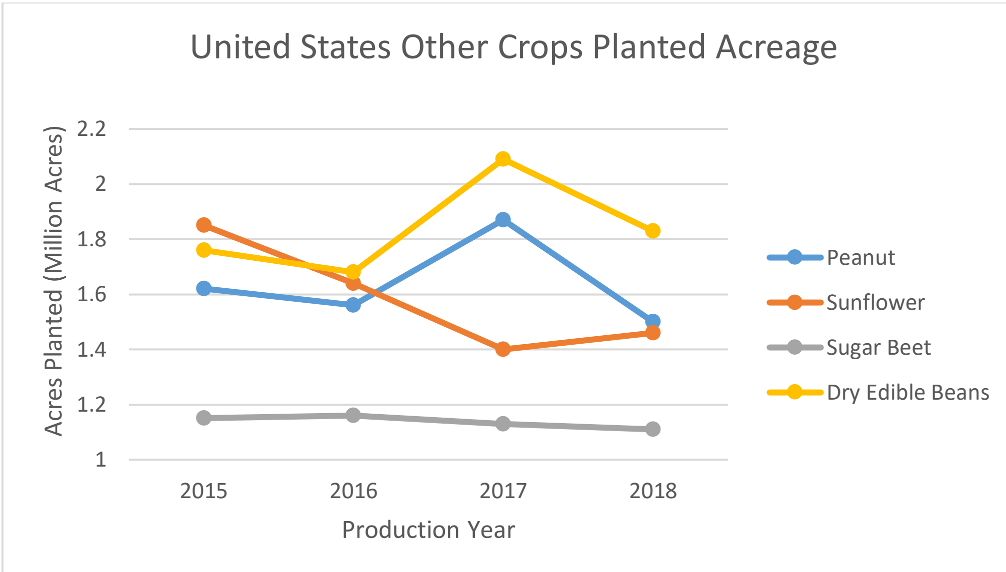

Figure 3.3 United States Other Crops Planted Acreage

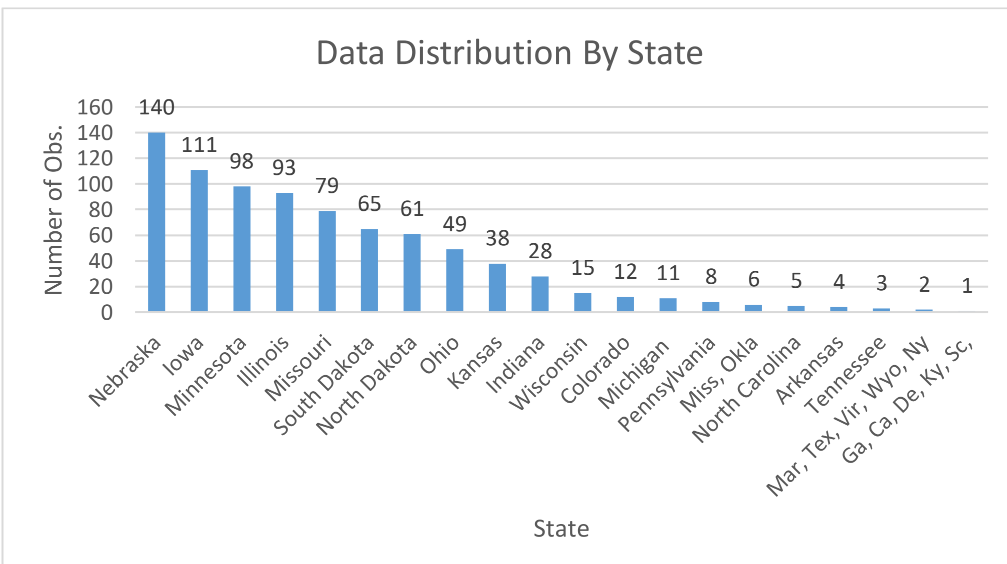

Figure 3.4 Data Distribution by State

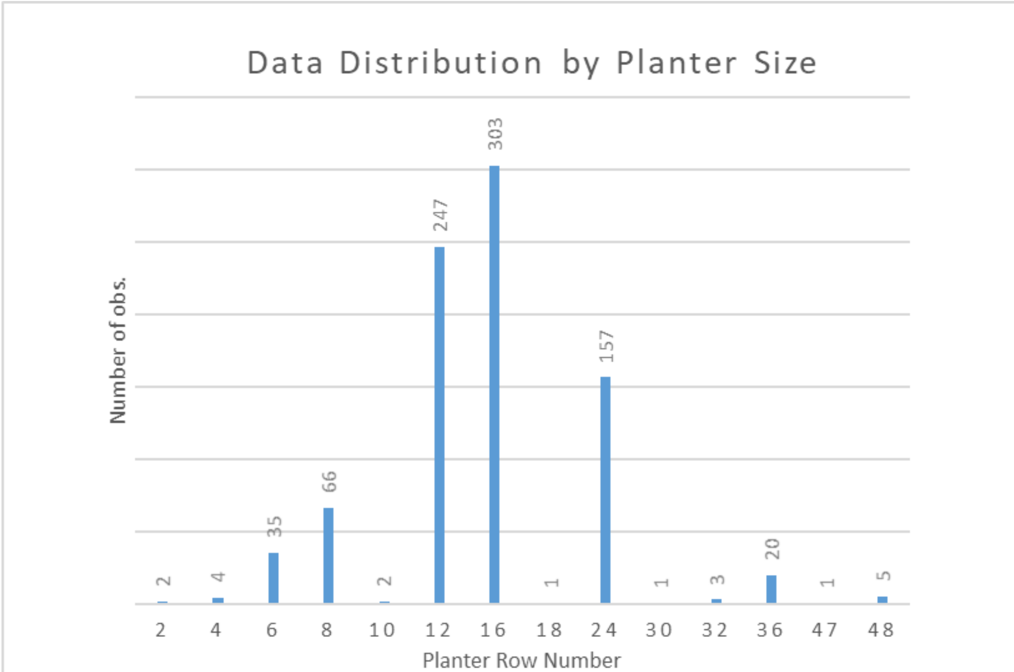

Figure 3.5 Data Distribution by Planter Size

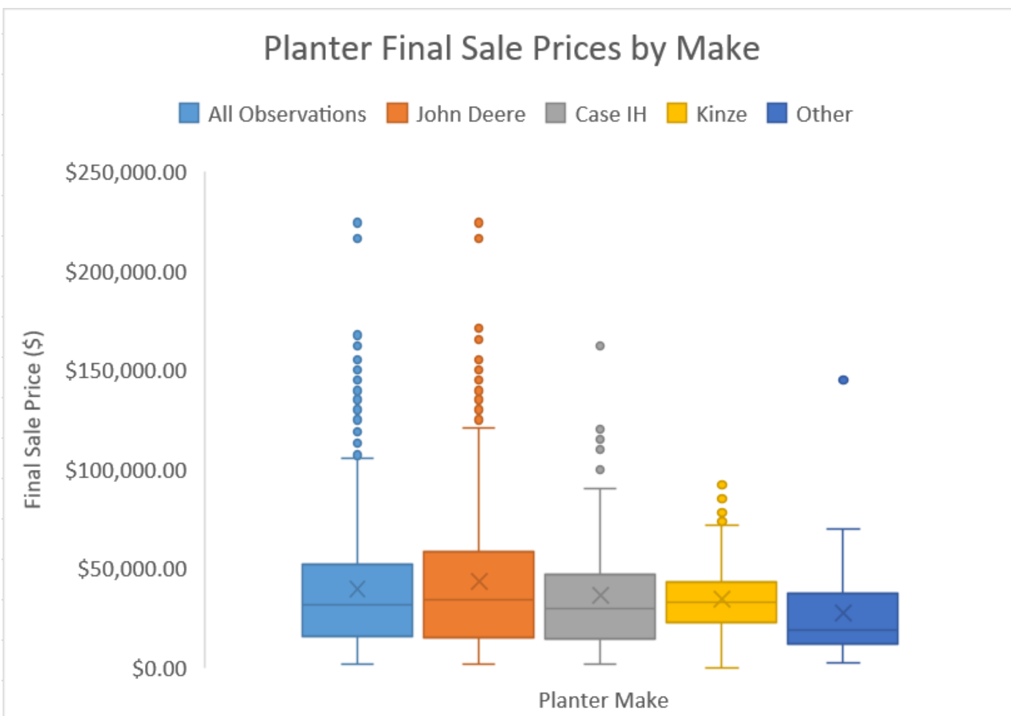

Figure 3.6 Planter Final Sale Price by Make

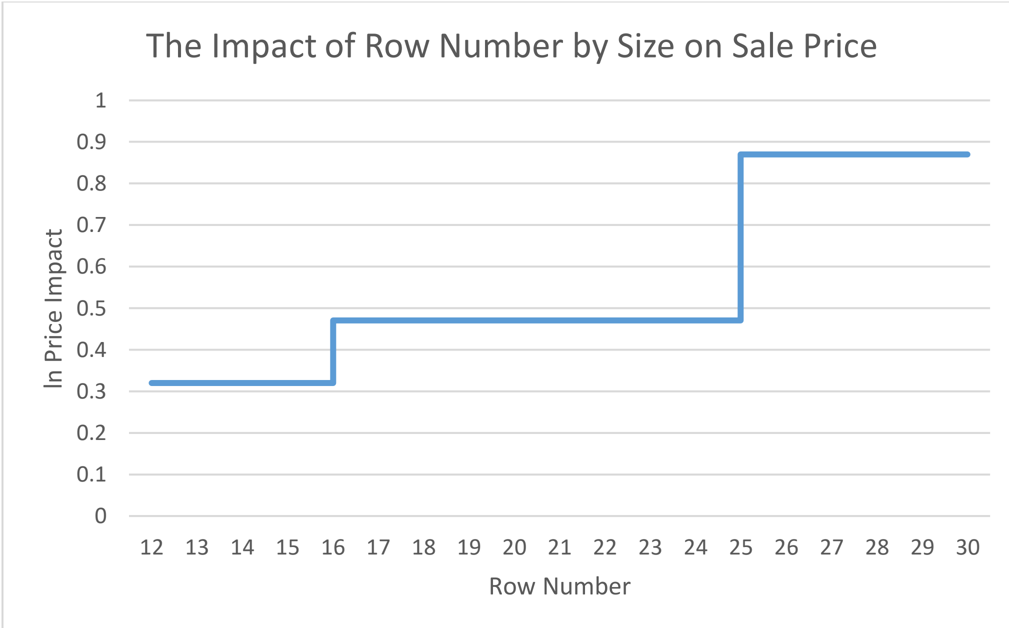

Figure 3.7 The Impact of Row Number by Size

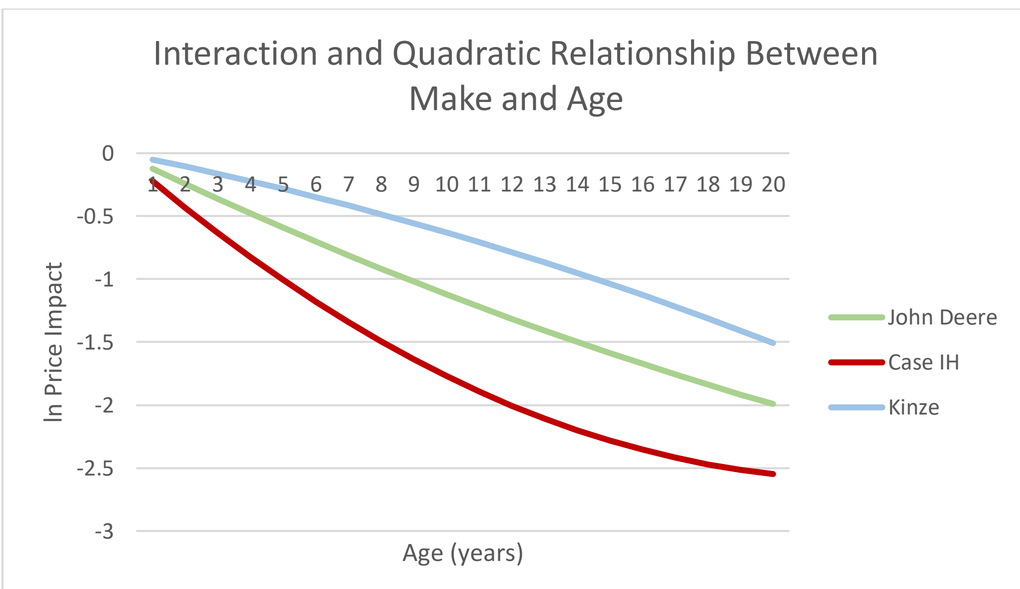

Figure 3.8 Interaction and Quadratic Relationship between Make and Age

CHAPTER 4. SUMMARY

With the complexity of production agriculture systems, there are a lot of input and output alternatives that a producer must consider when making decisions. There are also a lot of factors that influence the costs of production and prices for the inputs and outputs. To compound this further, producers must also stay up to date on macroeconomic factors, government policies, and changing consumer preferences. Through the continuation of research relating to input substitution and optimal decision making, information is provided to individuals and groups in the agriculture industry to aid in strategic planning and tactical execution. The essays and supplemental analyses presented in this thesis reinforce the difficulties relating to decision making, while also providing frameworks to aid the decision process and results that have the potential for real-world implementation.

The first essay stems from issues currently being faced in the conventional dairy industry where producers are considering the transition to alternative systems such as organic production. This system is a result of changing consumer preferences creating a niche market that proposes a new challenge for producers such as the potential for higher costs and increased risks. Research detailed in the first essay sought to optimize production for an organic dairy system in the Southeastern United States. Using mathematical programming, ration components and enterprise combinations were determined for four different milk production level cases that maximized whole-farm net returns. Equations were formulated to model for available resources, cow nutrient requirements, production balances, and marketing balances. Four complex forage mixtures were also proposed for the system, and their yield, quality, and totals costs were compared within the model. Once an optimal solution was determined, a post-optimality analysis was conducted that explored the sensitivity of whole-farm net-returns relative to changes in milk price. This also allowed for the break-even milk price to be determined for the four milk production level cases.

