Identification of Driving Factors in Farm Profitability and the Implications of a Transition from Conventional to Organic Row Crop Production

by

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Abstract

Management decisions during times of relatively low net farm income have become the focus of recent research and will likely continue to be important in the future. Volatile net farm income, low commodity prices combined with relatively high input costs have deteriorated farm incomes over the last several years. Extension personnel have been working to support producers in improving profitability to provide research, guidance, and software tools to aid in farm-management decision making. Understanding the factors of production that have significant impact on profitability can help producers focus their efforts during times of low net farm income as well as help extension personnel to make better recommendations for producers. Research also indicates that diversification of enterprises can serve as a risk mitigation tool in order to stabilize net farm income over time. Suggesting a primarily row crop producing farm could benefit from more consistent profits by diversifying their operation. One such diversification tactic is transitioning a portion of acreage to organic production. Over the past decade, the organic industry has gained popularity among both consumers and producers. Some profit-maximizing farmers producing cops under conventional practices may consider producing organic crops if consumers are willing to pay a premium sufficient to offset organic production and transition costs. Current organic standards require a three-year transition period from conventional practices in addition to strict production requirements before the crop can be labeled as "organic". Organic crop rotations are required to include the following: 1) maintain/improve soil organic matter, 2) control pests, 3) regulate plant nutrients, and 4) incorporate erosion control methods. Demand for organically produced food has continued to increase, causing producers to consider transitioning to organic production despite the challenges associated with the transition. This two-part study sought to understand factors affecting the profitability of conventional producers as well as analyze the profitability of transitioning to organic row crop production.

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Chapter 1 - Introduction

This thesis covers topics related to net farm income (NFI) and organic crop production. Recent structural changes in NFI were evaluated to determine factors correlated with farms being in the highest and lowest profitability categories. Given the recent reduction in NFI, this study evaluated alternatives to improve NFI specifically transitioning to production of organic crops. Organic crop production may be attractive to specific farmers that may be able to capture premiums in addition to commodity crop prices.

1.1 Farm Income History

Farm income has a history of being highly variable. The general trend in NFI since 2013 has been decreasing. From 2017 to 2018, NFI decreased by $12 billion. Figure 1.1 depicts these trends over the last 17 years (USDA, ERS 2019b). Figure 1.1 also indicates that farm income can be highly variable from year to year causing financial hardships when trying to make farm level management decisions that affect current and future years.

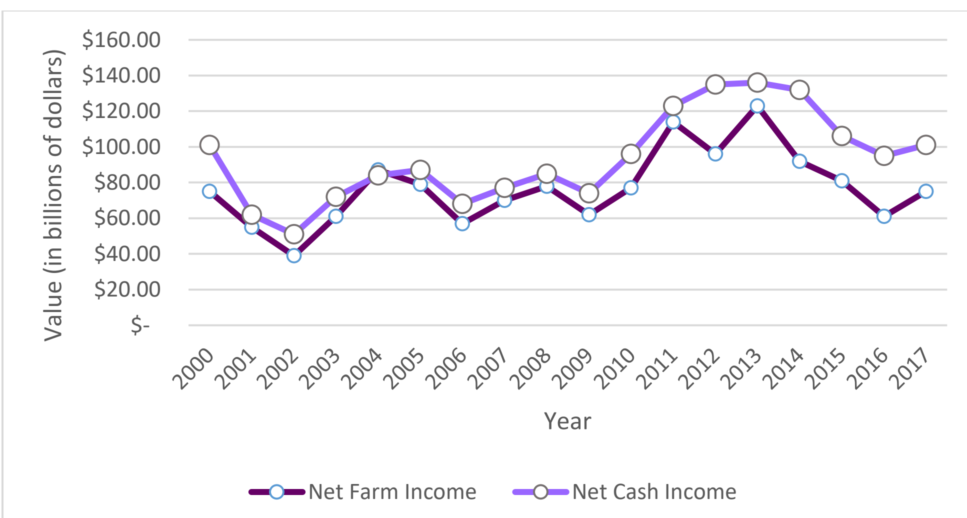

Figure 1.1 Net Farm Income and Net Cash Income Over Time (USDA, ERS 2019a)

In addition to reduced NFI in recent years there has been a drastic increase in the average debt on individual farms. Figure 1.2 shows the increase in average debt per acre from 2002-2017 in Kansas Farm Management Association (KFMA) data. The average debt per acre increased more than 90% from $212 per acre in 2002 to approximately $410 per acre in 2017. The decision for a producer to take on more debt is one that will affect profitability for many years and the ability to re-pay current and future debt is important in the decision to take on additional debt.

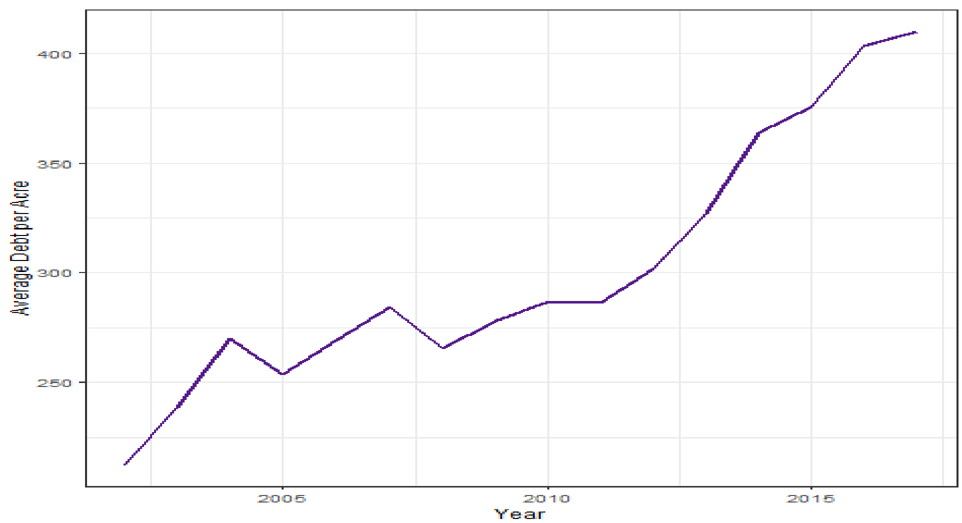

Figure 1.2 Average Debt per Acre on a Farm in Kansas

In addition to low net farm income and increasing debt, costs of production have increased. Total production expenses in 2000 totaled approximated $191 billion and by 2017 was about $354 billion, an 85% increase. Over the same period of time, the prices of corn, soybeans, and wheat (three of the top produced commodities in the Midwest United States), only increased by an average of 5.9%, 6%, 5.5% respectively (USDA, Quick Stats, 2019). Similarly, land values continued to increase over the last 15 years. The United States average value of agriculture land in 2000 was approximately $1,460 per acre and increased to $4,130 per acre in 2018, a 180% increase (USDA, Quick Stats, 2019). This drastic increase made it difficult for producers to purchase more land to expand their operations, especially beginning operations.

1.2 Farm Income Outlook

Although it is still too early to know what 2018 net farm incomes will be, the United States Department of Agriculture's (USDA) Economic Research Service (ERS) predicted a 12% decrease in net farm income in 2018 compared to 2017 (FAS, 2019). While the outlook for net farm income for 2019 is better (expectation of an increase of about $6.3 billion), it is still significantly lower than the 2011-2014 period (USDA, ERS 2019b). Depressed commodity prices caused in part by multiple years of record-breaking crop production, increased production costs, and trade negotiations have caused concern amount agriculturists. Understanding net farm income and ways to mitigate risk have become more important than ever. This thesis examined factors that had the greatest effect on net farm income as well as analysis of viable options to increase net farm income.

An earlier version of Essay 1 (Factors Affecting Row Crop Production in Kansas) was submitted for peer review and accepted to be published in the 2019 issue of the Journal of the American Society of Farm Managers and Rural Appraisers (Carls et al., 2019). An earlier version of Essay 2 (Farm Management Implications of Transitioning from Conventional to Organic Production) was presented at Annual Meetings of the Southern Agricultural Economics Association in Jacksonville, Florida (Carls et al., 2018a) and the Western Agricultural Economics Association in Anchorage, Alaska (Carls et al., 2018b).

Chapter 2 - Factors Affecting Row Crop Production in Kansas

2.1 Introduction

Agricultural production in the United States (U.S.) has a long history of highly variable net farm income (NFI). After reaching a high period in 2013, NFI steadily declined for the next three years (Kassel, 2018). Kansas producers also experienced decreased NFI during this period with a slight increase from 2015 to 2016 before, another decrease in 2017 (Figure 2.1).

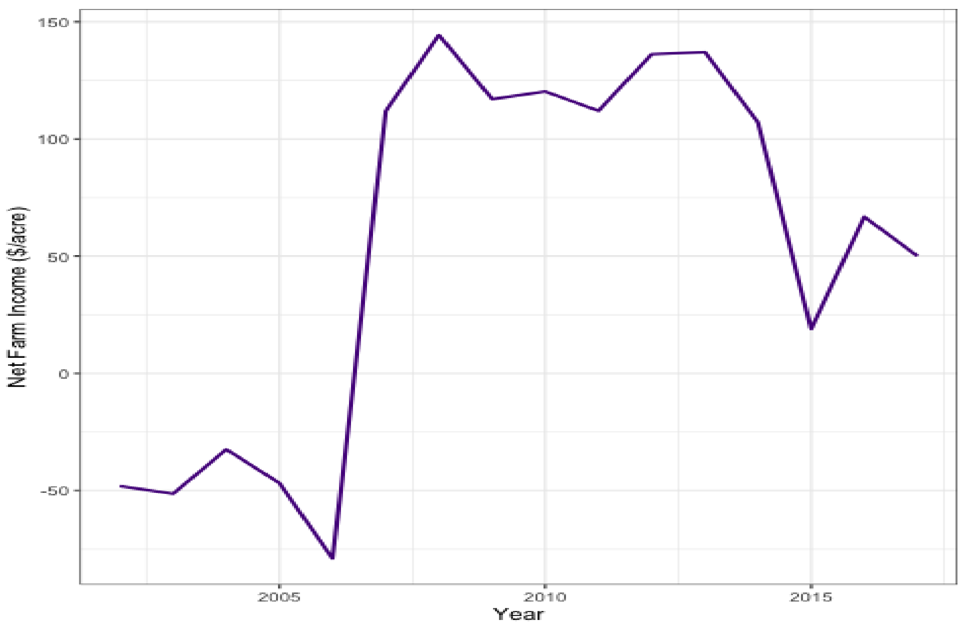

Figure 2.1 Average Net Farm Income in Kansas (Lanegmeier, 2010)

High NFI volatility has made it difficult for producers to make decisions affecting their present and future profitability. Highly variable NFI combined with low commodity prices forced producers to be efficient in other areas of production (machinery, inputs, investment, etc.) (Figure 2.2). Producers attempted to remain profitable by reducing input usage and avoiding costs while remaining at the same level of production.

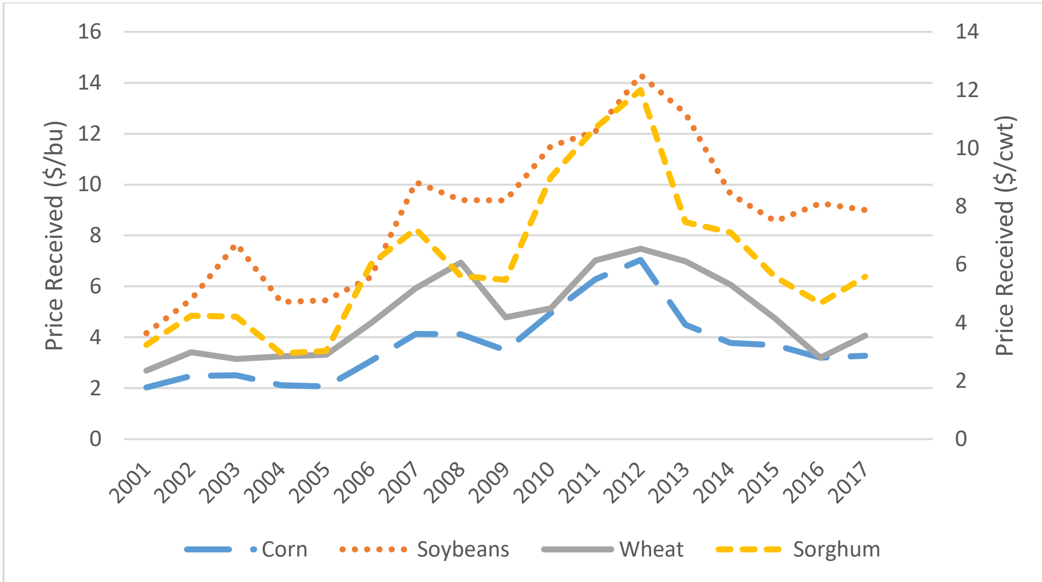

Figure 2.2 Average Price Received for Crops in Kansas

Extension professionals are assisting producers to improve profitability by providing the latest research, guidance for farm decisions, and software tools to aid in their decision making. However, without fully understanding specific factors affecting net farm income, education and outreach can be challenging. Having better knowledge of these factors, Extension personnel could make better recommendations for farmers to improve overall profitability (Stabel et al., 2018).

