

# **A Whole-Farm Profitability Analysis of Organic and Conventional Cropping Systems**

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## Introduction

There is a long history of research comparing the profitability of conventional and organic farm management systems in the midwestern United States. While some research has found that organic cropping systems are less profitable than conventional systems (e.g. Dobbs and Smolik, 1996), most studies have shown that returns to organic farm management are equal to or exceed those to conventional management. An early study by Lockeretz et al. (1981) compared diversified organic farms to similarly sized conventional farms from the same geographic area. Five years of management and yield data were collected and analyzed. The authors concluded that organic farms earned roughly the same per-acre returns as conventional farms, with lower production costs offsetting lower yields on the organic farms. Other studies have used long-term trial data, rather than case-studies, to examine the profitability of organic systems. Helmers et al. (1986) evaluated eight years of yield data from an experimental trial and concluded that organic rotations were neither less profitable nor more risky than the same rotations managed with synthetic pesticides and fertilizers. Similarly, based on three years of trial data in Iowa, Delate et al. (2003) found that a 4-year organic rotation earned greater net returns than a conventional corn-soybean rotation when organic price premiums were taken into account. More recently, data from a long term agricultural experiment in Wisconsin found that with organic premiums, an organic grain rotation outperformed conventional and no-till cropping systems. Furthermore, when measures of risk exposure were taken into account, the results were largely unchanged (Chavas et al., 2009). In Minnesota, 18 years of experimental trial data was used to find that returns to a 4-year organic grain and forage rotation exceeded the net returns to both an equivalent rotation and a 2-year corn-soybean rotation that were managed conventionally, but only when organic price premiums were considered (Delbridge et al., 2011).

The results of the previous research are supported by newly available empirical data on the financial performance of organic farms. The University of Minnesota Center for Farm Financial Management's FINBIN database, which collects data on both conventional and organic farm financial outcomes in Minnesota, shows that several major organic crop enterprises have outperformed their conventional counterparts in terms of per acre returns over direct expenses. In fact, FINBIN data show that from 2006 to 2009, growers of organic corn earned an average of \$442 per acre over direct expenses compared to \$200 per acre for conventional corn. Over this same period organic soybean returned an average of \$166 per acre, while conventional soybean returned \$157 (Center for Farm Financial Management, 2010). Though these data cannot be used to directly compare specific cropping systems, as they are averages drawing on a diverse set of farms and rotation designs, they are largely consistent with the findings of the previously mentioned studies.

Machinery ownership costs are an important factor when considering the profitability of alternative cropping systems. Unfortunately, much of the research on the comparative profitability of organic and conventional cropping systems has either ignored the overhead expenses that are associated with owning and housing farm machinery or has assumed that both organic and conventional crop management systems face the same machinery ownership costs. This assumption, though convenient for making comparisons of the profitability of cropping systems based on experimental trial data, may lead to an understatement of the true costs of organic farm management. Organic cropping systems in the midwestern United States include rotations of three or more crops and require machinery that conventional farms in the region often do not own (e.g. forage harvest equipment). Though additional machinery requirements on organic farms do not necessarily increase operating expenses (i.e. labor, fuel) relative to

conventional farms, they may increase overhead costs associated with the financing, maintenance, and depreciation of the additional equipment.

Furthermore, organic and conventional crop farms may have different optimum farm sizes, as management requirements differ between the two systems. To the authors' knowledge, there have not been any economic studies that have carefully considered the differences in farm size between organic and conventional farms and the effect that such size differences would have on machinery costs and overall farm profitability. Empirical data show that among contributors to the FINBIN farm financial database, the average Minnesota organic crop farm is smaller than the average conventional crop farm (664 acres and 1095 acres respectively) (Center for Farm Financial Management, 2010). If this size difference is the result of the differences in management requirements between the two systems, it should be considered in an analysis of whole-farm profitability. Not only could differences in farm size significantly impact the per-acre machinery ownership costs on organic and conventional farms, but farm-level profits could actually be smaller for organic crop farms even when the per-acre returns are considerably higher than those generated under conventional management. The objective of this study is to provide an analysis of the profitability of organic and conventional cropping systems at the whole-farm level that carefully considers the effects of farm size and machinery complement on total farm costs.