In the mathematical programming model, an underlying lactation curve was assumed based on the total annual milk production level. This curve was then distributed across four seasons, resulting in enterprise mix and feed mix solutions for each season within a given case. Results demonstrated that whole-farm net returns increased with a positive change in milk production, but at a decreasing rate where feed costs were simultaneously rising at an increasing rate. Results across the four cases suggest that the marginal revenue gained from additional milk sales is greater than the marginal costs associated with the increased production level. Optimal solutions across the four cases were similar with differences primarily relating only to the quantities produced or fed.

The optimal solution's combination of feeds moderately resembled production practices and rations that are seen in a conventional or grazing dairy. Research findings, specifically the slack related to available pasture utilization, potentially suggest that grazing maximization does not necessarily mean profit maximization for the given scenarios. This also supports that a higher milk production level can likely justify the production or purchase of supplemental feeds. Results from the milk price sensitivity analysis suggest economic sustainability in milk price where the break-even milk price was quite lower than the assumed base price in the model. Overall, this essay demonstrates the suitability of this whole-farm system approach to this alternative production system, and results provide insights to aid producer decision making.

The second essay sought to address a lack of knowledge pertaining to the used machinery market for agricultural planters. A hedonic analysis was conducted using three slightly differentiated models. The primary objective was to determine the factors that influence the resale price of planters and the individual contribution from each. Additionally, the research explored potential non-linear relationships between explanatory variables and sale price and interaction effects between the explanatory variables make and age. Three years of sale data were analyzed and variables for make, age, condition, planter specifications, sale type, sale location, season, and the sale year were included in the econometric models. The three models consisted of a base model for all observations, an interaction model that is similar to the base plus interaction terms and is applied to all observations, and a model for individual makes that explored observations for John Deere, Case IH, and Kinze separately.

Significant results that were consistent across all models related to the variables age, make, and planter specifications and significant results relating to seasonality and sale year varied by the model. For the most part, variables for sale type and sale region were found to not significantly influence the value of planters on the re-sale market. Non-linear relationships were also found relating to the variables age and row number. Age was found to have a quadratic relationship with price suggesting that planters values decrease at a decreasing rate as the machines get older. A non-linear relationship was also found for row number where structural breaks were identified at row numbers 12, 16, 24. Therefore, the impact and contribution of row numbers potentially vary by the range of row numbers that are considered. An interaction relationship between make was also confirmed where results suggest that the impact of age on price is dependent on the make of the planter. Through statistical testing of these results, it was found that Case IH depreciates at an accelerated rate compared to John Deere and Kinze and that Kinzes hold their value well with time. Overall, results suggest that a majority of the variation in the value of planters on the resale market was captured by the models.

In conclusion, the essays and supplemental analyses explored farm management concepts relating to decision making at varying levels and from alternative perspectives. Econometric and mathematical programming methods were applied with additional support from enterprise budgeting, sensitivity analysis, and break-even analyses. The research presented offers contributions to not only agricultural producers, but other groups and individuals across the agriculture industry.

APPENDICES

APPENDIX 1. Organic Dairy Model Components and Summation Notation

Maximize Net Returns:

$$(\mathbf{1}) \quad MAX \quad Z\,(NR) = \sum_{O,S} Price_O Sell_{O,S} - \sum_E ProdCost_E Produce_E - \sum_{C,S} FeedCost_C ConcFed_{C,S} - AlfCost * AlfaFed_S$$

Subject to:

$(\mathbf{2})$ $\boldsymbol{Total\ Pasture\ Land}$:

$$PastureLandReq_{"PastA"} Produce_{"PastA"} + PastureLandReq_{"PastB"} Produce_{"PastB"} + PastureLandReq_{"PastC"} Produce_{"PastC"} + PastureLandReq_{"PastD"} Produce_{"PastD"} \leq TotPastureLand$$

$(\mathbf{3})$ $\boldsymbol{Total\ Crop}$ & $\boldsymbol{Hay\ Land}$:

$$CropHayLandReq_{"SorSud"} Produce_{"SorSud"} + CropHayLandReq_{"AnnRye"} Produce_{"AnnRye"} + CropHayLandReq_{"CornSil"} Produce_{"\mathrm{CornSil}"} + CropHayLandReq_{"MixHay"} Produce_{"MixHay"} \leq CropHayLand$$

$(\mathbf{4})$ $\boldsymbol{Total\ Labor\ Endowment}$: $\sum_E TotLabReq_{E,M} Produce_E \leq TotLabEnd_M \ \forall\ M$

$(\mathbf{5})$ $\boldsymbol{Field\ Labor\ Endowment}$: $\sum_E FieldLabReq_{E,M} Produce_E \leq FieldLabEnd_M \ \forall\ M$

$(\mathbf{6})$ ***Minimum Herd Nutrient Requirements***:

$$\sum_F ForNutr_{F,N,S}ForFed_{F,S} \; + \; \sum_C ConcNutr_{C,N}ConcFed_{C,S} \; +$$

$$AlfaNut_N AlfFed_S \;\; \geq \;\; NutrLowLim_{N,S}Produce_{"Milk"} \; \forall \; N,S$$

$(\mathbf{7})$ ***Minimum Dry Matter Intake***:

$$\sum_F ForDM_F ForFed_{F,S} \; + \; \sum_C ConcDM_C ConcFed_{C,S} + AlfaDM \; AlfaFed_{\,S} \; \geq$$

$$MinDM_s \; Produce_{"Milk"} \; \forall \; S$$

$(\mathbf{8})$ ***Maximum NDF From Forages***:

$$\sum_F NDF_{F,S}ForFed_{F,S} + AlfaNDF \; AlfFed_S \;\; \leq \;\; MaxNDF_S Produce_{"Milk"} \; \forall \; S$$

$(\mathbf{10})$ ***Minimum Forage Required***:

$$\sum_F ForDM_F ForagesFed_{F,S} \; + AlfaDM \; AlfFed_{\,S} \;\; \geq \;\; MinForDM_S \, Produce_{"Milk"} \;\; \forall \; S$$

$(\mathbf{11})$ ***Minimum Dry Hay***:

$$ForDM_{"MixHay"}ForagesFed_{\text{"MixHay"},S} + AlfaDM \; AlfFed_S \;\; \geq$$

$$MinDryHay_S Produce_{"Milk"}$$

$(\mathbf{11})$ ***Organic Cert. Pasture Rule***:

$$ForDM_{"PastA"} \; ForFed_{\text{"PastA"},S} + \; ForDM_{"PastB"} \; ForFed_{\text{"PastB"},S} +$$

$$ForDM_{"PastC"} \; ForFed_{\text{"PastC"},S} + ForDM_{"PastD"} \; ForFed_{\text{"PastD"},S} +$$

$$ForDM_{"SSPast"} \; ForFed_{\text{"SSPast"},S} + ForDM_{"ARPAst"} \; ForFed_{\text{"ARPast"},S} \;\; \geq$$

$$MinPast_S \; Produce_{"Milk"} \; \forall \;\; S$$

$(\mathbf{12})$ $\boldsymbol{Maximum\ Concentrates\ Fed}$:

$$\textstyle\sum_{\boldsymbol{C}} ConcDM_C ConcFed_{C,S} \;\leq\; Max\ ConDM_S Produce_{"Milk"} \;\forall\; S$$