Several factors influencing profitability include but are not limited to trade, policy including government subsidies, fiscal policy, interest rates, and weather. While these factors are important to consider when making farm-level management decisions, the aforementioned factors are uncontrollable by producers. However, other factors influencing profitability are within the control of producers, including but are not limited to machinery, production management, investment, and financial decisions. Understanding which factors had the greatest effect on NFI can aid producers in making farm-level management decisions.

The overall goal of this analysis was to estimate the characteristics of highest and lowest profitability Kansas farms to determine factors that producers should focus their management efforts.

2.2 Literature Review

Factors affecting the profitability of a farm operation have been studied. Morris et al. (2018) used the Kansas Farm Management Association (KFMA) data base to analyze how a farm's relative performance differed from the average in a given region in Kansas on a net farm income per acre basis. They found that farm size, workers per acre, government payments, crop specialization, planting intensity, machine costs, yield management, and price management were all statistically significant to farm performance. In addition, they found that farms do not outperform the average in regard to yield and price management on a consistent, yearly basis; however, consistently well managed operations can result in higher net income over time. Stabel et al. (2018) used Markov switching models and the KFMA data set to determine transition probabilities between five profitability categories. They found that farms persisted in their current profitability category; however transition probabilities were greater for the highest and lowest profitability categories while they were lower for the middle category of profitability. Ibendahl (2015) also analyzed KFMA data to determine if investment in machinery was the difference in profitability groups. He separated the data set into three different profitability categories (high, medium, low) and analyzed it on a per acre basis. He found that it was not until after the 2008 corn price shock that there was a difference in machinery investment and concluded that this was a result of high profitability and not a cause of high profitability. Dhuyvetter (2010) analyzed the persistence of different management traits in Kansas. He split data into thirds based on profitability and analyzed the difference in profitability from the average. He found that farms that had economies of scale, controlled costs, and adopted technology (relevant to their operations) were consistently above the average. Dunn and Williams (2000) again used KFMA data to analyze the variability in net farm income. They used a combination of cross-section and panel data to examine the changes in the standard deviation and variability in net farm income. They found that gross income, government payments, and costs were the most important and other factors were less important.

Gloy and LaDue (2003) studied financial management practices producers have adopted and analyzed the relationship between adoption of practices and profitability. They conducted a survey which they combined with Cornell University's Dairy Farm Business Summary (DFBS) to analyze different areas of financial management. They found that the most common investment analysis was the use of a cash flow to determine if loans could be repaid. They concluded that there was a need for continued education in importance of financial management practices. Headley (1967) utilized Illinois Farm Business Farm Managements (FBFM) data to conduct an analysis of 195 farms in Illinois using over 60 variables to evaluate how producers should allocate resources. Given their variables and analysis techniques, they were not able to adequately contribute to their overall goals of getting valuable management information to producers. Weersink et al. (2011) sought to understand different factors that affect farm and off-farm income variability in Canada. They ranked each farm by their coefficient of variation and then separated them into weighted quintiles to analyze the volatility. They used an ordinary least squares (OLS) regression to analyze differences in the coefficient of variation. They looked at variables relating to farm type and size, enterprise, location, age, and government payments. They found that the variation was greater for farm income as opposed to off-farm income and that as more focus was put onto the farm, the variability of farm income went down. They also found that larger commercial farms have higher variation in their farm incomes and that government payments help stabilize farm income. Similarly, Jette-Nantel et al. (2011) analyzed the relationship between farm income risk and off-farm income in Canada. They use utility theory to determine how resource allocation decisions are made. They found that off-farm employment income and farm income risk is stronger among operators of larger farms and that additional policies to assist rural families to manage risk would be beneficial. Mishra et al. (2009) used data from the 2005 United States Department of Agriculture (USDA) Agricultural Resource Management Survey (ARMS) to analyze the financial performance of new and beginning farmers. They used a weighted least squares regression with the return on assets as the dependent variable. They found that increasing the number of decision makers, engaging in value-added farming, and having a written business plan can lead to increased profitability. In addition, the education of the operator, size, variable costs, and participation in government programs all affect the financial performance of new and beginning farmers.

Regression analysis is used to analyze the relationship between a dependent variable and one or more independent variables. Ordinary least squares (OLS) regressions are used to fit a line through a set of observations to minimize the sum squares of residuals. An OLS regression is also useful when there is a continuous dependent variable. However, sometimes there is a dependent categorial variable such as, gender, education level, or geographic region. Discrete choice models are used to analyze the likelihood of a given alternative being chosen. A discrete choice model is useful when the dependent variable is a set of choices such as, choosing a form of transportation, a secondary school, or purchasing a house. A binary logistic regression then, is commonly used when the dependent variable is a binary variable. This theory can be applied in various ways. Lohr and Park (1995) sought to apply a two-equation utility decision model to survey data from Michigan and Illinois on participation in a filter strip Conservation Reserve Program (CRP). The first decision was to determine if a producer decided to participate in the program and the second was to determine how many acres to enroll in the program. They utilized a logistic distribution model to test the discrete-continuous variable model. Negri and Brooks (1990) used a logistic regression to model the choice of irrigation technology and the decision to adopt tailwater recovery pits. They found that the decision to adopt water saving irrigation technologies was heavily based on physical characteristics (soil slope, texture, and quality) as well as the cost of pumping groundwater. Lambert et al. (2014) used a logistic regression to determine the decision of cotton producers to adopt precision soil sampling technology and how long they wait before retesting soils after adopting the technology. They found that producers who received their information from trade shows, hired consultants, generated yield maps, or used handheld devices to manage data were more likely to adopt precision soil sampling technologies. Bagi (1983) used a logistic regression to analyze the factors that affect the probability that a farmer will use short-term and long-term credit in Tennessee. He found that the probability a farmer will use credit is related to factors such as the size of the farm, farm experience, education, frequency of contact with Extension agents, the perception that credit can increase farm profits, and the number of children below 14 years of age. Johnson et al. (2010) used a binomial logistic regression to analyze the probabilities of adoption of certain technologies in stocker cattle production. They analyzed six management practices and found that operational characteristics, operation size, and income dependency were the most statistically significant in regard to management practice adoption. Banerjee et al. (2008) used a binomial logistic model to determine adoption of GNSS guidance systems by cotton producers in 11 states. They determined that adoption of previous technologies, age, and size of farms (yields) were the most influential in a producer's likeliness to adopt the technology. Additionally, Stabel (2018) used a logit model to determine characteristics of farms that persisted in profitability groups. This study builds upon previous literature by using a binomial logistic regression to analyze differences in the top and bottom profitability Kansas grain farms.

2.3 Data

This analysis used data from the Kansas Farm Management Association (KFMA) database. The KFMA has served Kansas producers for over 80 years and currently has near 2,500 farmer-members (O'Brien and Yeager, 2017). This study analyzed 71 variables over sixteen years of data from 2002 to 2017. To ensure validity, data were first sorted based on variable V007, which was used to flag any data that may be incomplete or atypical from the region (Langemeier, 2010). Data were then sorted based on the region and farm type. The database was subset to only grain farms in the eastern portion of Kansas. The farm type variable describes the enterprises produced by the farm (i.e. grain, livestock, mixed grain/livestock). For the purpose of this analysis, only grain farms were considered. Additional data cleaning included filtering to ensure outliers were omitted from the final dataset. All variables were put on a per crop acre basis to account for number of acres in an operation.

Quintiles were calculated based on net farm income per acre to separate farms into profitability categories. These quintiles were calculated for each farm in each year of the data set. These quintile ranks were averaged over all years to assign a final quintile rank for each farm in the dataset. The top quintile was labeled as Quintile 5 with the remaining quintiles labeled in order from Quintile 4 through Quintile 1.

Additional variables were calculated for use in this analysis: deviation from yield and deviation from price. These were defined as the amount an individual observation differed from the state average. To calculate these, additional data were collected. Data were gathered from USDA NASS for average yield by county in the state of Kansas and average price received for the state over each year in the data set. Individual observations were then subtracted from the state averages; observations with a negative value meant they were above the state average (favorable) while positive values meant they were below the state average (unfavorable).

Box plots were created during the exploratory data analysis phase to identify variables that were different between the five quintiles. If the bar of a given variable were increasing (or decreasing) across variables, it was determined that differences in values of that variable between all five quintiles existed and could be further analyzed with regressions (Figure 2.3). Results of exploratory data analysis narrowed candidate variables from 71 down to, 11. Summary statistics for the variables included in this analysis are presented in Table 2.1.

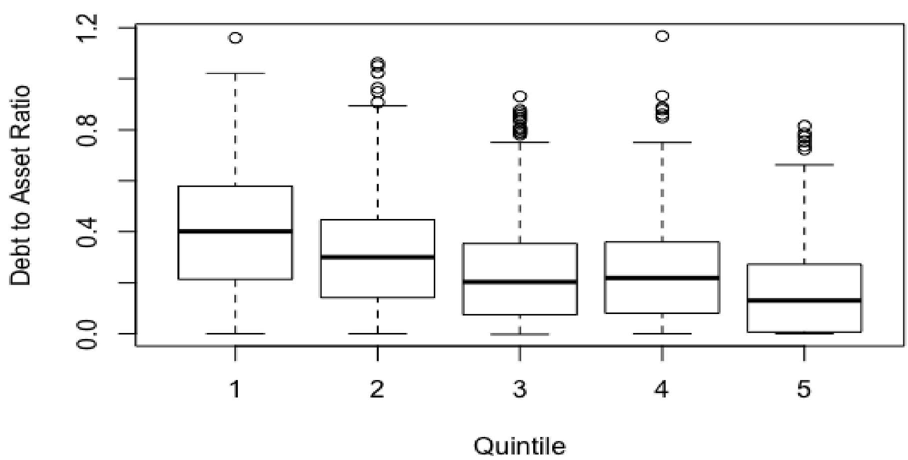

Figure 2.3 Debt to Asset by Quintile

Finally, data were filtered to include only farms assigned to either Quintile 1 or Quintile 5 so that analyses could be conducted on how characteristics differed between extremes. In all, 726 unique farm observations were evaluated. Of these 726 farms, 50 produced irrigated corn, all

726 produced non-irrigated corn, 445 produced non-irrigated wheat, 712 produced non-irrigated soybeans, and 125 produced non-irrigated grain sorghum. Over the 16 years of this study, the average net farm income per acre was $107.39. The maximum NFI per acre was $1,619.31 in 2014 while the minimum was -$338.64 in 2006.

Table 2.1 Summary Statistics of Select Variables

Variable	Mean	Median	Min	Max	Standard Deviation
Corn Yield per Acre	54.24	56	0.61	126.82	23.16
Corn Price	4.38	3.96	0	10.1	1.40
Fertilizer Cost per Acre	57.62	50.38	0	361.25	37.10
Machinery Investment per Acre	271.6	236	0	1424.4	174.12
Debt to Asset Ratio	0.27	0.24	-0.002	1.17	0.22
Deviation in Yield	55.36	56.7	-20.18	119.16	21.70
Deviation in Price	0.06	0.07	-6.9	4.49	0.51
Machinery Repairs per Acre	26.59	22.6	0	383.79	19.33
Return on Assets	0.06	0.04	-0.5	1.46	0.12
Value of Farm Production	425.91	389.81	7.89	4513.13	217.68
Current Assets	379	318	-30.3	2950	298.77
Total Crop Production Costs	276.43	258.95	13.39	1157.97	121.43

Pairwise correlations were calculated for all variables. Correlations above 0.5 or below -0.5 were further evaluated. Net farm income per acre and value of farm production per acre had a correlation of 0.697. Value of farm production was defined as the gross farm income which is equal to the value of farm production plus the accrual feed purchased (Langemeier, 2010). This indicated that with a high value of farm production per acre a high net farm income per acre was observed. Value of farm production per acre and current assets per acre had a correlation of

0.508. Current assets include inventory changes (sale of grain) which is also included in the value of farm production. This could be one explanation for the high correlation between the value of farm production per acre and current assets per acre. Machinery investment per acre and total crop production cost per acre have a correlation of 0.679. This demonstrates how impactful machinery management decisions can be on managing costs. Average equity per acre is highly correlated with average assets per acre, total assets per acre, non-current assets per acre, and current assets per acre with correlations of 0.960, 0.953, 0.917, and 0.574 respectfully. In addition, average assets per acre are highly correlated with total assets per acre (0.99), non-current assets per acre (0.965), and current assets per acre (0.561). Total assets per acre are highly correlated with non-current assets per acre (0.974) and current assets per acre (0.558). Lastly, current liabilities per acre are highly correlated with total debt per acre (0.693). The above variables are all subsets of each other which explains the high correlations.

