A LONG-TERM ECONOMIC COMPARISON BETWEEN ORGANIC AND CONVENTIONAL CROP ROTATIONS

by

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To my family and all the friends whose unwavering support made this possible.

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ABSTRACT

The results of previous studies generally show that organic production is more profitable than conventional production. However, as a source of these results, the trials are either of short duration or do not specifically examine the benefits during the transition period, suggesting that previous work may not have captured the full variability of crop net returns. The purpose of this study was to compare the net returns and risks of conventional, transition, and organic cropping systems using long-term crop budgets and stochastic simulations. Conventional crop rotations were represented by a corn / soybean rotation and a corn / soybean / wheat rotation. The organic crop rotation produced corn, soybean and wheat. Historical prices, crop budgets, and FINBIN data are used to develop the long-term crop budgets. The organic crop rotation included a three-year transition period. Ten-year enterprise budgets were created for each crop and rotation so that we could compare the net returns of the transition year of organic crop rotation and the year of organic production. This thesis summarizes the enterprise budget information for each crop in the conventional and organic cropping systems, and summarizes the information used for the simulation analysis. Using @ risk, differences in annual net returns to land between crop rotations were summarized. Results are as follows. First, the transition and organic cropping system was found to have higher net returns to land than the two conventional crop rotations under most of the simulation iterations. Second, the annual net returns during the transition period were relatively low. Third, the highest average annual net return was for organic corn.

1. INTRODUCTION

Organic production in the United States has grown rapidly since the 1990s (Peterson et al., 2012). Mercaris' 2017 Acreage Report estimates that there were 17,188 organic operations, certified by the National Organic Program, which is housed within the USDA Agricultural Marketing Service. More recently, the 2018 report found an increase of 460 certified operations, representing a 3% increase. Results from Statista (2018a) indicate that the total certified organic land in the U.S. shows an increasing trend from 2014 to 2016 and amounted to 5.02 million acres. Certified organic field crops harvested amounted to approximately 1.68 million acres in 2016. Currently, organic production occurs in all 50 U.S. states (Dangour et al. 2009). The number of certified organic corn operations reached 5,566 as of August 2018, up 4% from 2017. Similarly, the number of certified organic operations that produced soybeans (2,545) and wheat (1,949) increased nearly 7% and 4%, respectively, from 2017 to August 2018 ("Organic and Non-GMO Commodity Market Data and Trading"; Mercaris, 2017). In total, organic crop sales reached $26.5 million in 2017, which represents a 6.4% increase from the previous year.

Continued interest in organic production is the result of tremendous growth in organic food sales and lower net returns for conventional crop production in the last few years. Annual growth in U.S. organic food sales was over 15 percent or more prior to the downturn in the U.S. economy in 2008, and has generally exceeded 10 percent. U.S. organic food sales approached an estimated $35 billion in 2014 (Greene et al., 2016) and amounted to approximately $45.2 billion U.S. dollars in 2017 ("Organic Food Sales in the U.S. 2017"; Statista, 2018b). Organic corn and soybean operations are often more profitable than conventional operations, despite higher economic costs and lower yields, because organic prices tend to be much higher than conventional prices (McBride and Greene 2015; Greene et al., 2016). In fact, price premiums for organic corn and soybeans are often more than double, and sometimes triple, conventional prices (Greene et al., 2016).

To meet organic crop production standards, land must have no prohibited substances applied to it for at least three years before the harvest of an organic crop. Prohibited substances would include GMO seed, and most synthetic fertilizer, herbicides, and insecticides. The use of genetic engineering, ionizing radiation and sewage sludge is prohibited; and soil fertility and crop nutrients need to be managed through tillage and cultivation practices, crop rotations, and cover crops, however, crops can be supplemented with animal and crop waste materials and allowed synthetic materials.

There are several factors for producers to consider when they are examining the transition from conventional to organic production. Peterson et al. (2012) indicated that this transition may be related to profitability, environmental stewardship, an organic lifestyle, or a combination of these three motivations. Crop producers that are considering transferring acreage to organic production need to examine each of these factors. The variability of net returns to farm operations that result from fluctuating yields, costs, and prices is also an important factor when examining organic crop production. In particular, net returns may be relatively low during the three-year transition period.

Results from previous studies almost universally show that organic production is economically competitive with conventional methods. However, the data on which these results are based are often from trials that are either short in duration or that did not specifically examine returns during the transition period, thereby potentially failing to capture the full variability in crop yields and net returns.

1.1. Objective

The objective of this study is to compare the net returns and risk of conventional, and transition and organic cropping systems using long-term crop budgets and a stochastic simulation. The organic production systems examined include the three-year transition period to fully account for the net returns during this period.

1.2. Hypotheses

The following hypotheses will be examined in this thesis. First, the transition and organic cropping system is expected to have higher average net returns than conventional cropping systems over a ten-year planning horizon. Second, annual net returns for the transition and organic cropping system is expected to be relatively lower during the transition phase and relatively higher during the organic phase. Third, the highest annual average net return is expected to be associated with organic corn.

1.3. Definitions

1.3.1. Cropping System

The term cropping system refers to the crops, crop sequences, and management techniques used on a particular agricultural field over a period of years. It includes all spatial and temporal aspects of managing an agricultural system. Historically, cropping systems have been designed to maximize net returns, but modern agriculture is increasingly concerned with promoting environmental sustainability in cropping systems.

1.3.2. Conventional Cropping

Conventional farming, also known as industrial agriculture, refers to farming systems which include the use of synthetic chemical fertilizers, pesticides, herbicides and other continual inputs, such as genetically modified organisms.