$(\mathbf{13})$ $\boldsymbol{Maximum\ Concentrates\ Fed\ (Indiv.)}$:

$$ConcDM_C ConcFed_{C,S} \;\leq\; MaxIndConDM_{C,S} Produce_{"Milk"} \;\forall\; C,S$$

$(\mathbf{14})$ $\boldsymbol{Set\ Herd\ Size\ and\ Milk\ Production\ Level}$:

$$Produce_{"Milk"} \;=\; 50$$

$(\mathbf{15})$ $\boldsymbol{Milk\ Market\ Balance}$:

$$Sell_{"\text{Milk}",\text{S}} - Yield_{"\text{Milk}",S} Produce_{Milk} \;\leq\; 0 \;\forall\; S$$

$(\mathbf{16})$ $\boldsymbol{Hay\ Market}$ & $\boldsymbol{Feed\ Balance}$:

$$Sell_{"\text{Mix Hay}",S} + ForFed_{"\text{Mix Hay}",S} - Yield_{"\text{Mix Hay}",S} Produce_{"Mix\ Hay"} \;\leq\; 0 \;\forall\; S$$

$(\mathbf{17})$ $\boldsymbol{Sorghum - Sudangrass\ Baleage\ Feed\ Balance}$:

$$\textstyle\sum_{\boldsymbol{S}} ForFed_{"\text{SSBale}",S} - Yield_{"SorSud",S} Produce_{"SorSud"} \;\leq\; 0$$

$(\mathbf{18})$ $\boldsymbol{Annual\ Ryegrass\ Baleage\ Feed\ Balance}$:

$$\textstyle\sum_{S} ForFed_{"\text{ARBale}",S} - Yield_{"AnnRye",S} Produce_{"AnnRye"} \;\leq\; 0$$

$(\mathbf{19})$ $\boldsymbol{Corn\ Silage\ Feed\ Balance}$:

$$\textstyle\sum_{S} ForFed_{"\text{CornSil}",S} - Yield_{"CornSil",S} Produce_{"CornSil"} \;\leq\; 0$$

$(\mathbf{20})$ $\boldsymbol{Pasture\ A\ Feed\ Balance}$:

$$\textstyle\sum_{S} ForFed_{"\text{PastA}",S} - Yield_{"PastA",S} Produce_{"PastA"} \;\leq\; 0$$

$(\mathbf{21})$ $\boldsymbol{Pasture\ B\ Feed\ Balance}$:

$$\sum_S ForFed_{\text{"PastB"},S} - Yield_{\text{"}PastB\text{"},S} Produce_{\text{"}PastB\text{"}} \leq 0$$

$(\mathbf{22})$ $\boldsymbol{Pasture\ C\ Feed\ Balance}$:

$$\sum_S ForFed_{\text{"PastC"},S} - Yield_{\text{"}PastC\text{"},S} Produce_{\text{"}PastC\text{"}} \leq 0$$

$(\mathbf{23})$ $\boldsymbol{Pasture\ D\ Feed\ Balance}$:

$$\sum_S ForFed_{\text{"PastD"},S} - Yield_{\text{"}PastD\text{"},S} Produce_{\text{"}PastD\text{"}} \leq 0$$

$(\mathbf{24})$ $\boldsymbol{Sorghum - Sudangrass\ \ Pasture\ \ Feed\ Balance}$:

$$\sum_S ForFed_{\text{"SSPast"},S} - Yield_{\text{"}SSPast\text{"},S} Produce_{\text{"}SSPast\text{"}} \leq 0$$

$(\mathbf{25})$ $\boldsymbol{Annual\ Ryegrass\ \ Pasture\ \ Feed\ Balance}$:

$$\sum_S ForFed_{\text{"ARPast"},S} - Yield_{\text{"}ARPast\text{"},S} Produce_{\text{"}ARPast\text{"}} \leq 0$$

Activities include:

Z = Net returns expected above specificed costs

Produce$_E$ = qunatity produced of enterprise E

Sell$_{O,S}$ = quantity of output product O sold in Season S

ConcFed$_{C,S}$ = quantity purchased and fed of concentrated feed C in season S

ForagesFed$_{F,S}$ = quantity fed of produced forage F in season S

AlfFed$_S$ = quantity of alfalfa purchased and fed in season S

Indices include:

E = Production Enterpise

O = Output product

C = Concentrated Feed

F = Forage

N = Nutrient factor

M = Month

S = Season

Coeficients include:

PriceO =price received per unit of output product O

ProdCost$_E$ = total cost of producing a unit of of enterprise E

FeedCost$_C$ = cost to purchase a ton of Concentrated feed C

AlfCost = cost to purchase and deliver a ton of alfalfa hay

Yield$_{E,S}$ = the amount of output produced from enterprise E

Yield2$_{E,S}$ = the amount of yield available for grazing for annual ryegrass and sorghum-sudangrass enterprises

PastLandReq$_E$ = pasture land required to produce enterprise E

TotalPastLand = total pasture land available

CropHayLandReq$_E$ = land required to produce crop or hay enterprises E

CropHayLand = total land availabe for crops and hay

FieldLabReq$_{E,M}$ = labor required for the field work of enterprise E in month M

TotLabReq$_{E,M}$ = total labor required for enterprise E in month M

FieldLabEnd$_M$ = total field labor endowment for month M

TotalLabEnd$_M$ = total labor endowment for month M

ForNut$_{N,F,S}$ = the amount of nutrient N in forage F during season S

AlfaNutr$_N$ = the amount of nutrient N in alfalfa hay

ConcNutr$_{C,N}$ = the amount of nutrient N in concentrate C

NutrLowLim$_{N,S}$ = the minimum amount of nutrient N required for milk production in season S

ForDM$_F$ = the amount of dry matter provided by forage F

ConcDM$_C$ = the amount of dry matter provided by concentrated feed C

AlfDM = the amount of dry matter provided by alfalfa hay

MinDM$_S$ = the minimum amount of dry matter required for milk production in season S

MinForDM$_S$ = the minimum amount of forages required for milk production in season S

MaxConDM$_S$ = the maximum amount of concentrates that can be consumed in season S

MaxIndConDM$_{C,S}$ = the maximum amount of dry matter from concentrate C that can be consumed in season S

NDF$_{F,S}$ = the amount of neutral detergent fibe in forage F during season S

AlfaNDF = the amount of neutral detergent fiber in alfalfa hay

MaxNDF$_S$ = the maximum amount of neutral detergent fiber that can be consumed in season S

MinPast$_S$ = the minimumum amount of pasture that must be consumed per USDA standards in season S

MinDryHay$_S$ **=** the minimum amount of dry hay that must be consumed in season S

APPENDIX 2. Organ Dairy Model Enterprise Budgets

Organic Dairy Budget - Estimated Annual Costs Per One Cow Unit				
Cow Breed:	Holstein Cross (Medium-Large Cow)		Milk Per Cow (lbs/year):	14,091
Cow Weight (lbs/cow):	1,300	Discard Milk: 3%	Rolling Herd Average (lbs)	40
First Calve:	24 Months	Cull Rate: 22%	Death Loss:	5%