Average crop acres for quintile one had the smallest acreage (1,426 acres) while the largest is the quintile five (1,781 acres). The acreage levels of the farms increase as the profitability level increase with the exception of the third quintile (1,464 acres) which was a decrease of 272 acres from quintile two (1,736 acres). There is a noticeable difference in average corn yield (bushels per acre) from quintile one to quintile five. A t-test shows, with a p-value of 1.233e-13, a statistically significant difference between the two quintiles. Quintile one has the lowest corn yield of about 46 bushels per acre while quintile five has the largest yield of approximately 60 bushels per acre. There's a steady increase in average corn price received by each quintile from quintile one ($3.87) through four ($4.58). However, quintile five has an average price received lower than that of the quintile below (quintile four) at $4.45. Fertilizer cost per acre also increases as the profitability levels increase.

Table 2.2 Variable Averages per Quintile

Variable	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Corn Yield	47.82	48.78	53.61	59.83	60.85
Corn Price	3.95	4.34	4.41	4.58	4.49
Deviation from Average Yield	56.56	54.19	54.66	58.38	51.94
Deviation from Average Price	0.16	0.07	0.08	0.01	0.02
Fertilizer Cost per Acre	44.14	53.73	58.60	62.74	66.76
Machinery Investment per Acre	205	253.55	297.64	291.80	288.24
Machinery Repairs per Acre	28.78	26.28	24.74	27.34	26.73
Debt to Asset Ratio	0.40	0.32	0.24	0.24	0.18
Return on Assets	-0.03	0.04	0.06	0.08	0.12

Quintile one has fertilizer cost of $41.66 per acre while quintile five has fertilizer cost of $66.75 per acre. Machinery investment per acre follows a similar trend as the price received per acre with a steady increase between quintile groups for quintile one through quintile four. However, quintile five has a $10 lower machinery investment per acre than quintile four. There is not a noticeable trend between quintiles for machinery repairs per acre and a t-test reveals that the mean for quintile five is not statistically different than the mean for quintile one. There is a general decrease in the debt to asset ratio from quintile one to quintile five. Quintile one has an average debt to asset ratio of 0.40 while quintile five has an average ratio of 0.18. There is not a noticeable trend between quintile groups in the deviation from the average yield, however a t-test reveals there is a statistically significant difference between the mean for quintile five and the mean for quintile one. Deviation from the average price follows a similar pattern of corn price received and machinery investment per acre with it steadily decreasing from quintile one to the quintile four and then an increase for quintile five. Return on assets increases as the profitability levels increase. The lowest return on assets is quintile one at an average of -0.028 while the highest return on assets is quintile five at 0.12. Averages for each variable and quintile are shown in Table 2.2 and t-test results between quintile 1 and quintile 5 are shown in Table 2.3.

Table 2.3 T-Test Results Between Quintile 1 and Quintile 5

Variable	p-value
Corn Yield	< 0.0001
Corn Price	< 0.0001
Deviation from Average Yield	0.0037
Deviation from Average Price	0.0001
Fertilizer Cost per Acre	< 0.0001
Machinery Investment per Acre	< 0.0001
Machinery Repairs per Acre	0.2572
Debt to Asset Ratio	< 0.0001
Return on Assets	< 0.0001

2.4 Models and Methods

Regression analysis was used to quantify the effect independent variables had on the dependent variable. The least squares approach has been the benchmark approach for regression modeling such that, coefficients for a least square's coefficient minimizes the sum of squared residuals (Greene, 2002). Ordinary least squares (OLS) is often used with linear regression models when the dependent variable is continuous. Discrete models are useful when the dependent variable has a finite number of values. Discrete choice models are used when the dependent variable is a choice among a set of alternatives (choosing to participate in the labor force, purchase a particular machinery implement, choose a variety of seed, etc.) (Greene, 2002). Often, the dependent variable takes one of two values, typically a zero or a one. In these binary outcomes, binomial logistic regression are useful with dichotomous dependent variables. The dependent variable takes the value of 1 if the value of the dependent variable is true or 0 if it is false. The probability that the dependent variables takes the value of 0 or 1 can be demonstrated in equations 1 and 2 (Greene, 2002).

$$Prob(Y = 1|x) = F(x, \beta) \tag{1}$$

$$Prob(Y = 0|x) = 1 - F(x, \beta) \tag{2}$$

where β reflects the marginal effects in x on the probability that it takes the value 0 or 1 (Greene, 2002).

To determine the marginal effects of the independent variable on the dependent variable, a model needed to be determined. The classical model is a linear model, however, due to heteroscedasticity, disturbance in the error term, and negative variance, the linear model is not always the best choice (Greene, 2002). Therefore, a requirement for the model needs to be consistent with equation 3 and 4 (Greene, 2002).

$$\lim_{x'\beta \to +\infty} Prob\ (Y = 1|x) = 1 \tag{3}$$

$$\lim_{x'\beta \to -\infty} Prob\ (Y = 1|x) = 0 \tag{4}$$

To meet these requirements, a continuous probability distribution needs to be defined. Two common models are the probit and the logit model. For the purpose of this analysis, a logit model was defined relying upon the logistic distribution as defined in equation 5 (Greene, 2002).

$$Prob(Y = 1|x) = \frac{e^{x'\beta}}{1 + e^{x'\beta}} \tag{5}$$

2.5 Specification of Model

Before the model could be specified, the definition of net farm income was needed. Net farm income can be defined by "…the amount by which revenue exceeds expenses, plus any gain or loss on the sale of capital assets" (Kay et al., 2004). In the case of a grain only farming operation, revenue can be defined as the price received for the grain (bushels per acre) multiplied by the amount of grain produced (bushels per acre).

To account for revenue in the model, four variables were used in different models: corn yield (bushels per acre), corn price (dollars per bushel), deviation from yield, and deviation from price. Expected signs for corn yield and corn price would be positive due to higher yields and prices generally lead to higher profitability. Due to how deviation from yield and deviation from price were defined (Chapter 2.3) expected signs were negative: negative values were favorable, so the expected sign would be negative to have an overall positive effect on NFI. Fertilizer cost per acre were included to account for the expense portion of the NFI equation. Expected signs were negative as costs have negative impacts on NFI. Literature has shown that machinery management decisions affect farm profitability (Morris et al., 2016). Therefore, additional variables were included to account for machinery management decisions: machinery investment per acre and machinery repairs per acre. Expected sign for machinery investment were positive; higher investment in machinery indicates financial profitability. Machinery repairs expected sign were negative, high repair costs indicates inability to update machinery sets. To account for the ability of a given operation to pay short-term obligations, debt to asset ratio and return on assets were included in models. The expected sign for debt to asset ratio were negative, as debt to asset ratio increases, it's expected that NFI decreases. Return on assets however, would be expected to have a positive sign, as it increases so does profitability.

Table 2.4 Abbreviation of Variables

Variable	Abbreviation
Corn Yield	CY
Corn Price	CP
Deviation from Yield	DY
Deviation from Price	DP
Fertilizer Cost per Acre	FC
Machinery Investment per Acre	MI
Machinery Repairs per Acre	MR
Debt to Asset Ratio	DA
Return on Assets	RA
Year Dummy	YD

Lastly, to determine how producers' management decisions differ in times of good and bad prices, a year dummy was included as an interaction term for each variable to determine how producer behavior differed in years with good and bad prices. This dummy variable was categorized by taking the mean and standard deviation of the average price in Kansas from USDA National Agriculture Statistics Service (NASS) (USDA, 2017). The mean and standard deviation were then used to create a range of prices, if an individual observation received a price above that range, it was considered a good year (with respect to prices), if an individual observation received a price below that range, it was considered a bad year, and if it fell within that range, it was considered a good year. In all models the year dropped was the good year, meaning all results are relative to a good year. There were four models analyzed, described in Equations 6 through 9 (variable abbreviations, in Table 2.4).

$$Y = CY + CP + FC + MI + DA + (CY * YD) + (CP * YD) + (MI * YD) + (DA * YD) \quad (6)$$

$$Y = DY + DP + FC + MI + DA + (DY * YD) + (DP * YD) + (MI * YD) + (DA * YD) \quad (7)$$

$$Y = CY + CP + FC + MR + DA + (CY * YD) + (CP * YD) + (MR * YD) + (DA * YD) \quad (8)$$

$$Y = CY + CP + FC + MI + RA + (CY * YD) + (CP * YD) + (MI * YD) + (RA * YD) \quad (9)$$

A summary of expected signs for each variable can be found in Table 2.5.

Table 2.5 Expected Signs for Each Variable

Variable	Expected Sign
Corn Yield per Acre	(+)
Corn Price	(+)
Deviation from Average Yield	(-)
Deviation from Average Price	(-)
Fertilizer Cost per Acre	(-)
Machinery Investment per Acre	(+)
Machinery Repairs per Acre	(-)
Debt to Asset Ratio	(-)
Return on Assets	(+)
Year Dummy (other)	(-)
Year Dummy (bad)	(-)

2.6 Results

The partial effects in binary logistic regressions are not directly interpretable (Greene, 2002). Partial effects of a continuous independent variable on a binary dependent variable in the logit model can be described in general form in equation 10 (Greene, 2002).

$$\frac{\partial E[y|x]}{\partial x} = \Lambda(x'\beta)[1 - \Lambda(x'\beta)]\beta \qquad 10$$

where Λ is the logistic distribution, and $(x'\beta)$ is a vector of coefficients and variable values. There are two ways to interpret the marginal effects. Effect can be evaluated at the sample means of the data or evaluated at every observation with the sample average of the individual marginal effects (Greene, 2002). The interpretation of an independent dummy variable on a dependent binary variable is slightly different than a continuous independent variable. The marginal effects of an independent dummy variable can be described in general form equation 11 (Greene, 2002).

$$Marginal\ effect = Prob\left[Y = 1 \middle| \overline{x}_{(d)}, d = 1\right] - Prob[Y = 1|\overline{x}_{(d)}, d = 0] \qquad 11$$

where $\overline{x}_{(d)}$ are the means of other variables in the model (Greene, 2002). There are two different ways of calculating marginal effects in a binary logistic regression.

When interpreting the partial effects of a continuous independent variable in a binary logistic regression it can be stated that an increase in the independent variable by one unit will change the probability that the binary dependent variable will take the value of either a 0 or 1 depending on how the model is specified. In this case, a positive partial effect would indicate that an increase in the independent variable by one unit would increase the probability that the dependent variable takes the value of 1 (or a farm is in the top quintile). Similarly, a dummy independent variable would explain the change in the probability of the dependent variable taking a specific value relative to the base value of the variable. For this analysis, marginal effects are reported at the means, meaning they are reported at the average for the data set.

Model one shows that fertilizer cost per acre, debt to asset ratio, and the interaction between fertilizer cost, corn price, and corn yield and the year dummy variable are significant variables. The signs on all variables are as expected with the exception of fertilizer cost per acre. Expected sign for fertilizer cost was negative because it was included in the model to account for costs. The positive sign could be explained by a number of things. It could account for quality of soil, i.e. those who spend more on fertilizer have better soil and therefore a better crop. Another explanation could be that when farm revenue is low, farmers lower the amount they spend on fertilizer. Debt to asset ratio has a negative effect which indicates that those producers who manage their debt more effectively have higher profitability. The signs on the interaction terms between average priced years and corn price and corn yield are both positive meaning that in average years of pricing, higher yields and prices increase the probability that a producer will be in the top quintile. Oppositely, the interaction term between the average priced year and fertilizer cost per acre is negative indicating that in average priced years, higher fertilizer costs lower the probability that a producer is in the top quintile. The marginal effects for fertilizer costs are 0.006, this indicates that with a one unit increase in fertilizer cost per acre, the probability that a producer is in the top quintile increase by 0.006 for a value at the mean of the data set. Similarly, marginal effects for the debt to asset ratio are 0.97 indicating that a one unit increase in the debt to asset ratio would decrease the probability that a producer was in the top quintile by 0.97. The marginal effects for the interaction term for corn yield, corn price, and fertilizer cost are 0.006, 0.16, and -0.004 respectively. These can be interpreted as the change in the probability that a producer is in the top quintile relative to a good year of pricing. For example, the marginal effects between the year dummy (average priced year) and corn yield is 0.006, meaning that a one unit increases in corn yield in an average priced year increases the probability a producer is in the top quintile by 0.006. The interpretation for the other interaction terms is similar. A summary of results for model one can be found in Table 2.6.