1.3.3. Organic Cropping

Land used will have no prohibited substances applied to it for at least three years before the harvest of an organic crop. Use of genetic engineering, ionizing radiation and sewage sludge is prohibited; and soil fertility and crop nutrients have to be managed through tillage and cultivation practices, crop rotations, and cover crops. Crops can be supplemented with animal and crop waste materials and allowed synthetic materials.

1.3.4. Transition Period

Any land used to produce raw organic commodities must not have had prohibited substances applied to it for the past three years. Until this transition period is met, you may not sell, label, or represent the product as “organic" or use the USDA organic or certifying agent's seal. There are two aspects to conversion, one is grower skills and experience to farm using an organic cropping system, and the second is transition of the land.

1.3.5. Net Returns

For cropping systems examined in this study, net returns represent the difference between gross revenue, which includes crop revenue, government payments, and crop insurance indemnity payments, minus all cash and opportunity costs except for those associated with land.

2. LITERATURE REVIEW

This chapter will discuss differences in crop prices, crop yields, crop costs, and crop net returns between conventional and organic cropping systems. In addition, this chapter discusses the transition period needed for an organic cropping system.

2.1. Crop Prices

Organic grain farming entails production and marketing practices that are distinct from conventional grain farming and from organic fruit and vegetable farming (Peterson et al., 2012). For example, conventional farmers can store the entire harvest at a local grain elevator, whereas an organic crop must have its identity preserved throughout production and distribution channels. Frequently, organic grain sales are handled through individual contracts directly with the buyer or through a trader. In addition to default risk associated with individual contracts, organic grain farmers are exposed to the risk of the commodity not meeting organic certification as a result of genetically modified crop contamination or spray drift from neighboring conventional farms.

Clark (2009) noted the importance of organic price premiums in influencing the profitability of transitioning to organic production. On average, organic corn, soybean, and wheat premiums were about 142%, 107% and 47%, respectively. Using survey information, Brock et al. (2019) indicated that the average market price of corn sold by organic farm respondents was $9.49 per bushel and the average crop revenue for corn per acre was $1,266 (not all income was realized because most corn was fed to livestock on the same farm where corn was grown).

As indicated above, organic crops typically receive a premium compared to conventional crops. Crop price, crop yield, crop cost, and crop net return data are available from the University of Minnesota FINBIN database (2019). Using FINBIN data for the 2014 to 2018 period, the average price per bushel for corn was $3.40, approximately one third of the average price per bushel for organic corn. Similarly, the average values for soybean and winter wheat, $9.06 and $4.65, were also lower than the average prices for organic soybean and organic winter wheat which were $21.17 and $9.11, respectively. Average prices for conventional alfalfa production were $131 per ton during the five-year period compared to an average price of $160 per ton for organic alfalfa production. Average prices for organic oats ($6.02 per bushel) were more than double average prices for conventionally produced oats ($2.58 per bushel).

It is often useful to express price premiums in percentage terms when making comparisons between organic and conventional crop production. Using FINBIN averages for the 2014 to 2018 period, the smallest price premium was 22 percent for organic alfalfa, while the largest price premium was 176 percent for organic corn. The price premiums for oats, soybeans, and winter wheat were 133 percent, 134 percent, and 96 percent, respectively.

2.2. Crop Yields

Organic crop yields also affect relative net returns during and after the transition period. It is said that without commercial chemicals and fertilizers, organic production systems may encounter increased weed populations and reduced crop yields (Delate and Cambardella, 2004). Dabbert and Madden (1986) indicated that after the initial transition yield penalty, due to the accumulation of organic soil materials, the yield should be restored to the conventional yield level. However, yield penalties could last up to six years.

Experiments carried out at the Rodale Institute compared organic animal-based, organic legume-based, and conventional systems from 1981 to 2005. According to crop, soil, and weather conditions, the yield of organic managed crops per hectare can be equal to that of traditional agriculture (Pimentel et al., 2005). Except for the 1999 drought year, the crop yields for corn and soybeans were similar in the organic animal, organic legume, and conventional farming systems. In contrast, Smolik et al. (1995) found that corn yields in South Dakota were somewhat higher in the conventional system, with an average yield of 5708 kg per ha, compared with an average of 4767 kg per ha for the organic legume system. However, soybean yields in both systems were similar at 1814 kg per ha. In a second study comparing wheat and soybean yields, wheat yields were fairly similar, averaging 2600 kg per ha in the conventional system and 2822 kg per ha in the organic legume system. Soybean yields were 1949 kg per ha and 2016 kg per ha for the conventional and the organic legume systems, respectively (Smolik et al., 1995). In the Rodale experiments, corn, soybean, and wheat yields were considerably higher than those reported in South Dakota. These results might be expected, given the shorter growing season (146 days) and lower precipitation (460 mm) in South Dakota.

European field tests indicate that yields of organically grown wheat and other cereal grains average from 30 to 50 percent lower than conventional cereal grain production (Mäder et al., 2002). The lower yields for the organic system in these experiments, compared with the conventional system, appear to be caused by lower nitrogen-nutrient inputs in the organic system. In New Zealand, organic wheat yields were reported to average 38 percent lower than those in the conventional system, a finding similar to the results for a European study (Nguyen et al., 1995). In New Jersey, organically produced sweet corn yields were reported to be 7 percent lower than in a conventional system (Brumfield et al., 2000). In the Rodale experiments, nitrogen levels in the organic systems have improved and did not limit the crop yields except during the first 3 years. In the short-term, organic systems may create nitrogen shortages that reduce crop yields temporarily, but these can be eliminated by raising the soil nitrogen level through the use of animal manure or legume cropping systems, or both.

In field tests in South Dakota, corn yields in the conventional system and the organic alternative system were 7652 and 7276 kg per ha, respectively (Dobbs and Smolik, 1997). Soybean yields were significantly higher in the conventional system, averaging 2486 kg per ha, compared to an average yield of only 1919 kg per ha in the organic alternative system.