	Quantity	Unit	Price	Total
Variable Costs Per Head				
Feed Costs (Dry Matter Basis)				
Pasture (Mix A - D)	0.00	ton	$0.00	$0.00
Hay (Mix and Alfalfa)	0.00	ton	$0.00	$0.00
Baleage (AR and SS)	0.00	ton	$0.00	$0.00
Corn Silage	0.00	ton	$0.00	$0.00
Corn (Shelled)	0.00	lb	$0.00	$0.00
Soybeans (Roasted)	0.00	lb	$0.00	$0.00
Soybean Meal	0.00	lb	$0.00	$0.00
Oats	0.00	lb	$0.00	$0.00
Barley	0.00	lb	$0.00	$0.00
Wheat	0.00	lb	$0.00	$0.00
Salt and Minerals	250.00	lb.	$0.50	$125.00
Milk/Calf Feed	0.00	lb.	$1.50	$0.00
Total Feed Costs				$125.00
Livestock Costs				
Dairy Supplies	1.00	head	$208.00	$208.00
Freight/ Trucking/ Hauling	140.91	cwt	$0.23	$32.41
Veterinary & Medicine	140.91	cwt.	$0.50	$70.46
Breeding Fees	1.00	head	$40.00	$40.00
DHIA/Accounting/ Legal	1.00	head	$30.00	$30.00
Marketing	140.91	cwt	$0.30	$42.27
Bedding Costs	0.75	ton	$100.00	$75.00
Gas/Fuel/Oil	14.00	gal	$2.50	$35.00
Electricity	594.00	kWh	$0.11	$65.34
Other (oper. Int. phone)	1.00	head	$180.00	$180.00
Total Livestock Costs				$778.48
Total Variable Costs				$903.48
Fixed Costs Per Head				
Facility and Equipment Costs				
Milking Center/Parlor	12%	head	$600.00	$72.00
Dairy Housing	10%	head	$1,400.00	$140.00
Manure Storage	10%	head	$500.00	$50.00
Machinery and Equipment	18%	head	$650.00	$117.00
Cow Ownership Costs	6%	head	$1,092.50	$54.63
Heifer Replacement Costs	0.22	head	$1,650.00	$363.00
Labor Costs	52	hour	$13.50	$702.00
Total Fixed Costs				$1,498.63
Total Variable & Fixed Costs Per Head				**$2,402.10**

Organic Dairy Budget - Estimated Annual Costs Per One Cow Unit

Cow Breed:	Holstein Cross (Medium-Large Cow)			**Milk Per Cow (lbs/year):**	15,891
Cow Weight (lbs/cow):	1,300	**Discard Milk:**	3%	**Rolling Herd Average (lbs)**	45
First Calve:	24 Months	**Cull Rate:**	22%	**Death Loss:**	5%

	Quantity	Unit	Price	Total
Variable Costs Per Head				
Feed Costs (Dry Matter Basis)				
Pasture (Mix A - D)	0.00	ton	$0.00	$0.00
Hay (Mix and Alfalfa)	0.00	ton	$0.00	$0.00
Baleage (AR and SS)	0.00	ton	$0.00	$0.00
Corn Silage	0.00	ton	$0.00	$0.00
Corn (Shelled)	0.00	lb	$0.00	$0.00
Soybeans (Roasted)	0.00	lb	$0.00	$0.00
Soybean Meal	0.00	lb	$0.00	$0.00
Oats	0.00	lb	$0.00	$0.00
Barley	0.00	lb	$0.00	$0.00
Wheat	0.00	lb	$0.00	$0.00
Salt and Minerals	252.00	lb.	$0.50	$126.00
Milk/Calf Feed	0.00	lb.	$1.50	$0.00
Total Feed Costs				$126.00
Livestock Costs				
Dairy Supplies	1.00	head	$213.00	$213.00
Freight/ Trucking/ Hauling	158.91	cwt	$0.23	$36.55
Veterinary & Medicine	158.91	cwt.	$0.50	$79.45
Breeding Fees	1.00	head	$40.00	$40.00
DHIA/Accounting/ Legal	1.00	head	$30.00	$30.00
Marketing	158.91	cwt	$0.30	$47.67
Bedding Costs	0.75	ton	$100.00	$75.00
Gas/Fuel/Oil	14.00	gal	$2.50	$35.00
Electricity	594.00	kWh	$0.11	$65.34
Other (oper. Int. phone)	1	head	$180.00	$180.00
Total Livestock Costs				$802.01
Total Variable Costs				$928.01
Fixed Costs Per Head				
Facility and Equipment Costs				
Milking Center/Parlor	12%	head	$600.00	$72.00
Dairy Housing	10%	head	$1,400.00	$140.00
Manure Storage	10%	head	$500.00	$50.00
Machinery and Equipment	18%	head	$670.00	$120.60
Cow Ownership Costs	6%	head	$1,092.50	$54.63
Heifer Replacement Costs	0.22	head	$1,650.00	$363.00
Labor Costs	52.5	hour	$13.50	$708.75
Total Fixed Costs				$1,508.98
Total Variable & Fixed Costs Per Head				**$2,436.99**

Organic Dairy Budget - Estimated Annual Costs Per One Cow Unit

Cow Breed:	Holstein Cross (Medium-Large Cow)			**Milk Per Cow (lbs/year):**	17,689
Cow Weight (lbs/cow):	1,300	**Discard Milk:**	3%	**Rolling Herd Average (lbs)**	50
First Calve:	24 Months	**Cull Rate:**	22%	**Death Loss:**	5%

	Quantity	Unit	Price	Total
Variable Costs Per Head				
Feed Costs (Dry Matter Basis)				
Pasture (Mix A - D)	0.00	ton	$0.00	$0.00
Hay (Mix and Alfalfa)	0.00	ton	$0.00	$0.00
Baleage (AR and SS)	0.00	ton	$0.00	$0.00
Corn Silage	0.00	ton	$0.00	$0.00
Corn (Shelled)	0.00	lb	$0.00	$0.00
Soybeans (Roasted)	0.00	lb	$0.00	$0.00
Soybean Meal	0.00	lb	$0.00	$0.00
Oats	0.00	lb	$0.00	$0.00
Barley	0.00	lb	$0.00	$0.00
Wheat	0.00	lb	$0.00	$0.00
Salt and Minerals	254.00	lb.	$0.50	$127.00
Milk/Calf Feed	0.00	lb.	$1.50	$0.00
Total Feed Costs				$127.00
Livestock Costs				
Dairy Supplies	1.00	head	$218.00	$218.00
Freight/ Trucking/ Hauling	176.89	cwt	$0.23	$40.68
Veterinary & Medicine	176.89	cwt.	$0.50	$88.44
Breeding Fees	1.00	head	$40.00	$40.00
DHIA/Accounting/ Legal	1.00	head	$30.00	$30.00
Marketing	176.89	cwt	$0.30	$53.07
Bedding Costs	0.75	ton	$100.00	$75.00
Gas/Fuel/Oil	14.00	gal	$2.50	$35.00
Electricity	594.00	kWh	$0.11	$65.34
Other (oper. Int. phone)	1	head	$180.00	$180.00
Total Livestock Costs				$825.54
Total Variable Costs				$952.54
Fixed Costs Per Head				
Facility and Equipment Costs				
Milking Center/Parlor	12%	head	$600.00	$72.00
Dairy Housing	10%	head	$1,400.00	$140.00
Manure Storage	10%	head	$500.00	$50.00
Machinery and Equipment	18%	head	$690.00	$124.20
Cow Ownership Costs	6%	head	$1,092.50	$54.63
Heifer Replacement Costs	0.22	head	$1,650.00	$363.00
Labor Costs	53	hour	$13.50	$715.50
Total Fixed Costs				$1,519.33
Total Variable & Fixed Costs Per Head				**$2,471.86**