### Methods

This study extends the analysis of per-acre net returns presented in Delbridge et al. (2011) to account for differences in farm size and machinery costs that result from differing management requirements of conventional and organic cropping systems. Much of the methodology used in Delbridge et al. (2011) with respect to the analysis of the VICMS trial data,

as well as the prices of inputs and commodities, is repeated here in order to present a whole-farm analysis that is easily compared to the previous per-acre results. Additionally, a similar stochastic dominance analysis is employed to compare the net return distributions from each of the crop rotation and farm size scenarios.

### *Data*

As described in Porter et al. (2003) and Coulter et al. (2011), the Variable Input Crop Management Systems (VICMS) trial was initiated in 1989 in southwestern Minnesota (44°15' N, 95°19' W). Two crop rotations and four management strategies were included in the trial in each crop year resulting in eight distinct rotation-strategy treatments. Each of the 8 treatments was replicated in 3 plots each year. The crop rotations were a two-year corn-soybean rotation, and a four-year corn-soybean-oat/alfalfa-alfalfa rotation. The management strategies were zero-input, low-purchased-input, high-purchased-input (HI), and organic-input (OI). For the purposes of this study, only the OI 4-yr rotation and the HI 2-yr rotation are analyzed, as these rotations are considered to be the closest to representing the predominant organic and conventional crop rotations in the region.

In the HI strategy, weeds and insect pests were controlled with broadcast pesticides, synthetic fertilizers were applied at rates appropriate for aggressive yield goals, and insect and herbicide resistant seed was planted in later years of the trial. In the OI strategy, weeds were managed mechanically, beef manure was used for fertilization, and organically produced seed was used when available (Coulter et al., 2011). Records were kept of each field operation carried out in each treatment, as well as the formulations and rates of all input applications. Additionally, days suitable for fieldwork were recorded throughout the duration of the VICMS trial.

As explained in detail in Delbridge et al. (2011), costs of purchased inputs for all years of the trial were calculated using input prices from 2010. Nutrients applied through synthetic fertilizer and beef manure were priced using market rates for synthetic fertilizers. Costs of chemical pesticide applications were calculated using 2010 prices when possible. In some cases herbicides that were applied in early years of the trial were no longer available, in which case the last available price for the product was inflation-adjusted to 2010 rates (Delbridge et al., 2011). Although 2010 prices were attributed to all seed used in the trial, different prices were applied depending on whether the planted seed was conventional, organic, or contained insect or herbicide resistant traits. A constant per-acre land rent charge was attributed to the production costs of both rotations that was equal to the average land rent paid by corn producers in southwest Minnesota in 2010 (Center for Farm Financial Management, 2011). Additionally, direct government payments were considered for both the OI and HI cropping systems. A total of \$21 per acre, meant to represent the direct payments likely to be received by crop farms in southwest Minnesota, was added to the revenues derived from each cropping system. This payment level is based on the assumption that half of each system's total crop acres would be registered as corn base-acres and half would be registered as soybean base-acres. Though the organic rotation currently being considered also includes crop acres planted in alfalfa or oat, which would not be eligible for direct payments, all acres are assumed to have been registered as corn or soybean base-acres prior to organic certification (USDA- Farm Service Agency, 2008).

As in Delbridge et al. (2011), prices for both organic and conventional corn, soybean, and oat were the average prices received by growers contributing to the FINBIN database for each year from 2006 to 2010. Conventional alfalfa prices were taken from the Southwest Minnesota Farm Business Management Association Annual Reports from 1993 to 2010. No organic price

premiums were considered for alfalfa in order to reflect the inconsistency of organic alfalfa prices in southwestern Minnesota.