The Rodale crop yields were similar to those for conventional and organic legume farming system experiments conducted in Iowa (Delate, 2002). In the Iowa experiments, corn yields were 8655 and 8342 kg per ha for the conventional and organic legume systems, respectively. Soybean yields averaged 2890 kg per ha for the conventional farming system and 2957 kg per ha for the organic legume system.

A report published by USDA showed that average organic yield for each crop was significantly lower than for conventional crops (McBride and Greene, 2015). The average yield for organic corn was 118 bushels per acre in 2010, compared to 161 bushels for conventional corn. In 2009, organic wheat producers had average yields of 30 bushels per acre compared to 44 bushels per acre for conventional wheat producers. The average yield of organic soybean producers in 2006 was 31 bushels per acre, compared to 47 bushels for conventional soybean producers. This equates to an average yield loss of 27 percent for corn, 32 percent for wheat, and 34 percent for soybeans on commercial farms. The 2011 data showed that organic corn yields were 41 bushels per acre below conventional yields, organic wheat yields were 9 bushels per acre below conventional yields, and organic soybeans were 12 bushels per acre below conventional yields. The estimated organic/conventional yield differences based on USDA-ERS, ARMS data are slightly larger at 43 bushels, 14 bushels, and 16 bushels per acre for corn, soybeans, and wheat, respectively.

Brock et al. (2019) conducted a survey of organic corn growers in Ohio, Indiana, Michigan, and Pennsylvania. Respondents reported an average corn yield of 133.9 bushels per acre, which was 14.4 bushels per acre higher than the USDA's estimate of 119.5 bushels per acre in 2016.

Using FINBIN data, average corn yields for conventional and organic corn were 180.8 and 122.1 bushels per acre during the 2014 to 2018 period. Average yields for conventional soybeans and organic soybeans were 46.7 and 31.4 bushels per acre, respectively. Average winter wheat yields were 58.3 and 44.2 bushels per acre for conventional and organic winter wheat, respectively, and average oat yields were 73.8 and 57.0 bushels per acre, respectively, for conventional and organic oats. Average alfalfa yields for conventional and organic production during the 5-year period were 4.37 and 3.99 tons per acre, respectively. Using the FINBIN results above, yield drags for the five organic crops ranged from 8.7 percent for alfalfa to 32.8 percent for soybeans, and averaged 24.2 percent during the 2014 to 2018 period.

2.3. Crop Costs

Organic production often involves higher manure, machinery, and labor costs, and lower seed, fertilizer, herbicide, and insecticide costs. Organic producers also have costs associated with certification and annual audits. Hamm and Martin (2015) note that the cost of certification relative to the economic benefit is nominal.

Clark (2009) compared production costs for traditional corn and soybeans to that of organic corn and soybeans. Organic costs were found to be $27 per acre lower for corn and $14 per acre lower for soybeans.

FINBIN averages can be used to examine the difference in total expenses during the 2014 to 2018 period. For alfalfa, total expenses for organic production were $72 per acre or 18 percent higher than total expenses for conventional production. Total expenses for organic corn were $48 per acre or 7 percent higher than total expenses for conventional corn. It was particularly difficult to control total expenses for organic soybeans. Total expenses for organic soybeans were $158 per acre or 41 percent higher than total expenses for soybeans. In particular, machinery costs and labor costs were substantially higher for organic soybeans. It was also relatively difficult to control expenses for organic oats and winter wheat. Organic oats and wheat had total expenses that were $108 and $105 per acre higher than conventional oats and wheat. In percentage terms, total expenses for organic production were 49 percent higher for oats and 33 percent higher for winter wheat. Seed, land rent, and machinery costs were relatively high for organic oats and winter wheat compared to conventional oats and winter wheat.

2.4. Net Returns and Other Benefits

Farming organically allows producers to incur many economic and social advantages compared to farming conventionally. Delate et al. (2003) showed that, in Iowa, higher organic prices and lower production costs more than compensated for lower yields. The size of the economic advantage will differ by the crops within the rotation, the time period of the study, and geographic location of the farm. However, there has been enough consistency among the research comparing conventional and organic production systems to permit some degree of confidence (Chase et al., 2015). Also, several studies based on long-term experimental trials have reported that organic cropping systems are at least as profitable as conventional cropping systems (Mahoney et al., 2004; see Greene and Kremen (2003) for reviews of other studies).

Results of a study in Minnesota showed that with current price premiums, an organic crop farm in the Upper Midwest can earn greater per hectare profits with a corn–soybean–oat/alfalfa–alfalfa rotation than a conventional farm using an equivalent four-year rotation or the two-year corn–soybean rotation that is predominant in the region (Delbridge, et al., 2011).

Another study provided an economic comparison of an organic corn–soybean rotation and conventional corn–soybean systems over the 1991 to 2001 period. Without price premiums for the organic rotation, the net returns for both rotations were similar. However, the net returns for the conventional rotation were more variable. When the costs of the biological transition for the organic rotation (1982–1984) were included, the net returns for the organic rotation were reduced, while the conventional net returns remained unchanged. Even with the inclusion of the biological transition and family labor costs, however, the organic price premium required to equalize the organic and conventional returns was only 10 percent above the conventional product (Pimental, 2005).

Hiroki and Ashok (2012) expected organic farmers to earn significantly higher household income than conventional farms. Though organic crop producers earned higher revenue, they incurred higher production expenses as well. Dabbert and Madden (1986) used a multi-year simulation model to investigate the trend in income of a 117-hectare crop-livestock farm in Pennsylvania. They showed that income was severely depressed by a yield decline during the transition phase. Specifically, the first year of their simulation model resulted in a 43 percent reduction in income.