Table 2.2 Summary of Results for Model 1

	Estimate	Standard Error	Z-Value	Pr(>|z|)	Partial Effects
Intercept	-2.62	1.83	-1.43	0.15	
CY	0.02	0.01	1.55	0.12	0.004
CP	0.26	0.27	0.98	0.32	0.06
FC	0.03	0.006	4.02	0.00006***[1]	0.006
MI	-0.0003	0.002	1.82	0.86	0.00007
DA	-3.96	1.08	-3.66	0.0003***	-0.97
YD (other)	-2.84	2.04	-1.39	0.16	0.59
YD (bad)	27	17711.14	0.002	0.99	0.71
CY*YD (other)	0.03	0.01	2.14	0.03*	0.006
CY*YD (bad)	-0.05	91.12	-0.001	0.99	-0.01
CP*YD (other)	0.66	0.33	1.99	0.05*	0.16
CP*YD (bad)	-20.76	3793.64	-0.005	0.99	-5.08
FC*YD (other)	-0.02	0.007	-2.30	0.02*	-0.004
FC*YD (bad)	-0.08	88.20	-0.001	0.99	-0.02
MI*YD (other)	0.0006	0.002	0.36	0.72	0.0002
MI*YD (bad)	-0.007	11.80	-0.001	0.99	-0.002
DA*YD (other)	-0.6	1.20	-0.50	0.62	-0.15
DA*YD (bad)	4.11	6658.20	0.001	0.99	1.01
AIC	719.52				

[1] *** significant at the 99% level, ** significant at the 95% level, * significant at the 10% level

Model two exchanged corn yield and corn price for deviation in yield and deviation in price. This model has fewer significant variables with only fertilizer cost per acre and debt to asset ratio being significant at the 99% confidence level. The sign on fertilizer cost per acre is positive again which is similar to model one. The partial effects increased slightly to 0.007 indicating that a one unit increase in the cost of fertilizer increases the probability that a producer is in the top quintile. Debt to asset ratio has a negative sign which was expected as an increase in the debt to asset ratio decreases profitability. The partial effects are -0.99 indicating that a one unit increase in the debt to asset ratio decreases the probability that a producer will be in the top quintile. A summary of model two can be found in Table 2.7.

Table 2.3 Summary of Results for Model 2

	Estimate	Standard Error	Z-Value	Pr(>|z|)	Partial Effects
Intercept	-0.22	0.65	-0.34	0.74	
DY	-0.02	0.01	-1.38	0.17	-0.004
DP	-040	0.35	-1.12	0.26	-0.09
FC	0.03	0.006	4.32	0.00002***[2]	0.007
MI	0.0008	0.002	0.50	0.61	0.0002
DA	-4.04	1.08	-3.73	0.0002***	-0.99
YD (other)	0.81	0.77	1.06	0.29	0.19
D (bad)	-19.45	6224.83	-0.003	0.99	-0.55
DY*YD (other)	0.005	0.01	-0.41	0.68	0.001
DY*YD (bad)	0.01	73.97	0.00	0.99	0.003
DP*YD (other)	-0.33	0.44	-0.75	0.45	-0.08
DP*YD (bad)	11.34	1033.15	-0.01	0.99	2.80
FC*YD (other)	-0.01	0.007	-1.42	0.16	-0.003
FC*YD (bad)	-0.03	52.24	-0.001	0.99	-0.008
MI*YD (other)	0.001	0.002	0.63	0.53	0.0003
MI*YD (bad)	-0.0005	7.64	0.00	0.99	0.0001
DA*YD (other)	-0.54	1.19	-0.45	0.65	-0.13
DA*YD (bad)	3.68	4072.47	0.001	0.99	0.91
AIC	773.95				

[2] *** significant at the 99% level, ** significant at the 95% level, * significant at the 10% level

Model three used machinery repairs per acre instead of machinery investment per acre. Results are similar to model one; fertilizer cost per acre, debt to asset ratio, and the interaction terms between average priced year dummy and corn yield, corn price, and fertilizer cost are significant. The sign on fertilizer cost is positive which is consistent with the other models. The marginal effects for fertilizer cost are 0.006 which are consistent with the first two models. The sign for debt to asset ratio is negative which was expected and the marginal effects are 0.0001. The marginal effects for the interaction terms corn yield, corn price, and fertilizer cost with year dummy (other) are 0.02, 0.05, and 0.03 respectively. These can be interpreted as in model one. A summary of results for model three can be found in Table 2.8.

Table 2.4 Summary of Results for Model 3

	Estimate	Standard Error	Z-Value	Pr(>|z|)	Partial Effects
Intercept	-2.63	1.84	-1.43	0.15	
CY	0.02	0.01	1.63	0.10	0.004
CP	0.27	0.26	1.03	0.30	0.07
FC	0.03	0.006	4.20	0.00003***[3]	0.006
MR	0.0001	0.01	0.009	0.99	0.00003
DA	-4.01	1.05	-3.81	0.0001***	-0.98
YD (other)	-2.62	2.05	-1.28	0.20	-0.56
YD (bad)	21.87	9971.83	0.002	0.99	0.68
CY*YD (other)	0.03	0.01	2.37	0.02*	0.007
CY*YD (bad)	-0.02	56.91	0.00	0.99	-0.005
CP*YD (other)	0.65	0.33	1.97	0.05*	0.16
CP*YD (bad)	-19.39	7373.24	-0.008	0.99	-4.76
FC*YD (other)	-0.02	0.007	-2.13	0.03*	-0.004
FC*YD (bad)	-0.04	61.20	-0.001	0.99	-0.01
MR*YD (other)	-0.007	0.01	-0.49	0.63	-0.002
MR*YD (bad)	-0.05	64.42	-0.001	0.99	-0.01
DA*YD (other)	-0.61	1.17	-0.52	0.60	-0.15
DA*YD (bad)	5.85	4478.23	0.001	0.99	1.43
AIC	718.11				

[3] *** significant at the 99% level, ** significant at the 95% level, * significant at the 10% level

Model four results show that fertilizer cost, return on assets, and the interaction term for the average priced year dummy and return on assets are significant. Similar to the other models, fertilizer cost per acre has a positive sign. The marginal effects are 0.003 indicating that a one unit change in fertilizer cost per acre increases the probability that a producer is in the top quintile. Return on assets has a positive sign as expected. As the return increases, it's expected that profitability also increases. The marginal effects are 0.00001 which means that a one unit increase in the return on assets increases the probability that a producer is in the top quintile by 0.00001. The marginal effects for the interaction variable return on assets and year dummy (other) are 0.02. The interpretation of the interaction terms is similar as in Model one where a one unit increase in return on assets in an averaged price year results in approximately a 0.02 increase in the probability that a producer is in the top quintile. A summary of model four results can be found in Table 2.9.

Table 2.5 Summary of Results for Model 4

	Estimate	Standard Error	Z-Value	Pr(>|z|)	Partial Effects
Intercept	-3.75	2.05	-1.83	0.07	
CY	0.02	0.01	1.57	0.12	0.006
CP	0.18	0.29	0.60	0.55	0.04
FC	0.01	0.007	1.99	0.05*[4]	0.003
MI	0.003	0.002	1.70	0.09	0.0008
RA	15.11	3.44	4.39	0.00001***	3.76
YD (other)	-1.04	2.34	-0.44	0.66	-0.25
YD (bad)	30.71	11051.35	0.003	0.99	0.69
CY *YD (other)	0.02	0.01	1.08	0.28	0.004
CY*YD (bad)	-0.06	71.68	-0.001	0.99	-0.02
CP*YD (other)	-0.12	0.39	-0.31	0.76	-0.03
CP*YD (bad)	-20.75	2728.41	-0.008	0.99	-5.16
FC*YD (other)	-0.008	0.008	-1.01	0.31	-0.002
FC*YD (bad)	-0.08	63.79	-0.001	0.99	-0.02
MI*YD (other)	0.002	0.002	0.82	0.41	0.0004
MI*YD (bad)	-0.01	7.73	-0.001	0.99	-0.003
RA*YD (other)	10.23	4.25	2.41	0.02*	2.55
RA*YD (bad)	-10.64	11972.29	-0.001	0.99	-2.65
AIC	553.01				

[4] *** significant at the 99% level, ** significant at the 95% level, * significant at the 10% level

The variables most correlated with quintile one and quintile five are fertilizer cost per acre and debt to asset ratio. In all four models, fertilizer cost was statistically significant which indicates that the amount of fertilizer applied to fields highly impacts the level of profitability. Additionally, in the three models that debt to asset ratio was in, it was statistically significant indicating that producers who are able to maintain their debt level, experience higher levels of profitability. The Akaike Information Criteria (AIC) is commonly used to compare the goodness of fit of binomial logistics regressions. Regressions with a lower AIC score have a better goodness of fit relative to other regressions with the same dependent variable data. The AIC scores can only be used to compare models with the same dependent variable data and are not useful to compare models with different dependent variable data. Comparing the AIC scores of the four models analyzed, model four had the lowest AIC score meaning it had the best goodness of fit of the four models.

2.7 Conclusions

American agricultural producers have experienced substantial declines in net farm incomes over the past four years. Continued depressed commodity prices coupled with relatively high input costs have caused the need for producers to maximize their efficiency. The marginal impact of many farm-level management decisions has increased, further emphasizing the need for producers to be aware of what factors affect net farm income. Results from this analysis indicate that decisions pertaining to land management (nutrient application) and management of debt have a high impact on farm profitability. Further analysis could expand on these areas to determine more details on how these farm-level management decisions affect farm profitability. By taking into account nutrient application rates, nutrient costs, soil quality, land values, etc., one could determine best management strategies relative to land decisions. Additionally, looking into more financial indicators as well as processes to determine the viability of adding more debt to an operation could be beneficial for producers across the mid-west. One possible change in production to mitigate low commodity prices and associated reduced NFI may be alternative production strategies such as production of organic crops on existing farms. The next essay examines existing midwestern farms' ability to transition to organic crop production.

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Chapter 3 - Farm Management Implications of Transitioning from Conventional to Organic Production

3.1 Introduction

Organic farming has been around for decades, it was only the past 30 years that the organic industry gained in popularity. As consumers' wealth started to increase, more consideration was placed on the quality of foods purchased. Demand for organically produced goods has continued to show double-digit growth (Greene, 2017). Increased marketing for organically produced foods in grocery stores, farmer's markets, and specialty stores has occurred as the organic industry comprised larger portions of the food market. Consumer's propensity to purchase organically grown food has continued to rise as the number of organic options available for purchase continue to increase. As of 2017, organic sales accounted for over 4% of total food sales in the United States (Greene, 2017).

The percentage of organic farmland in production is still relatively low considering increased demand for organically produced food. In 2011, 1,505,757 cropland acres were certified organic. Compared to total U.S. cropland harvested acres of 641,801,727 (USDA, 2011). Price premiums associated with organic products remained high as demand for organic products increased (Green, 2017). To capture price premiums associated with organic production, producers must become certified in organic production. Current organic standards require a 3-year transition period where no synthetic fertilizer or pesticides are applied (USDA, Organic, 2018). These challenges, among others, associated with the transition to organic may cause hesitation as producers consider the switch from conventional to organic production. Prices of corn and other commodities continued to decrease, resulting in producers questioning how they can become more profitable. Some of those farmers may consider organic production.

Given price premiums associated with organic commodities, many producers are wondering if switching to organic production will allow them to become more profitable relative to their existing farming operation. The question remains, however, regarding how much organic premiums have to be to entice producers to endure the 3-year transition period, to become certified organic producers. In addition to the cost of transition, it is important to consider the whole-farm and machinery implications of switching to organic production. Due to different production methods, there is a different machinery set for organic production of row crops. It logically follows that at initial transition time, a producer may begin by custom hiring organic production field operations. The question then becomes, at what level of organic production does it become more profitable for the producer to purchase machinery as opposed to custom hire. This study analyzed a farm in west central Illinois to determine at what organic price premium it would be logical for the farm to begin switching to organic production and then further analyzed at what point they would begin to purchase machinery for organic production.

3.2 Literature Review

The profitability of organic farming versus conventional farming has been studied. This section discusses previous studies conducted to better understand organic production. Delbridge et al. (2011) used the University of Minnesota's Variable Input Crop Management Systems (VICMS) data to study the profitability between an organic input rotation versus a chemical input system. They analyzed the cumulative distribution functions (CDF's) by stochastic dominance. They found that per acre net returns for the organic system were significantly higher when the full organic price premium was applied. Delbridge et al. (2013) expanded upon this to examine profits under different machinery complements considering overhead costs. They expanded upon the economic procedures in Delbridge et al. (2011) for net returns and applied stochastic dominance to intermediate optimization results to determine machinery complements. Delbridge et al. (2013) reported that with full organic premiums, the organic input rotation had higher average net returns than the chemical input rotation under all machinery complements. Delbridge (2014) updated these analyses to include the price influx in 2011 and 2012 as well as update the price and yield information and adjusted prices for inflation to 2012 terms. Clark (2009) used a net present value analysis to study the profitability of conventional and organic production in Indiana by utilizing projected cash inflows and outflows for each production method. They found that organic production has a lower cost and the lower cost combined with high enough organic premiums made organic production more profitable than conventional.