### *Optimal Farm Size Determination*

Researchers have previously used linear programming models to find optimal farm machinery complements for a given farm size and crop rotation (Pfeiffer and Peterson, 1980; Edwards and Boehlje, 1980). Others have considered the impact of weather variability, in the form of suitable field days, on the timeliness of field operations and subsequent farm size decisions (Apland, 1993). In this study, farm size was maximized by grid search using a spreadsheet tool developed for the scheduling of field operations on crop farms. Maximum crop acreage was determined for three different machinery size groupings and each of the two relevant crop rotations, subject to timeliness penalties for delayed planting, harvest, and weed control. Days with suitable conditions for field operations were included in the model to account for historical weather variability. The final results of this procedure were estimates of the largest farms, in total crop acres, that could be managed within a corn-soybean-oat/alfalfa-alfalfa rotation managed organically and a corn-soybean rotation managed conventionally, without suffering unacceptable yield loss, given “small”, “medium”, or “large” machinery.

The three machinery complements were chosen based on discussions with local crop growers and university extension researchers, and by consulting empirical data on farm machinery sizes in Minnesota (Table 1)(Gorman, 2010). The machinery complements were not meant to represent the machinery that would likely be present on a farm of any particular size, but rather the different machinery that would likely be used together. For example, it is not likely that any grower would use both a 16-row corn planter (large) and a 4-row corn head for

harvesting (small) on the same farm, so these pieces of equipment were not grouped together. Of course, one would expect the larger equipment to be found on a larger farm, but it is the comparison of the constraints of organic and conventional management that are of interest here rather than the maximum crop acres that could be farmed with each machinery complement.

Yield penalties are assumed for delays in planting and weed control based on agronomic research relevant to the region. Based on the guidelines provided by Nafziger (2009), penalties attributed to a delay in corn planting range from 0.5 bu/day to 2 bu/day as planting is delayed from the beginning to the end of May. Similarly, based on a study of soybean yield response to planting date, which was conducted on the same site as the VICMS trial, a penalty of 0.3% to 1.3% of yield per day is assumed for each day that planting is delayed by weather or unavailability of labor (Severson, 2011). A penalty of 0.5 bu/day is applied for each day that the planting of oat is delayed between April 18 and May 14, and a penalty of 1.0 bu/day for each day of planting delay after May 14 (Rankin, 2011). No late planting penalty is assumed for alfalfa, as alfalfa is planted with oat and no alfalfa harvest is carried out until the second year. For both corn and soybean, penalties for delayed mechanical weed control are assumed to be 2.0% for each crop stage that weeds are not removed after the beginning of the critical time for weed removal (Knezevic, 2003). Total yield losses from all delays (planting and weed control) are deemed unacceptable if greater than 5.0% of the actual recorded yield of corn, soybean, or oat. It is also considered unacceptable if poor weather or the lack of available labor precludes alfalfa harvest past the 15<sup>th</sup> of October. This date, which is earlier than the latest possible cutting date when over-wintering is not of concern (Undersander et al., 1994), reflects the importance of alfalfa biomass in meeting the following corn crop's nitrogen requirement.



Daily available labor is set at a maximum of 16 hours to reflect two full-time farm workers working 8 hours each day. Although 8 hours is surely shorter than the typical work day during critical planting, harvest and weed control periods, this accounts only for time spent actually operating machinery. No other farm management tasks are considered in the model. Machinery availability is considered separately from labor availability so that even though two workers are available on any given day, two field operations cannot be performed using the same machinery on different fields. No additional part-time or “peak-time” hired labor is allowed in this model, though this technique has been used in other studies. The initial farm size is set to 80 acres for each crop rotation and farm machinery complement, and the size is increased in 80 acre increments until unacceptable yield losses occur in more than one of the 18 years of trial data.