A survey of organic corn producers in Ohio, Indiana, Michigan, and Pennsylvania collected information on total return and expenditures (seeds, machinery, amendments, land) which was subsequently used to estimate net return to labor and management for organic corn fields. The average net return was $811 per acre, but there were significant differences in net returns among farms. Approximately one-half (46 percent) of the net returns were between $500 and $999 per acre. Yield varied widely among farms, but few farms lost money on corn. Overall, organic corn production was expected to be profitable in 2019 (Brock et al., 2019).

Analysis by Clark (2009) provided evidence that although the cost of organic systems was slightly lower, production penalties associated with organic production reduced total net income. The average net income comparison excluding any premium showed that the profit of traditional corn and soybean was higher than that of organic corn and soybean. The income of traditional corn was on average of $77 per acre higher, while that of traditional soybean was on average $53 per acre than that of the respective organic crops. Once price premiums were introduced, organic corn and soybeans generated higher net returns than traditional corn and soybeans. One explanation for the significantly higher operating income for organic production systems compared to conventional production systems in the Clark (2009) study was that net income did not clearly reflect labor costs, due to their use of returns to land, labor, and management to measure net income. If these additional labor costs are included, the total cost of organic corn and soybeans would be similar to the total cost of traditional corn and soybeans. Overall, lower organic production costs coupled with adequate organic price premiums made organic production competitive and profitable.

The discussion of the FINBIN data above indicated that organic crops tend to have lower yields, receive a higher price, and have higher costs per acre. Essentially, for the net return of an organic crop to be higher than the net return of its conventional counterpart, the price received has to be high enough to offset the lower yields and higher costs. Differences in net return per acre were computed using FINBIN data from 2014 to 2018. Net returns excluded government payments, operator labor and management, and opportunity costs on owned assets. By far and away the largest premium (i.e., positive difference between organic and conventional production) was for corn. The net return for organic corn was $515 per acre higher than the net return for conventional corn. The next largest premium was a $101 per acre advantage for soybeans. Organic wheat had a net return that was $54 per acre higher than conventional wheat. Net returns between organic and conventional oats and alfalfa were similar. The difference in net returns among the five crops emphasizes the importance of getting organic corn into organic crop rotations.

2.5. Transition Period

Previous research has shown that an established organic farm can be as profitable, or even more profitable, than a conventional farm under certain circumstances. However, organic farming systems often require a transition period before they are fully established after a changeover from conventional farming. During this transition period, yields may decline and recover slowly, and a lower profit crop rotation may be required to establish an organic system (Dabbert and Madden, 1986). A farm's profits during the transition from chemical-intensive to organic farming methods are determined by a combination of five kinds of effects: rotation adjustment, biological transition, price, learning, and a perennial effect. The rotation adjustment effect on profits may be minimal or non-existent. Some farmers experience no adverse biological effects during the transition; yields may remain high (and in rare instances increase) and costs may not increase (in some instances decrease) with the adoption of organic methods. The price effect may be positive, as in situations where "organic" produce commands a premium price. Or the effect may be negative as in situations where transition crops are sold as commodities rather than specialty products. Clearly, the process of planning a transition is extremely complex, involving a learning process for farmers who often have to deal with unfamiliar production techniques and to adapt them to his or her specific circumstances. Advice of experts can be invaluable during the transition. Lack of technical information and advice regarding organic methods can be a major barrier to adoption of organic systems by significantly increasing the farmer's apprehension and uncertainty regarding the financial outcome of the transition.

Changing from conventional to organic production is a regulated process. Organic “Certification” requires that crops do not receive any synthetic chemicals including fertilizers or pesticides for three years prior to the harvest of the crops (see Delate (2003) for a full explanation of the certification process). These organic requirements may decrease crop yields, increase labor requirements, and slow the adoption of certified organic farming systems in some commodity sectors (Greene and Vilorio, 2018). While neither the process nor the cost of organic certification can be considered a barrier to entering the organic market, certification involves submitting an annual crop production plan to an accredited certifier and an annual inspection to verify compliance with applicable organic standards and regulations.

Organic agriculture is defined as a complex system (Brumfield et al., 2000). Under organic management, productivity increases with years (Lockeretz et al., 1981). Accompanied with similarly conventional production yields, some experimental transition studies reported that the yield was initially lower (Liebhardt et al., 1989; MacRae et al., 1990). The subject of many organic research programs in the United States is to develop strategies to reduce the risk of loss of production during the three-year transition from traditional to certified organic. (USDA-AMS, 2003).

3. METHODS

This chapter will discuss the methods used in the thesis. Specifically, this chapter will discuss enterprise budgets, long-term price, yield, and cost assumptions, and simulation.

3.1. Enterprise Budgets

Enterprise budgets are used extensively to examine net return prospects for crop and livestock enterprises (Kay et al., 2012). The major components of the enterprise budgets used in this thesis include gross revenue, direct costs, machinery costs, harvest costs, labor costs, and land costs. Gross revenue includes crop revenue, government payments, crop insurance indemnity payments, and miscellaneous income. Direct costs include seed cost, fertilizer costs, pesticide costs, insurance, operating interest, and miscellaneous cost. Machinery and harvest costs have variable and fixed components. The variable component includes fuel, utilities, and repairs, while the fixed component includes depreciation and interest for each field operation. Field operation costs exclude labor costs, which are categorized as a separate cost category. Cash rent is used to measure land costs.