Organic Dairy Budget - Estimated Annual Costs Per One Cow Unit

Cow Breed:	Holstein Cross (Medium-Large Cow)			**Milk Per Cow (lbs/year):**	19,189
Cow Weight (lbs/cow):	1,300	**Discard Milk:**	3%	**Rolling Herd Average (lbs)**	55
First Calve:	24 Months	**Cull Rate:**	22%	**Death Loss:**	5%

	Quantity	Unit	Price	Total
Variable Costs Per Head				
Feed Costs (Dry Matter Basis)				
Pasture (Mix A - D)	0.00	ton	$0.00	$0.00
Hay (Mix and Alfalfa)	0.00	ton	$0.00	$0.00
Baleage (AR and SS)	0.00	ton	$0.00	$0.00
Corn Silage	0.00	ton	$0.00	$0.00
Corn (Shelled)	0.00	lb	$0.00	$0.00
Soybeans (Roasted)	0.00	lb	$0.00	$0.00
Soybean Meal	0.00	lb	$0.00	$0.00
Oats	0.00	lb	$0.00	$0.00
Barley	0.00	lb	$0.00	$0.00
Wheat	0.00	lb	$0.00	$0.00
Salt and Minerals	256.00	lb.	$0.50	$128.00
Milk/Calf Feed	0.00	lb.	$1.50	$0.00
Total Feed Costs				$128.00
Livestock Costs				
Dairy Supplies	1.00	head	$223.00	$223.00
Freight/ Trucking/ Hauling	191.89	cwt	$0.23	$44.13
Veterinary & Medicine	191.89	cwt.	$0.50	$95.94
Breeding Fees	1.00	head	$40.00	$40.00
DHIA/Accounting/ Legal	1.00	head	$30.00	$30.00
Marketing	191.89	cwt	$0.30	$57.57
Bedding Costs	0.75	ton	$100.00	$75.00
Gas/Fuel/Oil	14.00	gal	$2.50	$35.00
Electricity	600.00	kWh	$0.11	$66.00
Other (oper. Int. phone)	1	head	$180.00	$180.00
Total Livestock Costs				$846.64
Total Variable Costs				$974.64
Fixed Costs Per Head				
Facility and Equipment Costs				
Milking Center/Parlor	12%	head	$600.00	$72.00
Dairy Housing	10%	head	$1,400.00	$140.00
Manure Storage	10%	head	$500.00	$50.00
Machinery and Equipment	18%	head	$710.00	$127.80
Cow Ownership Costs	6%	head	$1,092.50	$54.63
Heifer Replacement Costs	0.22	head	$1,650.00	$363.00
Labor Costs	53.5	hour	$13.50	$722.25
Total Fixed Costs				$1,529.68
Total Variable & Fixed Costs Per Head				**$2,504.32**

Warm Red Clover Mixture for Pasture (Mix A) - Estimated Annual Costs (Acre)						
Species: Annual Ryegrass, Red Clover, Crabgrass, Annual Lespediza				**Yield (DM Tons/Acre):**		**4.5**
		Quantity	**Unit**	**Price**		**Total**
Establishment Costs (prorated for stand life)		0.25	dollars	$64.00		**$16.00**
Variable Costs Per Acre						
Dairy Manure		2	tons	$15.00		$30.00
Annual Ryegrass Seed		20	lbs.	$0.95		$19.00
Crabgrass Seed		4	lbs.	$7.50		$30.00
Annual Lespediza Seed		15	lbs.	$4.50		$67.50
Other Labor		0	hrs.	$11.00		$0.00
Custome Hire		1	acre	$97.74		$97.74
Machinery Rental		1	acre	$0.00		$0.00
Machinery Fuel and Lube		1	acre	$0.00		$0.00
Machinery Repairs & Maintenance		1	acre	$0.00		$0.00
Cash Rent Equivalent		1	acre	$45.00		$45.00
Other Variable Costs		1	acre	$0.00		$0.00
Operating Interest	6%	$305.24	dollars	Months	6	$9.16
Total Variable Costs Per Acre						**$298.40**
Fixed Costs Per Acre						
Operator Labor		0	hrs.	$18.00		$0.00
Machinery Depreciation and Overhead		1	acre	$0.00		$0.00
Other Fixed Costs		1	acre	$0.00		$0.00
Total Fixed Costs Per Acre						**$0.00**
Total Variable & Fixed Costs Per Acre						**$314.40**
Average Cost Per Ton of Dry Matter						**$69.87**

Warm Crimson Clover Mixture for Pasture (Mix B) - Estimated Annual Costs (Acre)						
Species:	**Annual Ryegrass, Crimson Clover, Sorghum-sudangrass, Cowpea**			**Yield (DM Tons/Acre):**		**5**
		Quantity	**Unit**	**Price**		**Total**
Variable Costs Per Acre						
Lime & Application		0.5	tons	$20.00		$10.00
Dairy Manure		2	tons	$15.00		$30.00
Annual Ryegrass Seed		20	lbs.	$0.95		$19.00
Crimson Clover Seed		16	lbs.	$1.50		$24.00
Sorghum-Sudangrass Seed		30	lbs.	$1.06		$31.80
Cowpea Seed		25	lbs.	$1.69		$42.25
Other Labor		0	hrs.	$11.00		$0.00
Custome Hire		1	acre	$162.74		$162.74
Machinery Rental		1	acre	$0.00		$0.00
Machinery Fuel and Lube		1	acre	$0.00		$0.00
Machinery Repairs & Maintenance		1	acre	$0.00		$0.00
Cash Rent Equivalent		1	acre	$45.00		$45.00
Other Variable Costs		1	acre	$0.00		$0.00
Operating Interest	6%	$364.79	dollars	Months	6	$10.94
Total Variable Costs Per Acre						**$375.73**
Fixed Costs Per Acre						
Operator Labor		0	hrs.	$18.00		$0.00
Machinery Depreciation and Overhead		1	acre	$0.00		$0.00
Other Fixed Costs		1	acre	$0.00		$0.00
Total Fixed Costs Per Acre						**$0.00**
Total Variable & Fixed Costs Per Acre						**$375.73**
Average Cost Per Ton of Dry Matter						**$75.15**