Delate et al. (2009) reported economic findings from the long-term agroecological research (LTAR) site in Iowa which compared organic and conventional systems. Chavas et al. (2009) used data from the Wisconsin Integrated Cropping Systems Trial (WICST) to report risk analysis on organic and conventional systems. They used an econometric model to find the effect of government programs and organic price premiums and how risk affected net returns. Posner et al. (2008) also used data from the WICST to report on the productivity of organic versus conventional and found that on average, organic corn yielded 90% of conventional yield. These studies looked at the profitability of organic versus conventional production however, minimal research has touched on the transition to organic.

The use of linear programming (LP) to evaluate the profitability and viability of different farming operations has been used numerous times. Griffin and Lowenberg-DeBoer (2017) used an LP model to evaluate integration of mechanical weed control with banded herbicide application to control herbicide resistant weeds. They modeled a base farm off a representative equipment set in the Corn Belt of the United States. They found that automated guidance technology, mechanical weed control, and banded herbicide application could be an alternative to broadcast herbicide applications when the cost of the herbicide reaches a high enough level. In addition, Rosburg (2017) formulated an LP model to determine the timeliness of field operations from adding additional acreage to an existing farm. They found that given the parameters of the LP model, the farm was capable of acquiring additional acreage and still remain timely in their operations. Rosburg and Griffin (2018) explained how to parameterize an LP model for Extension purposes. Wright et al. (2018) used the LP model to evaluate how federal policy impacts farm level production in the Lower Mississippi River Basin. Their results indicate that certain combinations of crop prices and costs would make it profitable to produce corn in the Southern Mississippi River Basin. Linear programming is a useful tool to analyze whole-farm impacts of decision making.

Machinery investment decisions have been analyzed for farm management decisions. Reid et al. (1987) used net present value (NPV) and a multiperiod mixed integer programming (MMIP) model to determine optimal replacement of machinery. They analyzed multiple production systems in multiple scenarios to determine optimal production and investment decisions. Their study reported that optimal production and investment choices depend on anticipated profitability and machine age at the time of decisions. Cross et al. (1995) estimated the market value models for different farm machinery to provide better economic depreciation functions. They found that for different types of farm machinery, depreciation patterns were very different. Johnson et al. (1985) used a multivariate analysis to study the factors that affect machinery purchase and investment decisions and how machinery dealers and extension agents understand the producer’s machinery management decisions. They used a survey to see how farmers rank certain criteria when purchasing new machinery. They also asked machinery dealers and Extension agents to rank the same criteria based on how they thought the farmers ranked them. They found that few individual factors were significant however when taken together, are influenced by the circumstances surrounding the decisions. Farm type and farm size strongly influence machinery decisions and variables relating to soil zone, value of machinery inventory, operators age, and education differed depending on the level of the variable. Finally, they concluded that machinery dealers and extension agents rated criteria differently than farmers which indicates they don't understand farmers' machinery management decision. Gustafen et al. (1988) used a simulation analysis to determine optimal purchase/investment of machinery. In the simulation analysis they found that the highest-ranking factors were availability of cash, machinery prices, farm income prospects, and the present condition of their machinery complement while the least important were off-farm income, new machinery technology, tax reform, and changes in land values. They further used a fixed effects model to see the relative value of variables. These results indicated that variables related to tenure position, leverage, and machinery age were most significant. Coward (1964) analyzed custom work versus machinery purchase decisions in Illinois. He used a break-even analysis to determine optimal acreage for owning a given set of machinery. He found that many producers were below that optimal acreage and should instead be custom hiring specific field operations. He concluded that reasons for this could be attributed to one of five things: the opportunity cost of labor at harvest time, alternative possible uses of the necessary capital that may yield a higher return, timeliness, lack of skill on the farm for operating the machine, or personal prestige of machine ownership. Machinery management decisions are integral to farm success and these decisions become even more important when considering the transition to organic production.

As the organic industry continues to grow, the need for organic research increased. Total value of U.S. organic products sold in 2016 equaled $7.553 billion, up from $3.53 billion sold in 2011, a 114% increase. The number of certified acres increased 37% from 3,648,896 acres in 2011 to 5,019,496 acres in 2016, of which 2,409,869 were in cropland. (USDA, Organic Survey, 2016). Lee et al. (2015) investigated how consumers perceive organic food attributes. Hughner et al. (2007) collected various reports surrounding consumer behavior including who purchased organic and reported the reasons why consumers do or do not purchase organic. They found that the main reasons consumers purchase organic is the perceived health benefits from eating these products and the “quality” (taste) of organic is better while the driving factors behind not purchasing organic is high organic premiums and distrust of organic labeling. Lusk et al. (2017), studied consumer preference decisions regarding organic milk and apples. They found that even given similar prices in conventional and organic products, not everyone chooses to purchase organic. However, in-depth and extensive study of consumer behavior and the characteristics of the organic industry could be beneficial. This study builds upon previous literature to analyze the effects of transitioning to organic production on a farm in west central Illinois.

3.3 Models and Methods

In order to calculate the breakeven organic premiums needed, net present value (NPV) calculations were used. The NPV is defined as “…the sum of the present values for each year’s net cash flow (or net cash revenue) minus the initial cost of the investment” (Kay et al., 2004). The general form for NPV is demonstrated in Equation 12.

$$NPV = \frac{P_1}{(1+i)^1} + \frac{P_2}{(1+i)^2} + \cdots + \frac{P_n}{(1+i)^n} - C \qquad 12$$

Where P_n is net cash flow in yea n, i is the discount rate, and C is the initial cost of the investment (Kay et al., 2004).

Data from a west central Illinois conventional farming operation were used as the base farm. Conventional yields were based on historical yields from the base farm and costs and a price of $3.59 was used for corn based on a 17-year Illinois marketing average calculated from the USDA (USDA, 2017c). Conventional corn yield of 235 bushels per acre and total variable costs of $378 based off a 5-year average from the base farm. These costs are listed in Table 5.1. Research has suggested that after 3 to 5 years of organic production, yields of organic crops may be approximately 90% of conventional production (Posner et al. 2008). Therefore, for the purpose of this study organic yield was set at 211 bushels per acre (90% of 235 bushels). Direct expenses for organic were gathered from The Farm Financial Management Database (FINBIN). Direct expenses were averaged over five years (2013-2017) for a four-state area that includes Illinois, Missouri, Nebraska, and Wisconsin.

The NPV was taken every 5 years for 35 years which represented the length of time a farmer would be producing organic (the average length of a farmland loan) for three different scenarios (best, average, and worst). The best-case scenario represented the highest level of profit a producer would receive if they switched to organic (producing at 90% of conventional yields immediately). The worst-case scenario represented the lowest level of profit a producer would receive, meaning they experience a decrease in yield (producing at negative returns during transition years). The average case was one in which production broke-even (therefore, zero returns during the 3-year transition period). The NPV was taken for both the net return (which is price multiplied by yield) and the total variable costs, subtracted and summed over the years. The NPV analysis allowed the determination of what organic price was needed to breakeven between conventional and organic production. Equation 4 can be applied for this analysis and is demonstrated in Equations 13 and 14. The organic price is comprised of the conventional corn price and the organic premium. Figure 3.1 presents these determined organic premiums necessary to break even.

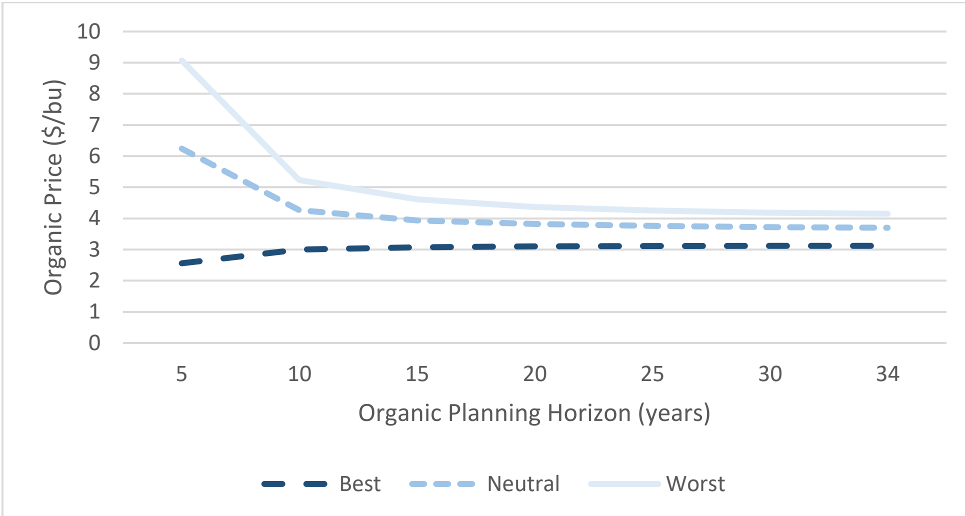

Figure 3.1 Breakeven Organic Premiums

$$\sum_{t=1}^{n} Conventional\ Return - \sum_{t=1}^{n} Organic\ Return = 0 \qquad 13$$

where n is the number of years in the planning horizon and conventional and organic returns are defined by Equation 14 below.

$$\sum_{t=1}^{n} \frac{Price*Yield}{(1+i)^t} - \sum_{t=1}^{n} \frac{TVC}{(1+i)^t} = 0 \qquad 14$$

where *i* is the discount rate, *t* is the time period, TVC are the total variable costs, and the remaining windows are as previously defined. The organic premiums necessary for the returns from organic production to be equivalent to conventional production over different planning horizons for each scenario (Figure 3.1). The longer the time horizon, the smaller the organic premium would need to be before conventional and organic returns to be equivalent for all cases except for the best-case scenario. As the time horizon lengthens for the best-case scenario, the organic premium needed actually increases. In the best-case scenario, organic production is more profitable from year 1 due to lower costs of production. This causes the inverted curve in Figure 3.1 because the organic profitability is being subdued. This indicates that given a high organic yield from year 1, the decreases in costs alone would make organic production more profitable. If a farmer only produces organic in a given field for 5 years (3-year transition with 2 years certified organic) the organic premium that would be needed in order to recoup any losses (due to yield penalties and other transition costs) incurred during those 3 transition years would need to be much higher than if the farmer produced organic for say, more than 10 years. At the end of 5 years the organic premiums needed for each scenario vary substantially, from $2.56 for the best-case scenario to $9.07 for the worst-case scenario. However, as the time horizon is extended out to 30 years, all scenarios, best, average, and worst, converge to within approximately $1.00 of each other, $3.12, $3.70, and $4.15 respectively.

A whole-farm analysis linear programming (LP) model was used to evaluate the potential profitability of systematically switching from a conventional row crop farm to an organic row crop farm. A LP model utilizes mathematics in order to optimize an objective function, often maximizing profit or minimizing costs. A LP model can provide a variety of useful information including but not limited to, best rotational practice, financial and investment decisions, and valuation of time and machinery. The purpose of utilizing an LP model for this analysis was to determine how organic premiums would affect the decision to transition to organic production and analyze the timeliness of labor and equipment. This analysis utilizes Purdue Crop/Livestock Linear Programming Model (PCLP) (Dobbins et al., 2001; Dobbins et al., 2006; Preckel et al., 1992) to maximize returns to a producer considering the transition from conventional to organic production. This analysis used a series of LP runs to evaluate various scenarios and the viability of switching to organic given different circumstances. Once the base farm had been properly parameterized, a series of LP iterations were run and analyzed.

The LP model can be written in standard summation notation as written in Boehlje and Eidman (1984, pp. 404-405) as:

$$\text{Max} \prod = \sum_{j=1}^{n} c_j X_j \qquad 15$$

subject to:

$$\sum_{j=1}^{n} a_{ij} X_j \leq b_j \text{ for } i = 1 \ldots m \qquad 16$$

$$X_j \geq 0 \text{ for } j = 1 \ldots n \qquad 17$$

where:

X_j = the level of the j^th production process or activity,
c_j = the per unit return to the unpaid resources (b_i's) for the j^th activity,
a_{ij} = the amount of the i^th resource required per unit of the j^th activity, and
b_i = the amount of the i^th resource available.