Enterprise budgets for corn, soybeans, and wheat grown in conventional and organic cropping systems were created for a ten-year period. The first-year budget includes detailed information pertaining to gross revenue, direct costs, machinery and harvest costs, labor costs, and land costs. Direct costs include seed, fertilizer, herbicide, insecticide, manure, crop insurance, general farm insurance, and operating interest. Budgets for years two through ten were created using long-run price, yield, and cost estimates, which are discussed in the next section. Conventional corn and conventional soybean enterprises are used to compute net returns for a conventional corn/soybean rotation. Conventional corn, conventional soybean, and conventional wheat enterprises are used to compute net returns for a conventional corn/soybean/wheat rotation. For the transition and organic corn/soybean/wheat crop rotation enterprise budgets for conventional corn, transition soybeans, conventional wheat, transition wheat, organic corn, organic soybeans, and organic wheat. The inclusion of conventional corn, transition soybeans, and transition wheat in the rotation reflects the fact that a transition period is needed before a farm can produce organic crops. The rotation was set up so that organic corn could be produced in the third year. The percentages of each crop in the transition and organic rotation during the ten-year period are as follows: conventional corn, 6.7 percent; transition soybeans, 3.3 percent; conventional wheat, 10.0 percent; transition wheat, 10.0%; organic corn, 26.7 percent; organic soybeans, 23.3 percent; and organic wheat, 20.0 percent. Table 3.1 illustrates the production plan for the organic crop rotation. Six fields, of equal acreage, were targeted for transition.

Enterprise budget data is summarized using the following categories: gross revenue, variable cost, contribution margin, fixed cost, earnings, and net return to land. The contribution margin is computed by subtracting variable cost from gross revenue. Earnings are computed by subtracting variable and fixed costs from gross revenue. Net return to land is computed by subtracting all costs, except land costs, from gross revenue.

The Purdue Crop Cost and Return Guide (Langemeier et al., 2019) and FINBIN data from the University of Minnesota (FINBIN, 2019) were used to estimate prices, yields, and government payments for each enterprise in the first year. Yield estimates (price estimates) for conventional corn and organic corn were 174.0 (3.75) and 117.5 (8.25), respectively. Yield estimates (price estimates) for conventional soybeans, transition soybeans, and organic soybeans were 54.0 (9.00), 36.5 (9.00), and 36.5 (16.80), respectively. Yield estimates (price estimates) for conventional wheat, transition wheat, and organic wheat were 77.0 (5.25), 58.5 (5.25), and 58.5 (8.20), respectively. Government payment, crop insurance, and miscellaneous income estimates for each enterprise for the first year's budget can be found in table 3.2.

Cost estimates were derived using the Purdue Crop Cost and Return Guide (Langemeier et al., 2019), FINBIN data from the University of Minnesota (FINBIN, 2019), Nebraska Crop Budgets (Klein et al., 2017), and Chase et al. (2009). The transition soybean and wheat enterprises were assumed to use the similar inputs as the organic soybean and wheat enterprises. More detail pertaining to the layout of the budgets used in this thesis can be found in the spreadsheet entitled "Comparison of Conventional and Organic Crop Rotations" posted on the web site for the Center for Commercial Agriculture.

3.2. Long-Run Price, Yield, and Cost Assumptions

Several sources were used to estimate prices, yields, and costs for budget years two through ten. Prices were assumed to be the same for the ten-year period. Ten-year average historical FINBIN prices were used as long-run price estimates. Assumptions regarding annual crop yield increases are reported in table 3.3. Variable and fixed costs were assumed to increase one percent per year during the ten-year period.

3.3. Net Present Value Analysis

Net returns for each enterprise during the ten-year period were used to compute the net return for conventional and organic cropping systems. To perform the simulation analysis, all enterprise net returns were discounted back to the present value. Given the low net returns of an organic system during the initial transition period, comparing the net present value of each system rather than average annual net returns is crucial. A 6 percent after-tax discount rate was utilized in the net present value computations.

The sensitivity of net returns for both conventional and organic cropping systems to crop prices was explored using simulation (discussed in section 3.4). In addition, breakeven prices for each crop were also summarized.

3.4. Simulation

Simulation was conducted using @risk. Simulation was used to examine the net present value of annual net returns to land for each crop rotation. @risk utilizes Monte Carlo simulation. By substituting a probability distribution for factors that have inherent uncertainty, the simulation produces distributions of possible results. The primary source of uncertainty examined in this study was crop prices. Distributions of crop prices were developed using historical crop prices reported in FINBIN and triangular distributions.

Historical crop price data were obtained using FINBIN data for the 2009 to 2018 period. Specifically, summary reports were generated for each of the following crops: conventional corn, conventional soybeans, conventional wheat, organic corn, and organic soybeans. Due to the limited data available for organic wheat, conventional wheat prices were multiplied by two to generate simulation prices for organic wheat. The triangular distribution was used to represent the crop price distributions in the @risk simulations. This distribution requires information on the minimum, most likely, and maximum values. The triangular distribution is often used when data is limited. Historical crop price information from FINBIN was used for the minimum, the most likely, and the maximum values for each crop. The 10-year average price for each crop was used to represent the most likely price for each crop.

In addition to the minimum, most likely, and maximum values, @risk requires information on the correlation coefficients between the crop prices. The correlation coefficient is a number between - 1 and 1, which is used to determine whether there is a relationship between two pairs of data. The closer to 1, the more likely the pair of values have a positive linear correlation, and the closer to –1, the more likely that there is a negative linear correlation. A correlation coefficient close to zero indicates that there is no relationship between the two pairs of data. The correlation coefficients between corn and organic corn, soybean and organic soybean, wheat and organic wheat were 0.87, 0.75 and 0.60, respectively. All of the p-values for these combinations were below 0.05, indicating that the coefficients were statistically different from zero. The correlation coefficients between corn and soybeans, and corn and wheat were 0.89 and 0.48, which are statistically different from zero. The correlation coefficient between soybeans and wheat was 0.91. All of the remaining correlation coefficients were above 0.60, and significantly different from zero.