Cool Season Mixture for Pasture (Mix C) - Estimated Annual Costs (Acre)						
Species: Alfalfa, Red Clover, Orchardgrass, Tall Fescue				**Yield (DM Tons/Acre):**	4.5	
		Quantity	**Unit**	**Price**		**Total**
Establishment Costs (prorated for stand life)		0.25	dollars	$215.00		**$53.75**
Variable Costs Per Acre						
Dairy Manure		2	tons	$15.00		$30.00
Other Labor		1	hrs.	$11.00		$11.00
Custome Hire		1	acre	$50.74		$50.74
Machinery Rental		1	acre	$0.00		$0.00
Machinery Fuel and Lube		1	acre	$0.00		$0.00
Machinery Repairs & Maintenance		1	acre	$0.00		$0.00
Cash Rent Equivalent		1	acre	$45.00		$45.00
Other Variable Costs		1	acre	$0.00		$0.00
Operating Interest	6%	$190.49	dollars	Months	6	$5.71
Total Variable Costs Per Acre						**$142.45**
Fixed Costs Per Acre						
Operator Labor		0	hrs.	$18.00		$0.00
Machinery Depreciation and Overhead		1	acre	$0.00		$0.00
Other Fixed Costs		1	acre	$0.00		$0.00
Total Fixed Costs Per Acre						**$0.00**
Total Variable & Fixed Costs Per Acre						**$196.20**
Average Cost Per Ton of Dry Matter						**$43.60**

Warm Crimson Clover Mixture for Pasture (Mix D) - Estimated Annual Costs (Acre)

Species: Forage Turnip, Forage Rape, Spring Oat, Annual Ryegrass, Sorghum-Sudangrass, and CowPea

Yield (DM Tons/Acre): 4.5

		Quantity	Unit	Price		Total
Variable Costs Per Acre						
Lime & Application		0.5	tons	$20.00		$10.00
Dairy Manure		2	tons	$15.00		$30.00
Forage Turnip Seed		3	lbs.	$2.50		$7.50
Forage Rape Seed		4	lbs.	$2.50		$10.00
Spring Oat Seed		32	lbs.	$0.40		$12.80
Annual Ryegrass Seed		12	lbs.	$0.95		$11.40
Sorghum-sudangrass Seed		30	lbs.	$1.06		$31.80
Cowpea Seed		25	lbs.	$1.69		$42.25
Other Labor		1	hrs.	$11.00		$11.00
Custome Hire		1	acre	$162.74		$162.74
Machinery Rental		1	acre	$0.00		$0.00
Machinery Fuel and Lube		1	acre	$0.00		$0.00
Machinery Repairs & Maintenance		1	acre	$0.00		$0.00
Cash Rent Equivalent		1	acre	$45.00		$45.00
Other Variable Costs		1	acre	$0.00		$0.00
Operating Interest	6%	$374.49	dollars	Months	6	$11.23
Total Variable Costs Per Acre						**$385.72**
Fixed Costs Per Acre						
Operator Labor		0	hrs.	$18.00		$0.00
Machinery Depreciation and Overhead		1	acre	$0.00		$0.00
Other Fixed Costs		1	acre	$0.00		$0.00
Total Fixed Costs Per Acre						**$0.00**
Total Variable & Fixed Costs Per Acre						**$385.72**
Average Cost Per Ton of Dry Matter						**$85.72**

Organic Mixed Hay - Estimated Annual Costs (Acre)						
Species: Grass- legume Mix Hay (Alfalfa & Orchardgrass)				Yield (DM Tons/Acre):		3.8
				Yield (As-Fed) Tons/Acre):		4.22
				Bale Weight (lbs.)		1,200
		Quantity	**Unit**	**Price**		**Total**
Establishment Costs (prorated for 4 year stand life)		0.25	dollars	$154.67		$38.67
Variable Costs Per Acre						
Poulty (Broiler) Manure		4	tons	$15.00		$60.00
Custome Hire (2018 Kentucky 30% Above Rate)						
Complete Harvest		2.532	bale	$28.00		$70.90
Mowing/ Conditioning		0	acre	$18.50		$0.00
Tedding		0	acre	$9.50		$0.00
Raking		0	acre	$9.00		$0.00
Bale (large round with net wrap)		0	bale	$15.00		$0.00
Move Round Bales to Storage		2.532	bale	$4.40		$11.14
Operating Interest	6%	$142.04	dollars	Months	6	$4.26
Total Variable Costs Per Acre						**$146.30**
Fixed Costs Per Acre						
Land (Cash Rent Equivalent)		1	acre	$53.00		$53.00
Total Fixed Costs Per Acre						**$53.00**
Total Variable & Fixed Costs Per Acre						**$237.97**
Average Cost Per Ton of Dry Matter						**$62.62**
Average Cost Per Ton As-Fed						**$56.39**

Organic Alfalfa Hay (Purchased) - Estimated Total Costs (ton)				
Description: Premium Organic Alfalfa (Large Squares) purchased and transported from Southern Minnesota to Southwest Kentucky (~750 miles)			Bale Weight (lbs.)	~ 1100
			Weight Per Load (tons)	25
			Avg. Number of Bales per Load	~ 45.5
	Quantity	**Unit**	**Price**	**Total**
Costs Per Load				
Alfalfa Hay (Farm Gate Price)	25	ton	$250.00	$6,250.00
Hauling Costs	750	miles	$2.75	$2,062.50
Total Costs Per Load				**$8,312.50**
Total Costs Per Ton (As-Fed)				**$333.00**
Total Costs Per Ton (88% Dry Matter Basis)				**$378.41**

Organic Corn Silage - Estimated Annual Costs (Acre)

Species:	Corn Silage	
Yield (DM Tons/Acre):	4.8	
Yield (As-Fed) Tons/Acre):	13.71	

		Quantity	Unit	Price		Total
Variable Costs Per Acre						
Lime & Application		0.5	tons	$20.00		$10.00
Poultry (Broiler) Manure		4	tons	$15.00		$60.00
Corn Seed (price per 1,000 seeds)		30,000	seeds	$2.50		$75.00
Custom Hire (2018 Kentucky 30% Above Rate)						
Moldboard Plow		1	acre	$27.00		$27.00
Tandem Disk		1	acre	$19.00		$19.00
Spread Manure		1	acre	$7.74		$7.74
Field Cultivate		1	acre	$17.50		$17.50
Plant (Conventional)		1	acre	$24.00		$24.00
Rotary Hoe		2	acre	$12.50		$25.00
Row Cultivate		2	acre	$17.00		$34.00
Chop, Haul, Fill Silo (Custom)		13.71	tons	$13.00		$178.23
Other Variable Costs		1	acre	$10.00		$10.00
Operating Interest	6%	$487.47	dollars	Months	6	$14.62
Total Variable Costs Per Acre						**$492.09**
Fixed Costs Per Acre						
Land (Cash Rent Equivalent)		1	acre	$153.00		$153.00
Total Fixed Costs Per Acre						**$153.00**
Total Variable & Fixed Costs Per Acre						**$645.09**
Average Cost Per Ton of Dry Matter						**$134.39**
Average Cost Per Ton As-Fed						**$47.05**

Organic Sorghum-Sudangrass Baleage - Estimated Annual Costs (Acre)

Species:	**Sorghum-Sudangrass**
Yield (DM Tons/Acre):	**2.8**
Yield (As-Fed) Tons/Acre):	**6.22**
Bale Weight (lbs.)	**1,200**