### *Machinery Costs*

Once optimal farm sizes for both the HI 2-yr and the OI 4-yr rotations are established for each of three possible machinery complements, machinery costs are estimated for each scenario based on the field operations records from the VICMS trial. Machinery operating costs, which include operator labor, fuel, oil, and operation related repairs, are calculated using the University of Minnesota Extension Farm Machinery Economic Cost Estimation Spreadsheet (Lazarus and Smale, 2010). The size of each implement is entered, along with farm size and the average number of annual machinery passes required each year to arrive at a per-acre operating cost. The cost of operating both the implement and the associated power unit is included in this estimate. Whereas Delbridge et al. (2011) used the use-related costs averaged over several machinery sizes provided in Lazarus (2009), the current study calculates operating costs separately for each implement’s width, appropriate power unit, and annual hours per use at each farm size scenario.

Ownership costs of farm machinery consist of interest, insurance, machinery housing, and depreciation. These costs, unlike operating costs, depend critically on the value, age, and annual hours of use of each piece of equipment. Although the annual hours of use is determined by the model depending on the machinery widths and farm size scenarios, a challenge in calculating ownership expenses is making reasonable assumptions with respect to the equipment's value and age. Of course, one possible approach would be to assume that farms operating within both the HI 2-yr and the OI 4-yr rotation have purchased all equipment new in the current year, in which case current machinery list prices can be assumed and costs can be easily estimated using the previously mentioned machinery cost tools. When this approach is taken, total machinery costs for the smaller farms are very high. For the OI 4-yr rotation, total machinery costs for the small, medium, and large machinery and farm size scenarios were \$1,120, \$823, and \$829 respectively. For the HI 2-yr rotation, total machinery costs for the small, medium and large scenarios were \$243, \$202, and \$172, respectively. Although this method can be consistently repeated for all rotations, farm sizes, and machinery complements, it does not accurately reflect the actual conditions and machinery replacement strategies being practiced on crop farms in Minnesota.

Many farms, especially smaller crop farms, use implements and power units that are well beyond the 12-year useful life often assumed in machinery cost estimate tools. To estimate the total machinery costs that would be faced by each cropping system when using older machinery, the same machinery and farm sizes were entered into the cost estimation tool, but rather than assume new machinery, all equipment was assumed to be 20 years old. The machinery cost estimation tool used in this study calculates machinery depreciation based on the methodology described in Wu and Perry (2004) and machinery value decreases with years since original

purchase. Thus, under this machinery age assumption, the current value of all equipment is much less than when new equipment is assumed, and yearly depreciation expense declines accordingly. In fact, when considering machinery that is 20 years old, the estimated machinery depreciation costs are comparable to, though still slightly higher than, the depreciation levels that are reported for organic crop farms in empirical farm financial data. However, conventional crop farms report machinery depreciation costs that are greater than those estimated under the assumption of 20 year old equipment (Center for Farm Financial Management, 2011). This suggests that organic farms, which tend to be smaller than conventional farms, may rely on older machinery to keep total costs at manageable levels. Another approach to estimating total machinery costs would be to use the machinery cost estimation tools in conjunction with empirical data on average machinery age, type and size currently being used on conventional and organic farms. Unfortunately, little data of this nature exist. (Lazarus, 2010).

Rather than rely on tenuous assumptions regarding machinery age and market value to estimate total machinery costs, this study uses average machinery ownership costs taken from the “Detailed Farm Income Statements” available in the FINBIN database for 2010 (Center for Farm Financial Management, 2011). This technique allows for differing machinery repair and replacement strategies that are likely practiced on conventional and organic crop farms. The cost categories within the FINBIN report that are used to calculate machinery ownership costs include “repairs”, “machinery and equipment depreciation”, “interest” and “machinery leases”. Though the “repairs” category may include repairs to buildings and other non-machinery related repairs, no attempt is made to separate these costs here. Additionally, because the FINBIN database does not distinguish between interest on machinery purchases and other interest paid,

interest expense related to machinery is estimated based on the proportion of machinery assets to total assets from the FINBIN “Balance Sheet- Market Values” for crop farms.