Due to differences in timing of annual returns between crops and rotations, the summary of the simulation results will focus on the net present value for each rotation. Specifically, the net present value over the 10-year period will be divided by 10 and compared among the three crop rotations for each simulation run or iteration.

Table 3.1. Transition and Organic Production Plan

Crop	Year1	Year2	Year3	Year4	Year5	Year 6	Year7	Year8	Year9	Year10
Field 1										
Conventional Corn	×									
Transition Soybeans		×								
Conventional Wheat										
Transition Wheat			×							
Organic Corn				×			×			
Organic Soybeans					×			×		×
Organic Wheat						×			×	
Field 2										
Conventional Corn										
Transition Soybeans	×									
Conventional Wheat										
Transition Wheat		×								
Organic Corn			×			×			×	
Organic Soybeans				×			×			×
Organic Wheat					×			×		
Field 3										
Conventional Corn			×							
Transition Soybeans				×						
Conventional Wheat		×								

Table 3.1 continued

Crop	Year1	Year2	Year3	Year4	Year5	Year 6	Year7	Year8	Year9	Year10
Transition Wheat					×					
Organic Corn						×			×	
Organic Soybeans							×			×
Organic Wheat								×		
Field 4										
Conventional Corn	×									
Transition Soybeans		×								
Conventional Wheat										
Transition Wheat			×							
Organic Corn				×			×			
Organic Soybeans					×			×		×
Organic Wheat						×			×	
Field 5										
Conventional Corn										
Transition Soybeans	×									
Conventional Wheat										
Transition Wheat		×								
Organic Corn			×			×			×	
Organic Soybeans				×			×			×
Organic Wheat					×			×		

Table 3.1 continued

Crop	Year1	Year2	Year3	Year4	Year5	Year 6	Year7	Year8	Year9	Year10
Field 6										
Conventional Corn			×							
Transition Soybeans				×						
Conventional Wheat		×								
Transition Wheat					×					
Organic Corn						×			×	
Organic Soybeans							×			×
Organic Wheat								×		

Table 3.2 Government Payments, Crop Insurance Indemnity Payments, and Miscellaneous Income by Crop Enterprise

Crops	**Long-Run Projections**
Conventional Corn	42.50
Conventional Soybeans	38.50
Conventional Wheat	22.50
Transition Soybeans	38.50
Transition Wheat	22.50
Organic Corn	22.50
Organic Soybeans	22.50
Organic Wheat	22.50

Table 3.3. Annual Crop Yield Increases by Crop Enterprise

Crops	**bu/year**
Conventional Corn	2.00
Conventional Soybeans	0.50
Conventional Wheat	0.35
Transition Soybeans	0.35
Transition Wheat	0.25
Organic Corn	1.50
Organic Soybeans	0.35
Organic Wheat	0.25

4. DATA

This chapter will summarize enterprise budget information for each crop in the conventional and organic cropping systems, and summarize information utilized for the stochastic simulation.

4.1. Summary of Conventional Crop Enterprise Budgets

Table 4.1 presents the average gross revenue, variable cost, contribution margin, fixed cost, earnings, and net return to land for each conventional crop enterprise for the ten-year period. The average net return to land per acre was similar for conventional corn and conventional soybeans. The average net return to land per acre for conventional wheat was approximately $85 lower than the net returns for the other two crops.

4.2. Summary of Transition Crop Enterprise Budgets

The transition crop enterprises were utilized in the organic corn/soybean/wheat rotation. Table 4.2 presents the average gross revenue, variable cost, contribution margin, fixed cost, earnings, and net return to land for transition soybeans and transition wheat. Because the transition crops have similar production practices and yields of the organic rotations, without the benefit of receiving the higher organic prices, and the average net return to land for the two transition enterprises are very low compared to net returns for the conventional enterprises.

4.3. Summary of Organic Crop Enterprise Budgets

A summary of revenue, costs, and net returns for organic corn, organic soybeans, and organic wheat is illustrated in table 4.3. Gross revenue for the organic crops was substantially higher than gross revenue for the conventional crops. The lower yields for the organic rotations were more than offset by the higher crop prices received. The largest difference was between organic corn and conventional corn. Organic corn gross revenue was 44 percent higher than the gross revenue for conventional corn. The organic rotations tended to have higher fixed costs and lower variable costs than their conventional counterparts for two reasons. First, the conventional rotations have higher direct costs. Second, the organic rotations utilize tillage to a greater extent, which results in a higher depreciation and interest expense on equipment. Total costs for organic and conventional rotations were similar. Net return to land for the organic corn, organic soybeans, and organic wheat were $402, $212, and $148 higher than conventional corn, conventional soybeans, and conventional wheat, respectively.

4.4. Breakeven and Crop Price for Each Crop Enterprise

Breakeven prices and crop prices for each crop enterprise can be found in table 4.4. Breakeven prices to cover variable and total costs are computed. The crop price in table 4 represents the most likely price used in the stochastic simulation (see section 4.6 below). The breakeven price and most likely crop price are very similar for conventional corn and conventional soybeans. In contrast, the breakeven price for conventional wheat is 13 percent below the most likely crop price. The transition enterprises utilize organic crop practices, but the crops are sold as conventional crops. Given this fact, it is not surprising to find that the breakeven prices for both soybeans and wheat are well above the most likely crop prices for these crops. The most likely prices for the organic crops are well above their respective breakeven prices.

4.5. Summary of Crop Rotation Net Returns

Table 4.5 contains a summary of revenue, costs, and net returns for a conventional corn/soybean rotation, a conventional corn/soybean/wheat rotation, and a transition and organic corn/soybean/wheat rotation. Net returns to land for the conventional corn/soybean rotation and the conventional corn/soybean/wheat rotation were $252 and $223, respectively. In contrast, the net return to land for the transition and organic corn/soybean/wheat rotation was $378 per acre, or approximately $155 per acre higher than the net return to land for the conventional corn/soybean rotation and $126 per acre higher than the net return for the conventional corn/soybean/wheat rotation.