		Quantity	Unit	Price		Total
Variable Costs Per Acre						
Lime & Application		0.5	tons	$20.00		$10.00
Poultry (Broiler) Manure		4	tons	$15.00		$60.00
Sorghum-Sudangrass Seed		30	lbs	$1.06		$31.80
Custom Hire (2018 Kentucky 30% Above Rate)						
Moldboard Plow		1	acre	$27.00		$27.00
Tandem Disk		1	acre	$19.00		$19.00
Spread Manure		1	acre	$7.74		$7.74
No-Till Drill		1	acre	$23.50		$23.50
Complete Harvest		10.37	bale	$33.00		$342.10
Mower/Conditioner		0	acre	$18.50		$0.00
Raking		0	acre	$9.00		$0.00
Baling (large round with net & Plastic)		0	bale	$19.00		$0.00
Move Round Bales to Storage		0	bale	$4.40		$0.00
Operating Interest	6%	$521.14	dollars	Months	6	$15.63
Total Variable Costs Per Acre						**$536.77**
Fixed Costs Per Acre						
Land (Cash Rent Equivalent)		1	acre	$53.00		$53.00
Total Fixed Costs Per Acre						**$53.00**
Total Variable & Fixed Costs Per Acre						**$589.77**
Average Cost Per Ton of Dry Matter						**$210.63**
Average Cost Per Ton As-Fed						**$94.82**
Average Cost Per Bale As-Fed						**$56.89**

Organic Annual Ryegrass Baleage - Estimated Annual Costs (Acre)

Species:	**Annual Ryegrass**	**Yield (DM Tons/Acre):**	**2.00**
		Yield (As-Fed) Tons/Acre):	**4.44**
		Bale Weight (lbs.)	**1,200**

		Quantity	**Unit**	**Price**		**Total**
Variable Costs Per Acre						
Lime & Application		0.5	tons	$20.00		$10.00
Poultry (Broiler) Manure		3	tons	$15.00		$45.00
Annual Ryegrass Seed		30	lbs	$0.95		$28.50
Custom Hire (2018 Kentucky 30% Above Rate)						
Moldboard Plow		1	acre	$27.00		$27.00
Tandem Disk		1	acre	$19.00		$19.00
Spread Manure		1	acre	$7.74		$7.74
No-Till Drill		1	acre	$23.50		$23.50
Complete Harvest		7.4	bale	$33.00		$244.20
Mower/Conditioner		0	acre	$18.50		$0.00
Raking		0	acre	$9.00		$0.00
Baling (large round with net & Plastic)		0	bale	$19.00		$0.00
Move Round Bales to Storage		0	bale	$4.40		$0.00
Operating Interest	6%	$404.94	dollars	Months	6	$12.15
Total Variable Costs Per Acre						**$417.09**
Fixed Costs Per Acre						
Land (Cash Rent Equivalent)		1	acre	$53.00		$53.00
Total Fixed Costs Per Acre						**$53.00**
Total Variable & Fixed Costs Per Acre						**$470.09**
Average Cost Per Ton of Dry Matter						**$235.04**
Average Cost Per Ton As-Fed						**$105.88**
Average Cost Per Bale As-Fed						**$63.53**

APPENDIX 3. Break-even Analysis of Pasture Yields

Table A.1 provides insight into the substitutability of the four proposed pasture mixes for the 45 lb. milk production level. The first column demonstrates the necessary yield that would be required for the other pasture mixtures to result in the equivalent whole-farm net returns of the optimal mixture (i.e., break-even yield). This same principle continues for the second and third column as well in relation to the next optimal mixture and overall depicts a ranking of the mixtures for the given scenario. The experiment was conducted using AIMMS software, where the model was constrained in a manner that prevented the optimal forage mixture from entering the final solution. The yield of the second most optimal forage mixture was then increased until the whole-farm net returns were equivalent to those from the original optimal solution. This process was then replicated five additional times.

The results demonstrate the superiority of the cool season mixture, where the required yields for substitution are not realistic. More specifically the yield of the warm red clover mixture would have to increase by almost five times its current level to achieve the same net returns as the cool season mixture. This is the result of much lower costs per acre, competitive yields, and superior quality that was found to be statistically significant (USDA C,2019). The lower costs of this mixture relate to the fact it consists entirely of perennial species where the costs are spread over the assumed four-year stand life. All other mixtures consisted primarily of annual species and substitutability between them was much more reasonable.

Table A. 1 Break-even Pasture Yields for Input Substitution equivalency

	Pasture Mix (CS)	Pasture Mix (WRC)	Pasture Mix (WCC)
Pasture Mix (WRC)	16.66 (483%)		
Pasture Mix (WCC)	40.52 (1170%)	3.60 (13%)	
Pasture Mix (WTR)	45.91 (1500%)	3.77 (31%)	3.35 (17%)

1 All yields are represented on a dry matter basis, and values represent the necessary yield per acre required for substitution

2 Percentages in parenthesis represent the percentage increase of the new yield compared to the actual or original yield

APPENDIX 4. Break-even Analysis of Planter Purchase Prices

Table A.2 presents a comparison of the substitutability of different planter makes. Using the coefficients from the base model applied in chapter two, predicted purchase prices for three planters of different makes were determined. Planters were assumed to have the same row number (16) and row spacing (30"). A 12-year useful life, a current age of 8 years, and an 8% interest rate were also assumed to determine total machinery expenses for the three planters. Using these assumptions and equations for machinery cost calculations from Edwards (2015), list price, salvage value, depreciation, interest, and repair and maintenance were calculated. These factors were then plugged into the end equation, which was used to determine the necessary purchase price for input substitution equivalency. The equation is as follows:

$$Breakeven\ purchase\ price\ John\ Deere\ = \frac{(Depreciation\ John\ Deere + Interest\ John\ Deere) + (Total\ Rel.Exp.Kinze - Total\ Rel.Exp\ John\ Deere)}{Salvage\ Value\ John\ Deere * Interest\ Rate\ John\ Deere}$$

Kinze had the highest predicted purchase price followed by John Deere and Case IH and the table below functions in descending order. The results demonstrate that the predicted purchase prices of Kinze and John Deere are very close with only approximately a 1% increase in the purchase price of John Deere to result in the same total machinery costs as Kinze. This suggests that Kinze and John Deere are relatively substitutable; therefore, their purchase prices are highly price sensitive. Based on the function applied and the necessary assumptions, the purchase price for Case IH is quite lower, and approximately a 55% and 57% increase in purchases prices are necessary for substitution equivalency. For this given scenario, results suggest that Case IH has a competitive advantage over the other makes and offers a potential deal for the buyer based on the factors considered.

Table A. 2 Planter Break-even Purchase Price for Input Substitution Equivalency

	Kinze	John Deere
John Deere	$39,020.69 (101%)	
Case IH	$44,126.42 (157%)	$43,436.18 (155%)

1 Assumptions: 16 Row Planters with 30" row spacing, 8 years old with a useful life of 12 years, 8% interest rate

2 The Price represents the necessary purchase price for the next planter to have the same machinery costs as the planter before it

3 The Percentage in parenthesis is the percentage of break-even price compared to that of the regression predicted purchase price

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Assistant Manager, Clark Family Farms, May 2015 – May 2017

Apprentice, University of Kentucky Horticulture Research Farm, May 2016 – December 2016

Conference Presentations

"Optimal Forage and Supplement Balance for Organic Dairy Farms in the Southeastern United States." Southern Agricultural Economics Association Annual Meeting. Birmingham, Alabama. February 2-5, 2019.