The objective function (Equation 15) maximizes per unit net returns (c_j) from all activities (X_j). Equation 16 defines the constraints on how many units of each activity that can be in the optimal solution. The *j* activities include production of two crops, corn and soybean, grown in rotation. The *i* resources include 1) land available for crop production, 2) available labor expressed as a combination of number of people, number of hours per day, and number of days suitable for fieldwork per period, and 3) the availability of machinery based on number of machines of each type, number of hours per day that the machine is available, and working rates expressed as acres per hour for each crop production task. The remaining variables *a* and *b* are the production process or activity resource requirements, and resource availability constraints, respectively. In all, there were nearly 1,000 constraints. The production season was segmented into 20 time period constraints; the most active planting and harvesting times were in one week increments and longer periods otherwise. Labor constraints were divided into unpaid and hourly wage earners. Equation 17 prevents negative production (Griffin and Lownberg-DeBoer, 2017).

Once the LP was parameterized and results gathered, a model was built to analyze machinery management decisions. In order to analyze decisions pertaining to machinery management a number of calculations were needed. Theoretical field time is the time that a machine is operating in the field at optimal speeds and width capacity. Field efficiency is the ratio between theoretical field time and time spent in the field but not conducting the intended task (refueling, loading or unloading, repairs, etc.). Working rate, also known as effective field capacity, is the number of acres a machinery implement can cover in an hour (Equation 18).

$$Working\ Rate = \frac{speed * width * feld\ efficiency}{8.25} \tag{18}$$

where speed is in miles per hour, width is in feet, and 8.25 is a constant (Hunt, 2001).

Machinery costs are allocated into one of two different categories: fixed costs and variable costs. Variable costs are incurred proportionally with the use of the machinery and include costs such as fuel and labor. Fixed costs are costs that are incurred separate from machine utilization such as taxes and insurance. Knowing and understanding the cost of machinery is an important aspect of the management role. Costs that need to be factored include but are not limited to depreciation, renting/leasing, machine life, and variable costs associated with the use of the implement. The annual cost of an implement is the sum of the fixed and variable costs (Equation 19).

$$Annual\ Cost = \frac{(FC\%)P}{100} + \frac{cA}{Swe}[(R\&M)P + L + O + F + T] \quad (19)$$

Where FC% = annual fixed cost of percentage
P = purchase price of machine
c = constant (8.25)
A = annual area use (acres)
S = forward speed, (mph)
w = effective width of action of machine (ft)
e = field efficiency (decimal)
R&M = repair and maintenance costs (percentage of purchase price)
L = labor cost ($/hr)
O = oil cost ($/hr)
F = fuel cost ($/hr)
T = cost of tractor use by machine ($/hr) (Hunt, 2001)

To analyze costs on a per acre basis, the equation presented is divided by the total number of acres. Per acre machinery costs are compared to a custom hire rate (per acre) to determine if it is more economical to purchase a given implement or custom hire that field operation. Analyses allow producers to determine optimal machinery inventory to maximize farm profitability.

3.4 Base Farm for Linear Program

The base farm was parameterized for corn and soybeans produced in rotation in west central Illinois. The 3,000-acre farm has four full time employees working 14 hours per day. All grain produced is stored and dried on farm. Weather constraints were estimated using days suitable for fieldwork (DSFW) (USDA NASS) for Illinois at the 20^{th} and the 40^{th} percentile best years in the spring and the fall, respectively, as suggested by Dobbins et al. (2010). Expected long run prices for each crop were determined with local cash prices. Machinery resources including size, labor hours, and working rate are presented in Table A.1, this machinery are supplemented by three tractors, two of which are considered “large” and one is considered “small”.

Implement utilization depended on crop rotation and soil texture, but in general followed the sequence: chisel, field cultivate, plant, pre-emerge spray, and post-emerge spray. All conventional acres are fall chiseled and spring field cultivated with the addition of a vertical tillage tool used in the fall for conventional corn. Organic corn is field cultivated in the spring and then a rotary hoe is pulled through 3 to 5 weeks after planting to control any emerging weeds. All yields, costs, and yield penalties were determined given historical data from the farm’s records.

Table 3.1 gives a description of field operations for all crops represented in the model. The list of machinery available is on the left, the different crops are along the top, and the values represent the time period that the respective field operations take place. For example, conventional corn is chisel plowed between the 18^{th} and 19^{th} time periods associated with the model. A description of time periods can be found in Table A.2.

Table 3.1 Description of Field Operations Timing (Week of Year)

	Conventional Corn		Conventional Seed Corn		Conventional Soybeans		Organic Corn	
	Beginning Time Period	Ending Time Period	Beginning Time Period	Ending Time Period	Beginning Time Period	Ending Time Period	Beginning Time Period	Ending Time Period
Dry Fertilizer Applicator	-	-	-	-	-	-	1	2
Chisel Plow	18	19	16	17	19	20	-	-
Anhydrous	19	20	19	20	-	-	-	-
Disc	17	18	-	-	-	-	-	-
Field Cultivator	1	4	2	5	3	5	2	3
Sprayer	1	7	-	-	3	9	-	-
Rotary Hoe	-	-	-	-	-	-	6	11
Vertical Tillage	17	18	17	18	-	-	-	-

Three different LP scenarios were run, collected, and analyzed after the base farm had been properly parameterized. Research indicated that long-term (3 to 5 years) organic yields can match up to 90-95% of conventional yields (Posner et al. 2008)). Therefore, Scenario 1 was a best-case scenario in which the producer had 90% of conventional yield in all three years of transition and the first year organic. The price in the three transition years was the same as conventional prices and then the first-year organic was assigned an organic premium. Scenario 2 was considered “average” such that profits were not realized but would use the crop produced for something other than sale, i.e. livestock feed. Scenario 3 was a worst-case scenario such that virtually no revenue was realized from the three-year transition period and the producer operated at a net loss.

3.5 Data

Before machinery implications from transitioning from conventional to organic production could be analyzed, a base machinery set was needed. Machinery used for conventional production was based off a primarily corn-soybean farm in West Central Illinois (Table A.4)[5]. Before a machinery set suitable for organic production could be determined, a typical organic crop rotation for the corn belt was needed. Iowa State University's Long-Term Agroecological Research (LTAR) site at Neely-Kinyon was established in 1998 to study organic production. This study chose the best yielding rotation in 2016 from LTAR, a corn-soybean-oat/alfalfa-alfalfa rotation, to base the machinery set for organic production (Delate et al. 2016). Once an organic crop rotation was established, a machinery set needed to be defined. Iowa State University's organic enterprise budgeting tool has organic machinery suggestions for each of the four organic crops (corn, soybeans, oats, and alfalfa) (Chase, 2016). Once machinery sets for both conventional and organic production were determined, purchase prices, implement widths, and horsepower requirements were collected. List prices were collected from John Deere's website along with implement widths and horsepower requirements (Deere and Company, 2018). The purchase price of machinery was assumed to be 85% of the list price.

The life of a machine can be separated into three different categories: physical life, accounting life, and economic life. Physical life is associated with necessary parts that are either discontinued or irreplaceable. Accounting life is associated with the expected hours of use before machine depletion. The economic life is associated with the depreciation of the machine and when it becomes more profitable to purchase a new machine as opposed to continuing to repair

[5] Due to lack of data for certain machinery implements, not all of the required machinery for organic production were included in this analysis.

the original machine (Hunt, 2001). This analysis focuses on the accounting life of the machine. The salvage value is how much the machine is worth at the end of its useful life. The expected lifetime repair and maintenance costs are expressed as a percentage of purchase price. Mississippi State Budget Generator (MSBG) is a computer program that allows for ease of calculation of costs for producers. Included in the program is data on machinery implements including useful life, salvage values and repair and maintenance percentages. These values were used in this analysis (Laughlin, 2003).

Field efficiencies needed to be determined for each implement. Iowa State University Extension and Outreach has a decision tool for estimating field efficiencies along with average implement travel speeds. These estimations are based off the American Society of Agricultural and Biological Engineering (ASABE) standards and were used in the calculation of working rates for this analysis (Hanna, 2016). Lastly, Iowa State Universities custom rate survey was used to compare total cost per acre of purchasing a machine to the custom hire rate to determine optimal acreage to purchase machinery (Plastina, 2018).

3.6 Results and Discussion

The base case resulted in a profit from operations of $1,113,344. Profit from operations decreased in each best, average, and worse cases by $69,297.04, $88,119.76, and $88,119.84 respectively. Table 3.2 presents the acres of each crop produced in each scenario. The best-case scenario resulted in organic production of 727.4 acres while both the worst case and average case resulted in 0 acres of organic production. The average and worst cases resulted in the same crop mix and the same profit from operations.

Table 3.2 Acre and Profit Results of LP Model

	Acres Produced of each Crop				Profit From Operations
Scenario	Conventional Corn	Conventional Seed Corn	Conventional Soybeans	Organic Corn	
Best	186.2	1136.2	836.2	727.4	$1,044,046.96
Average	1286	950	650	0	$1,025,224.24
Worst	1286	950	650	0	$1,025,224.16

Organic corn price premiums needed to make organic production as profitable as conventional given a 10-year time horizon are presented in Table 3.3. A 10-year time horizon was selected based on Figure 3.1. A 5-year time horizon would not allow enough time to recoup losses (due to yield loss) while a time horizon of 20+ years would result in organic premiums nearing $0. A 10-year planning horizon allowed for enough time to begin to see profit from organic production while still seeing substantial organic premiums.

Table 3.3 Breakeven Organic Corn Premium

Scenario	Premium
Best	$3.00
Average	$4.26
Worst	$5.23

To remain timely and efficient, it is important machinery are not under or over utilized. The limiting resource in all three of the LP scenarios were small tractors and the planter. Small tractors were especially limiting in the best-case scenario due to the production of organic acres and the addition of the rotary hoe for the land preparations for organic acres. A shadow value, or marginal value, is defined as the amount of money one would pay for an additional unit of a resource. Table 3.4 presents the shadow values of the limiting resources. In this case, the shadow value of a piece of machinery would be the amount of money a producer would be willing to pay for an additional hour of use for the respective machinery. Therefore, the producer would be willing to pay $8,379.47 for an extra hour in a small tractor from April 26 to May 2.

Table 3.4 Shadow Values for Machinery

	Small Tractors		**Planter**	
	Apr 22 – Apr 25	Apr 26 – May 2	Apr 22 – Apr 25	Apr 26 – May2
Best	$0	$8,379.47	$8,563.31	$0
Average	$4,442.55	$4,258.71	$0	$0
Worst	$4,442.56	$0	$0	$4,258.71

Results for machinery implications of transition to organic production can be loosely interpreted as the minimum number of acres to justify purchased use of an implement and can be separated into two categories: organic and conventional. Organic results can be interpreted as the minimum number of acres that would be needed to justify purchasing an implement as opposed to custom hiring the operation. The conventional results can be interpreted as the maximum number of acres to transition out of conventional (and into organic) to justify continue use of a given implement. Table 3.5 lists the acreage level needed to purchase each of the implements analyzed. Therefore, with a breakeven acreage of the conventional implement, chisel plow, of 80 acres, it is possible to transition 2,920 acres out of conventional production and into organic production before it becomes more economical to custom hire the operation.

Table 3.5 Acreage Needed to Purchase Implements

	Acreage	
Implement	**Small Implement**	**Large Implement**
Moldboard Plow	2,560	1,280
Grain Drill	580	820
Mower	1,040	1,240
Rake	220	260
Chisel Plow	80	120
Anhydrous Applicator	2,600	2,800
Sprayer	4,740	9,300
Vertical Till	280	280
Baler	1,920	2,080
Harrow Disk	360	120

Results for the chisel plow at both the 8 feet and 16 feet sizes are illustrated in Figure 3.2. The initial costs of the implement are high; however, as acreage increases, the per acre cost of the implement drastically decreases. Casual observation of all Figures indicated the cost structure of all implements were similar.

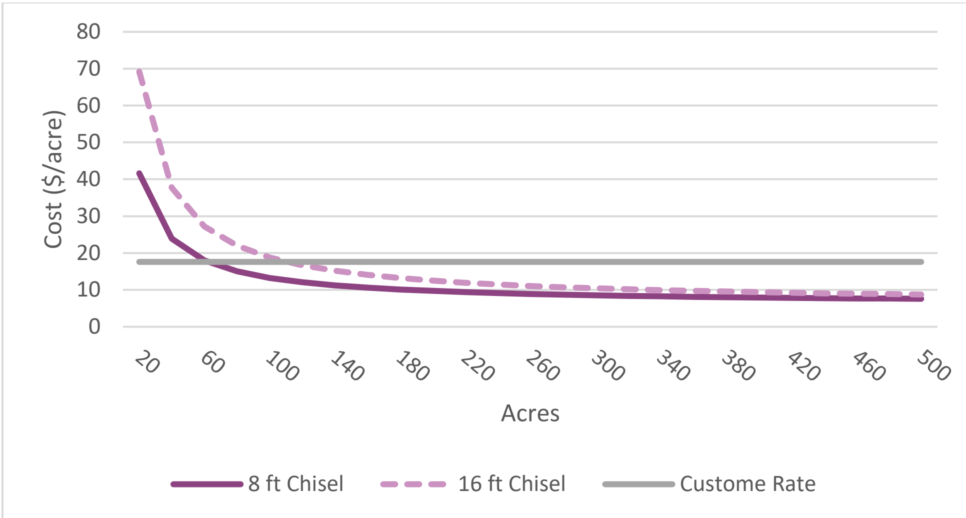

Figure 3.2 Breakeven Acreage for a Chisel Plow

In addition to breakeven acreage for each machinery implement, calculations were done to determine the cross over point, in percent acreage, between conventional and organic machinery; demonstrated in Figure 3.3. This indicates that at approximately 33% of acreage in organic production the per acre cost of machinery for both conventional and organic machinery is approximately the same.