4.6. Crop Price Information for Stochastic Simulation

Crop prices used for the stochastic simulation can be found in table 4.6. Because triangular distributions were utilized, minimum, maximum, and most likely crop prices are presented. As explained in the previous chapter, the prices in table 4.6 were derived using historical FINBIN crop prices from 2009 to 2018.

Table 4.1. Average Net Returns per Acre for Conventional Crop Enterprise Budgets

Enterprise	**Corn**	**Soybeans**	**Wheat**
Gross Revenue	809.38	619.56	443.62
Variable Cost	459.73	275.20	189.23
Contribution Margin	349.65	344.36	254.39
Fixed Cost	316.64	315.04	309.09
Earnings	33.01	29.32	-54.70
Net Return to Land	253.76	250.07	166.05

Table 4.2 Average Net Returns per Acre for Transition Crop Enterprise Budgets

Enterprise	**Soybeans**	**Wheat**
Gross Revenue	431.81	342.06
Variable Cost	225.19	193.10
Contribution Margin	206.62	148.96
Fixed Cost	376.83	351.73
Earnings	-170.21	-202.77
Net Return to Land	50.54	17.99

Table 4.3 Average Net Returns per Acre for Organic Crop Enterprise Budgets

Enterprise	Corn	Soybeans	Wheat
Gross Revenue	1221.45	850.26	661.08
Variable Cost	353.90	208.45	193.10
Contribution Margin	867.55	641.81	467.98
Fixed Cost	432.86	400.06	374.96
Earnings	434.69	241.75	93.02
Net Return to Land	655.45	462.50	313.78

Table 4.4 Breakeven prices for each enterprise

Crops	Cover VC	Cover TC	Crop Price
Conventional Corn	2.53	4.26	4.19
Conventional Soybeans	4.87	10.45	10.33
Conventional Wheat	2.35	6.19	5.36
Transition Soybeans	5.90	15.77	10.33
Transition Wheat	3.15	8.90	5.36
Organic Corn	2.88	6.40	9.65
Organic Soybeans	5.46	15.94	21.74
Organic Wheat	3.15	9.28	10.71

Table 4.5 Average Net Returns per Acre for Conventional and Organic Crop Rotations

Enterprise	Conv C/S	Conv C/S/W	Org C/S/W
Gross Revenue	714.47	624.19	805.98
Variable Cost	367.47	308.05	260.09
Contribution Margin	347.01	316.13	545.89
Fixed Cost	315.84	313.59	388.58
Earnings	31.17	2.54	157.31
Net Return to Land	251.92	223.29	378.06

Table 4.6. Crop Prices Used for Stochastic Analysis

Crops	Min	Most Likely	Max
Conventional Corn	3.19	4.19	6.50
Conventional Soybeans	8.50	10.33	13.80
Conventional Wheat	3.87	5.36	7.61
Transition Soybeans	8.50	10.33	13.80
Transition Wheat	3.87	5.36	7.61
Organic Corn	6.44	9.65	13.91
Organic Soybeans	18.36	21.74	26.85
Organic Wheat	7.74	10.71	15.22

5. RESULTS

This chapter will summarize the @risk simulation results. Specifically, this chapter will summarize the 1,000 @risk simulation runs, present the results by crop rotation quartiles, present the differences in annualized net return to land among the crop rotations, and present the results using net return to land quartiles for the organic crop rotation.

5.1. Summary Statistics for Simulation Runs

Table 5.1 provides a summary for the simulation runs for each crop rotation. The organic crop rotation has a higher minimum, maximum, and average annualized net return to land per acre than the two conventional crop rotations. The average annualized net return to land for the organic crop rotation is approximately 27 percent higher than the average for the corn/soybean rotation and approximately 46 percent higher than the average for the corn/soybean/wheat rotation. The standard deviation of annualized net returns is lower for the corn/soybean/wheat rotation than they are for the other two crop rotations.

5.2. Summary of Results by Crop Rotation Quartiles

Quartile simulation data for each crop rotation is presented in table 5.2. Even the maximum value for the corn/soybean/wheat crop rotation is lower than the minimum value for the organic crop rotation. Clearly the organic crop rotation dominates the corn/soybean/wheat crop rotation. The maximum value for the corn/soybean crop rotation falls within the first quartile for the organic crop rotation, indicating that there may be instances (i.e., simulation runs) for which the net returns for corn/soybean crop rotation are higher than those for the organic crop rotation. These instances are elaborated on below.

5.3. Differences in Net Return among Crop Rotations

Table 5.3 illustrates the differences in net returns among the crop rotations. The first column presents the difference between the conventional corn/soybean crop rotation (CCS) and the conventional corn/soybean/wheat crop rotation (CCSW). The second column presents the difference between the organic crop rotation (OCSW) and the conventional corn/soybean crop rotation (CCS). Finally, the third column presents the difference between the organic crop rotation (OCSW) and the conventional corn/soybean/wheat crop rotation (CCSW).

The average difference in annualized net returns between the two conventional crop rotations was $29.37. In 66 out of 1000 of the iterations, the CCSW crop rotation had a higher net return than the CCS crop rotation. The average difference in annualized net returns between OCSW and CCS, and OCSW and CCSW was $60.73 and $90.11 per acre, respectively. In contrast to the results for CCSW crop rotation where none of the iterations had a higher net return than the OCSW crop rotation, for 3 out of 1000 iterations the net returns for CCS crop rotation were higher than the net returns for the OCSW crop rotation.