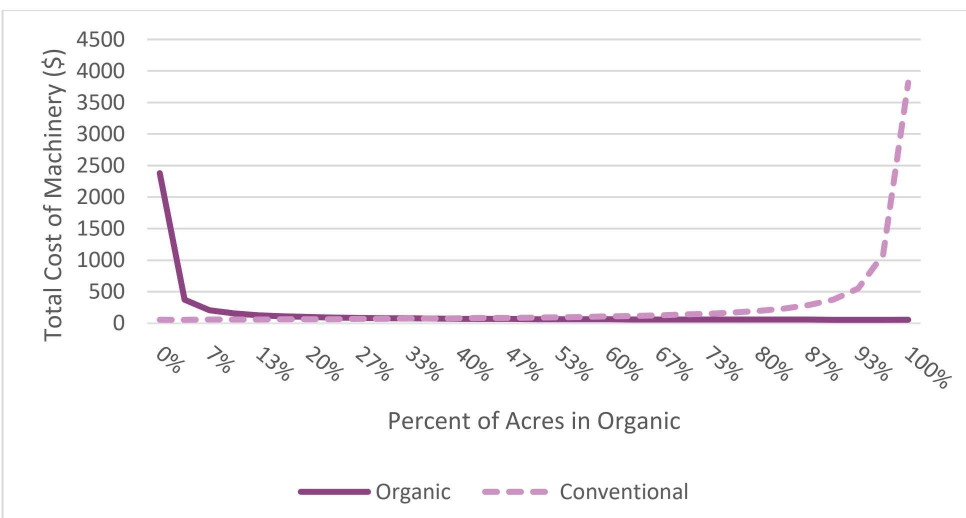

Figure 3.3 Total Machinery Breakeven Costs

It should be noted that while results indicated transitioning to organic production can be profitable under the best-case scenario, profits only increased from conventional production by approximately $19,000. The cost of transitioning to organic can be costly when record keeping, machinery, labor etc. costs are taken into account. An in-depth analysis of the costs of transitioning must be added to this analysis to ensure accurate depiction of the profitability of organic production. Additionally, organic market saturation is an important topic to consider. Current organic premiums exist due to high demand and limited supply. As more producers and acre's transition to organic production, the supply of organically produced goods rises, such that premiums associated with organic production may begin to decline. An analysis pertaining to the supply and demand of organic production could provide a broader perspective of the viability of producers transitioning to organic production.

3.7 Conclusions

Organic production can be a viable option for farmers desiring to increase profitability. The optimal decision depends on specific scenarios faced by the producer. Under the best-case scenario, producers could profitably transition to organic production. Higher organic premiums or higher yields would be necessary for the average and worst-case scenarios to be feasible options. Results indicated if farmers transitioned to organic production, machinery inventory would need to be modified to remain timely and efficient. Results suggested that only a few acres transitioned out of conventional into organic justified selling the anhydrous applicator (400 acres for small implement and 200 acres for the large implement). In addition, results indicate that despite having a sprayer in the machinery inventory, it is not currently profitable for the base farm to have a sprayer in their machinery inventory needing 4740 acres for the small sprayer and 9300 acres for the large sprayer.

This analysis has several limitations. The LP model only considered transitioning to organic corn. Certified organic guidelines state that a producer must have sustainable rotations in place, therefore planting continuous organic corn is not feasible. Future analyses could include additional organic crops to the rotation. The LP model considered simple land preparations for organic corn, e.g. only field cultivated and rotary hoe. An analysis elaborating upon land preparations for organic production could be more representative than the simplified sequence of field operations assumed by this study. The machinery analysis does not account for the timeliness aspect of field operations. Certain field operations are very time sensitive. Often with custom hire field operations, managing all field operations to be completed in a timely fashion may be difficult. Adding a penalty function for untimely field operations could improve this analysis. Lastly, this analysis only considered information from a single farm in west central Illinois. Results may differ in different regions for different crops.

The organic industry has continued to grow as some producers demand organically produced food. In addition, producers desire to become more profitable. These facets coupled with decreasing commodity prices and low NFI could entice farmers to transition at least some of their conventionally produced acreage to organic production to have less volatile farm income.

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Chapter 4 - Conclusion

This thesis analyzed different perspectives of whole farm profitability. The first essay examined factors that had direct impacts on net farm income. The second essay analyzed viability of an existing farm operation in Illinois transitioning a portion of acreage to organic production. The forecast for continued low net farm income and no expectation of an increase in commodity prices causes producers to have to be more efficient in their operations and decision making. In order for producers to survive the variable profitability of the agriculture industry they may look to improve profitability towards the top fifth of the producers to remain competitive. This research has indicated areas of management where producers could benefit spending their time and effort.

4.1 Analysis of Factors Affecting Net Farm Income

Results from the binomial logit model indicated that fertilizer cost per acre and debt to asset ratio were two factors that highly impacted farm profitability. Fertilizer cost indicated that those who spent more on fertilizer had higher profitability. This could indicate that those who have better soil health and quality are more profitable. Knowing areas to focus management efforts helps producers in spending their time and money where it will be of the most benefit. This research indicated that focusing on debt and soil quality management could benefit producers by increasing profitability.

Limitations of this research include being localized to one area and data availability. This research focuses on the eastern portion of Kansas. Expanding the area to include different areas of the Mid-West could improve the result so that producers in a larger portion of the United States could benefit. Results indicated that soil quality and health could be a potential area for more in-depth management to improve profitability. By analyzing specific soil quality variables, producers could benefit by knowing which areas of soil quality and health are most beneficial to focus on.

4.2 Transition from Conventional to Organic Production

This research analyzed the viability of a producer in Central Illinois transitioning part of their operation from conventional to organic production. Continued low NFI has caused distress in the agriculture industry on how to remain a viable operation. This research indicates that transitioning part of an operation to organic production could be a way to remain profitable. This research found that if faced with continued high yields (no “drop” in yields during the transition years), a producer could become more profitable after only a couple years of producing organically. If faced with an average or worst-case scenario, it could take a longer period of time for profitability of organic production to match that of conventional production.

Appendix – Figures and Tables

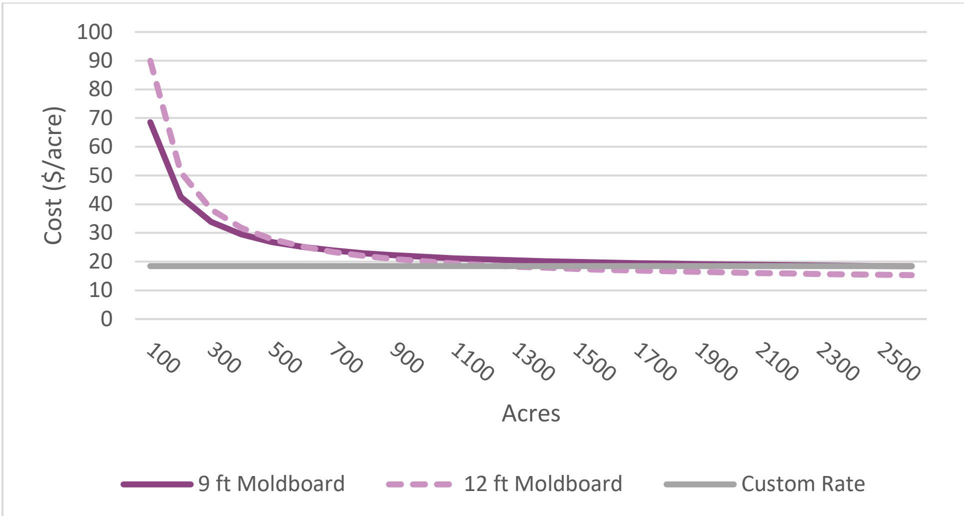

Figure A.1 Minimum Acreage to Purchase a Moldboard Plow

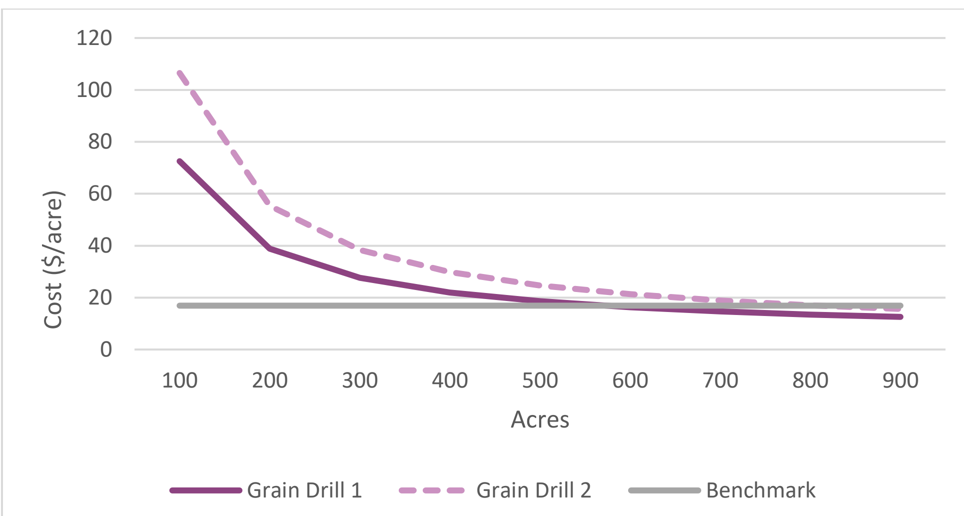

Figure A.2 Minimum Acreage to Purchase a Grain Drill

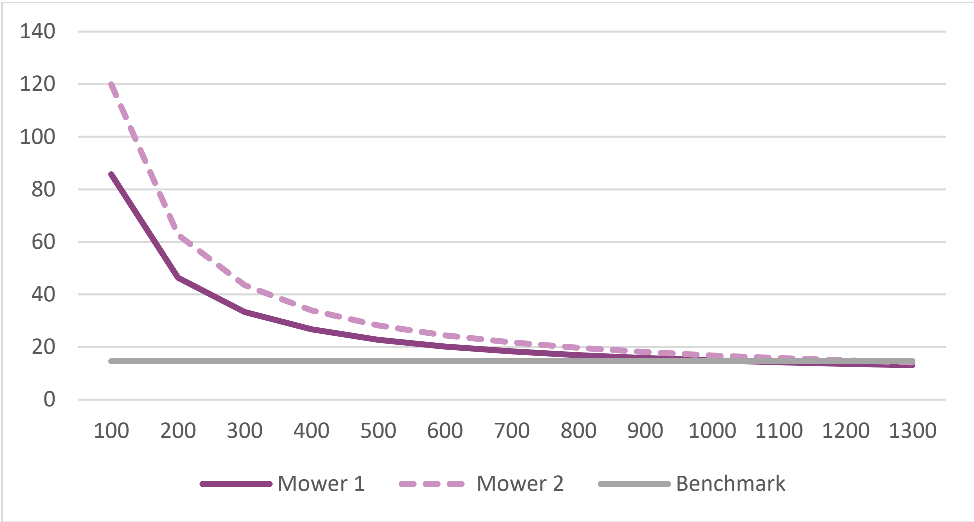

Figure A.3 Minimum Acreage to Purchase a Mower-Conditioner

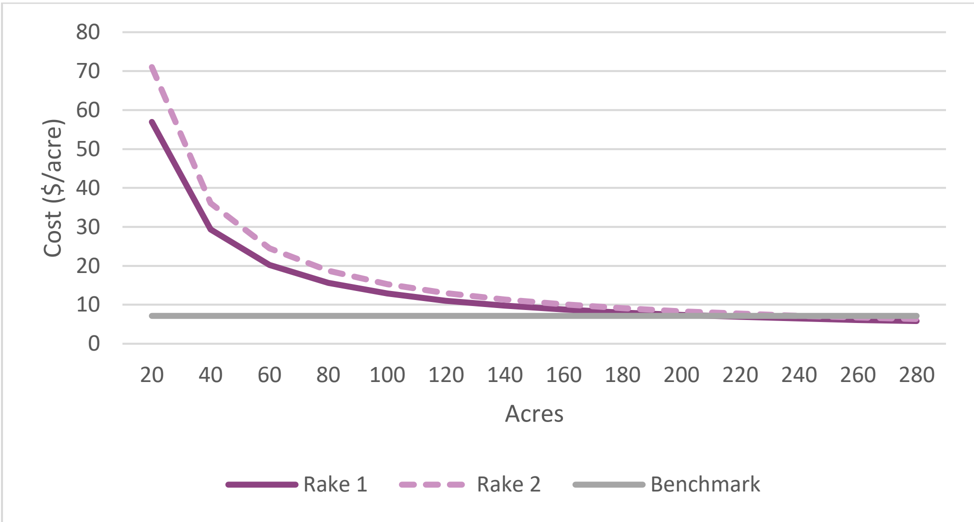

Figure A.4 Minimum Acreage to Purchase a Rake

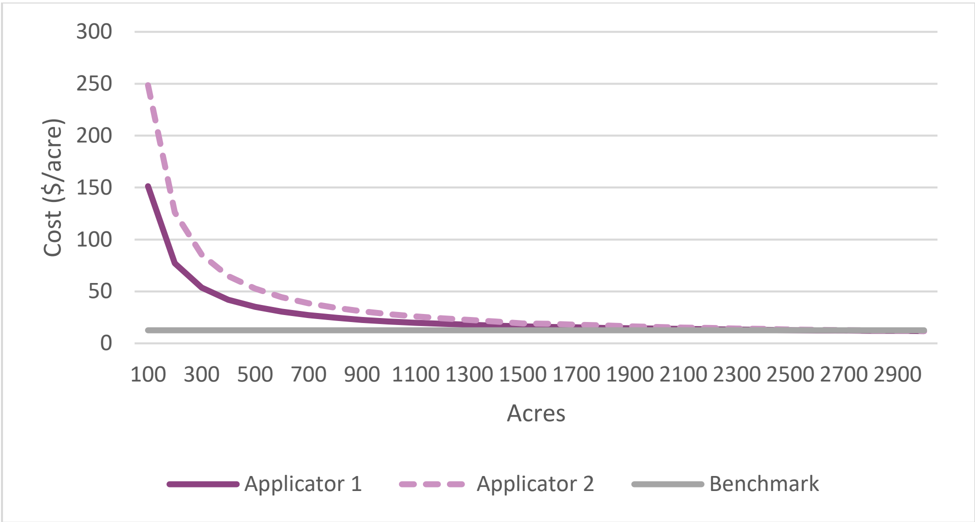

Figure A.5 Minimum Acreage to Sell an Anhydrous Applicator

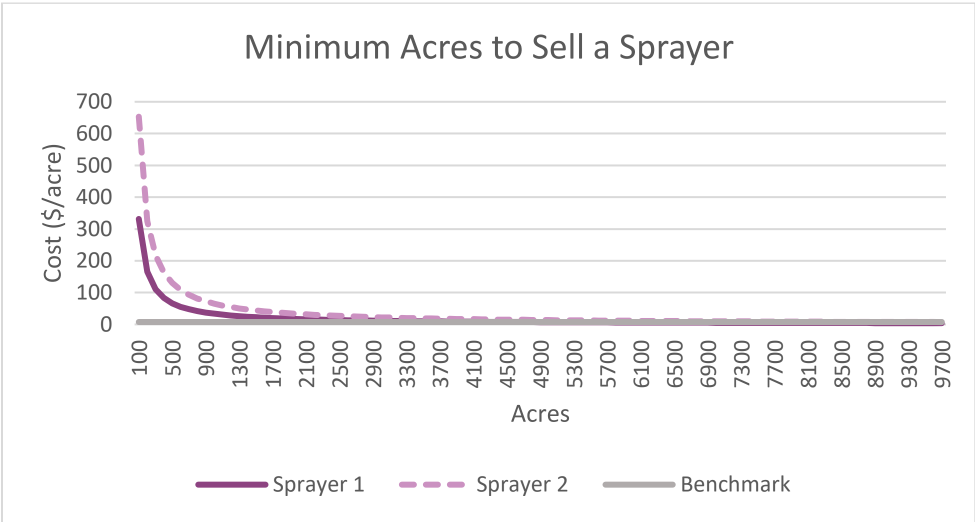

Figure A.6 Minimum Acreage to Sell a Sprayer

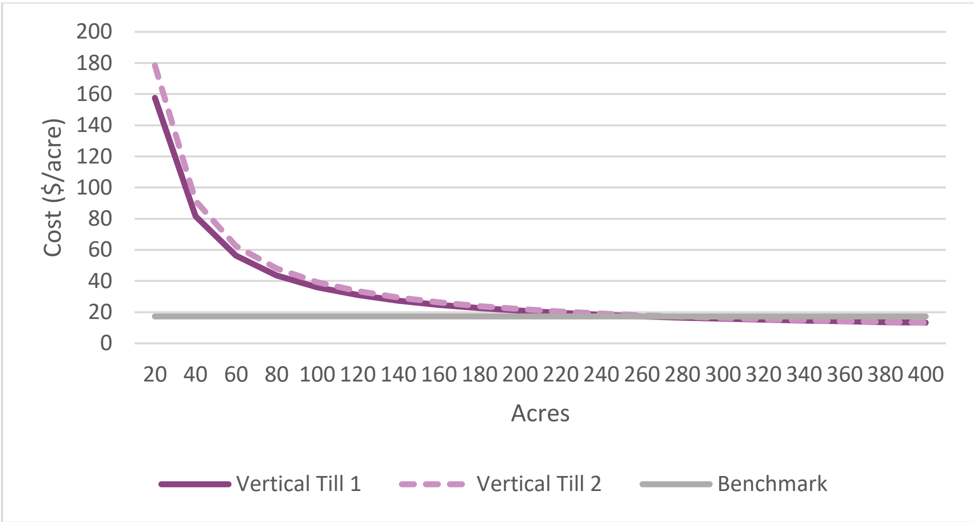

Figure A.7 Minimum Acres to Sell Vertical Tillage Implement

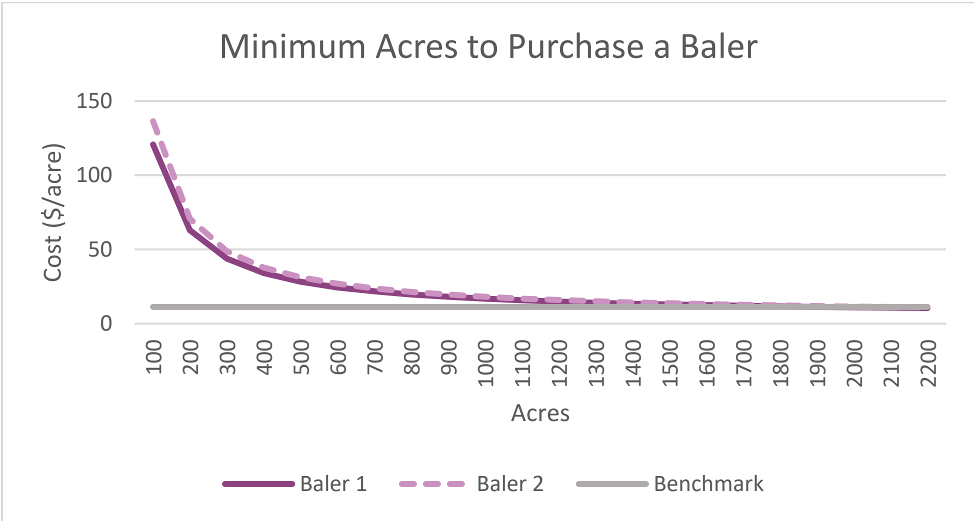

Figure A.8 Minimum Acreage to Purchase a Baler

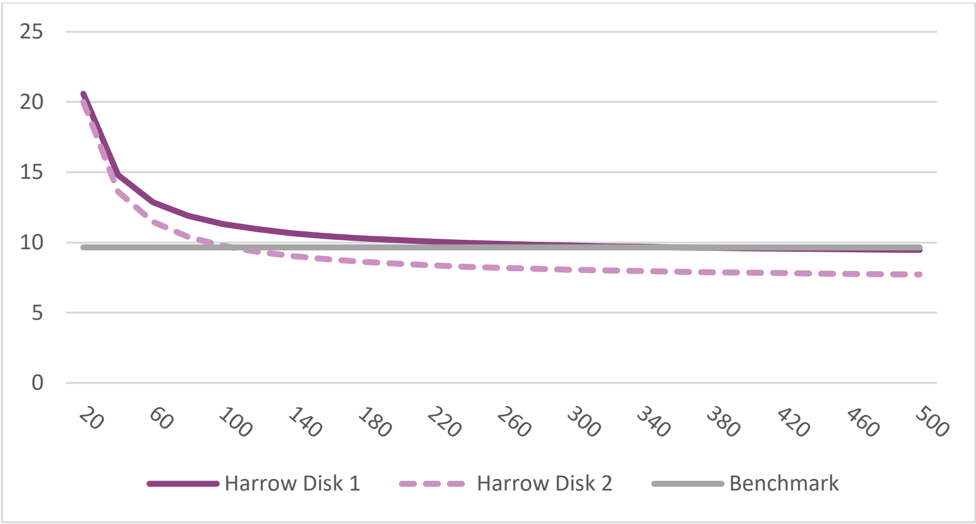

Figure A.9 Minimum Acreage to Purchase a Harrow Disk

Table A.1 Catalog of Machinery Implements

Machine	Width/Row	Number of Machines	Labor Hours per Machine Hour	Working Rate (acres/hour)
Dry Fertilizer Applicator*		1	1	66
Rotary Hoe	30”	1	1	30.2
Chisel	17’	1	1	10
Chisel	15’	1	1	10
Anhydrous Applicator	30”	1	1.5	20
Disc	40’	1	1	20
Field Cultivator	60’	1	1	40
Sprayer	80’	1	2	110
Vertical Tillage Tool	40’	1	1	10
Planter (corn)	30”/16 row	1	1.8	20.5
Planter (soybeans)	30”/16 row	1	1.8	25
Harvester (corn)	8 row	1	1.9	10.5
Harvester (soybeans)	30’	1	1.9	13.7

Table A.2 Description of Time Periods (Dobbins et al. 2006)

Time Period	Associated Weeks
1	Dec. 6 – Apr. 21
2	Apr. 22 – Apr. 25
3	Apr. 26 – May 2
4	May 3 – May 9
5	May 10 – May 16
6	May 17 – May 23
7	May 24 – May 30
8	May 31 – Jun. 6
9	Jun. 7 – Jun. 13
10	Jun. 14 – Jun. 20
11	Jun. 21 – Jun. 27
12	Jun. 28 – Jul. 4
13	Jul. 5 – Jul. 11
14	Jul. 12 – Aug. 29
15	Aug. 30 – Sep. 19
16	Sep. 20 – Sep. 26
17	Sep. 27 – Oct. 10
18	Oct. 11 – Oct. 31
19	Nov. 1 – Nov. 14
20	Nov. 15 – Dec. 5

Table 0.3 List of Machinery Sets

Conventional Machinery	Organic Machinery
Chisel Plow (x2)	Field Cultivator
Anhydrous Applicator	Harrow Disk
Tandem Disk	Grain Drill
Field Cultivator	Cultipack
Sprayer	Mower
Vertical Tillage Tool	Rake
Planter (corn)	Baler
Planter (soybeans)	Liquid Manure Spreader
Harvester (corn)	Moldboard Plow
Harvester (soybeans)	Planter (corn)
	Planter (soybeans)
	Tandem Disk
	Rotary How
	Harvester (corn)
	Harvester (soybeans/oats)

Table A.4 Breakdown of Conventional Costs

Category	Cost
Seed	$130
Soil Fertility	$138
Pesticides	$40
Machinery Repairs	$22
Fuel & Oil	$34
Machine Hire and Lease	$5
Other Power and Equipment Cost	$28
Drying	$9
Storage	$0
Paid Labor	$69
Insurance	$19
Total	$494

Table A.5 Breakdown of Organic Costs

Category	Cost
Seed	$77.52
Fertilizer	$83.90
Cover Crop	$0.72
Insurance	$22.31
Drying	$7.69
Storage	$0.89
Fuel & Oil	$33.06
Machinery Repairs	$44.76
Machinery Hire and Lease	$33.22
Paid Labor	$4.17
Utilities	$3.00
Hauling & Trucking	$3.82
Marketing	$0.08
Organic Certification	$3.78
Interest	$6.31
Other	$6.28
Total	$331.51