5.4. Summary of Results by Quartiles for Organic Crop Rotation

Annualized net returns for each crop rotation are summarized using the quartiles for the organic crop rotation in table 5.4. To create this table, we sorted all of the iterations using the net returns for the organic crop rotation. The net return information for the other two crop rotations was organized using this sort for the organic crop rotation. For example, the minimum for each crop rotation presented in table 5.4 represents the annualized net return for each crop rotation for the iteration representing the smallest net return for the organic crop rotation. Similar to the results described above, the net returns for the organic crop rotation are clearly higher for each quartile than the net returns for the two conventional crop rotations.

Table 5.1. Summary Statistics for Annualized Net Return to Land for Each Rotation

Crops	Avg	Std Dev	Min	Max
Conventional Corn/Soybeans (CCS)	225.20	16.41	172.11	272.49
Conventional Corn/Soybeans/Wheat (CCSW)	195.82	11.48	157.32	229.86
Organic Corn/Soybeans/Wheat (OCSW)	285.93	15.70	240.56	338.37

Table 5.2. Summary of Annualized Net Return to Land by Crop Rotation for Each Quartile

Crops	Min	25%	50%	75%	Max
Conventional Corn/Soybeans (CCS)	172.11	214.27	225.21	236.16	272.49
Conventional Corn/Soybeans/Wheat (CCSW)	157.32	187.89	195.54	203.68	229.86
Organic Corn/Soybeans/Wheat (OCSW)	240.56	275.29	285.47	296.93	338.37

Table 5.3. Difference in Annualized Net Return to Land among Crop Rotations

Statistics	CCS - CCSW	OCSW - CS	OCSW - CSW
Average	29.37	60.73	90.11
Standard Deviation	19.87	22.48	19.46
Minimum	-25.92	-9.02	0.00
Maximum	85.39	130.50	142.07
Negative Values (out of 1,000)	66	3	0
Postivive Values (out of 1,000)	934	997	1000
Percentage of Values > 0	93.4%	99.7%	100.0%
Percentage of Values < 0	6.6%	0.3%	0.0%

Table 5.4. Summary of Annualized Net Return to Land by Quartiles for Organic Crop Rotation

Crops	**Min**	**25%**	**50%**	**75%**	**Max**
Conventional Corn/Soybeans (CCS)	233.08	194.81	233.66	228.21	223.49
Conventional Corn/Soybeans/Wheat (CCSW)	195.25	194.54	175.30	202.60	199.40
Organic Corn/Soybeans/Wheat (OCSW)	240.56	275.29	285.47	296.93	338.37

6. SUMMARY, CONCLUSION, AND LIMITATIONS

This chapter provides a summary of the methods, data, and results for this study. The chapter will also discuss limitations of this study and guide individuals to possible ways that the analysis in this thesis could be extended.

6.1. Summary and Conclusions

The objective of this study was to compare the net returns of conventional and organic crop rotations using long-term crop budgets and stochastic simulation. The organic crop rotation included a three-year transition period. The conventional crop rotations were represented by a corn/soybean rotation and a corn/soybean/wheat rotation. The organic crop rotation produced corn, soybeans, and wheat. Historical prices, crop budgets, and FINBIN data were used to develop the long-term crop budgets. Annualized net returns to land for each crop rotation were computed using the net present value of net returns over a ten-year period. Annualized net returns to land for each rotation were simulated using a triangular distribution of historical crop prices and 1,000 iterations.

The annualized net return to land per acre for the organic crop rotation was $61 higher than the net return for the corn/soybean rotation, and $90 higher than the net return for the corn/soybean/wheat rotation. Only 6.6 percent of the simulation iterations exhibited a higher net return for the corn/soybean/rotation compared to the corn/soybean rotation. Only 3 out of 1000 iterations exhibited a higher net return for the corn/soybean rotation than for the organic crop rotation. None of the iterations for the conventional corn/soybean/wheat rotation were higher than the net returns for the organic crop rotation.

Three hypotheses were tested in this thesis. First, the transition and organic cropping system was expected to have higher average net returns than the conventional cropping systems over the ten-year planning horizon. Second, average annual net returns for the transition and organic cropping system were expected to be relatively lower during the transition phase and relatively higher during the organic phase. Third, the highest annual net return was expected to be associated with organic corn. All of these hypotheses failed to be rejected.

6.2. Limitations of Study

This study compared two conventional crop rotations involving corn and soybeans, and corn, soybeans, and wheat to an organic crop rotation involving corn, soybeans, and wheat. An analysis of this sort requires a lot of assumptions. Producers considering transitioning a portion of their acres to certified organic crop production should carefully examine the sensitivity of net returns to alternative price, yield, and cost assumptions. It is also important to note that the crops grown, manure used, and tillage practices very substantially among organic crop farms.

Also, this study focused on historical crop price comparisons. There certainly are no guarantees that the historical price premiums received for the organic crops will persist in the future. Having said that, unlike that for the conventional crops, it is important to point out, that current organic crop prices are still considerably above the breakeven levels computed in this thesis.

In addition, this study did not examine crop yield risk since there was not enough individual farm data available for that. Yield risk is likely a larger concern for the organic crops than it is for the transition and organic crops. Thus, incorporating crop yield risk would likely make the organic crop rotation relatively less attractive.

Last but not the least, the results of this study should be carefully used by farms who are interested in pursuing organic crop production, particularly those with a relatively weak working capital position. Net returns during the transition period are very low and would further erode working capital.

6.3. Need for Further Work

As noted above, there are a lot of assumptions involved when examining the net returns of conventional and organic crop rotations. Further work could involve further sensitivity analysis involving the assumptions regarding relative prices, relative yields, and relative production costs. Research involving other organic crop rotations would also be useful. For example, many organic crop rotations include forages, such as alfalfa, in the rotation. Whether an organic crop rotation that includes forages is more profitable than the crop rotations examined in this study is an open question.

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