The FINBIN database allows queries to distinguish between organic and conventional farms, as well as by farm size. Though there are not enough organic crop farms in the database to calculate separate costs for each farm size used in this study, separate ownership costs are calculated for conventional crop farms between 500 and 1,000 crop acres, 1,000 and 1,500 crop acres, and 1,500 and 2,000 crop acres to reflect the optimal farm sizes found for each machinery complement. A single machinery ownership cost is calculated for the organic system based on the FINBIN data for organic farms that are between 250 and 1,000 crop acres.

#### *Net Return Distributions and Stochastic Dominance Analysis*

Machinery operating cost, machinery ownership cost, land rent, and input purchase cost are added together to achieve a total per-acre production cost for each of the 6 cropping system and farm size scenarios for each of the 18 years of the VICMS trial. This total production cost is combined with crop yields from the corresponding year and matched with each of the five sets of commodity prices. This per-acre net revenue, along with estimated government payments, is then simply multiplied by the total crop acres found in the optimal farm size model for each machinery size grouping to arrive at a distribution of whole-farm net returns. The distribution for each of the six scenarios includes  $5 \times 18 = 90$  states of nature that account for the variability in crop yield and commodity prices over time.

Distributions of net returns are compared by both first-degree (FSD) and second-degree (SSD) stochastic dominance (Hardaker et al., 1997; Stanger et al., 2008; Delbridge et al., 2011). Distribution A dominates distribution B by FSD if A is less than or equal to B for all levels of X.

Distribution A dominates distribution B by SSD if the area under the cumulative distribution of A is less than the area under distribution B at all values of X. FSD is the least restrictive of the stochastic efficiency criterion so if a distribution dominates by FSD then it also dominates by SSD.

For this methodology to be valid, two assumptions must be made. First, for 2006 – 2010 commodity prices to be applied to crop yields from 1993 – 2010, independence must be established between these state level price averages and farm level crop yields. To test for this independence, correlation coefficients were calculated for crop yields from the VICMS trial from 1993 – 2010 and conventional corn, soybean, oat, and alfalfa prices from the FINBIN database for the same years. The only significant negative correlation was found to be that between alfalfa hay production and the state average of alfalfa hay price received. As a result, corn, soybean, and oat prices from recent years are matched with historical trial yields, while trial alfalfa yields are matched with local prices from the production year (Nordquist et al., 2011). The second necessary assumption is that prices, yields, and production cost estimates can be adjusted to current terms. To satisfy this condition, input prices are taken from 2010 and yields are detrended to 2010 levels for corn and soybean, which exhibit yield trends over time (Delbridge et al., 2011).

## Results

### *Crop Yields*

Detrended corn yields within the VICMS trial are not significantly different between the OI 4-yr and the HI 2-yr rotations, though soybean yield is significantly less in the OI 4-yr rotation (Table 5). Oat and alfalfa crops are not included in the HI 2-yr rotation and are therefore

not directly compared with yields from the OI 4-yr, although Delbridge et al. (2011) shows that yields of oat and alfalfa within the OI system are equal to or greater than those from the same rotation managed conventionally. Coulter et al. (2011) presents a complete discussion of trial yields for all systems and rotations.

### *Farm Size*

Estimated maximum farm sizes differ dramatically for the HI 2-yr and OI 4-yr rotations. For machinery complement #1 (the smallest grouping) the maximum size is 320 total farm acres for the OI 4-yr rotation whereas the maximum size is 560 total farm acres for the HI 2-yr rotation. Machinery complement #2 allows for larger operations for both rotations, though the increase in acreage is larger for the HI system. Under machinery complement #2 the OI 4-yr rotation reaches a maximum of 560 acres while the maximum acreage for the HI 2-yr rotation is 1,020 acres. For machinery complement #3 (the largest machinery complement), the OI 4-yr cropping system can be managed on up to 800 total acres and the HI 2-yr system can be managed on up to 1,520 total crop acres before the model returns unacceptable yield losses. An increase in farm machinery size from complement #1 to complement #3 allows an increase in acreage of 960 acres for the HI system but only 480 acres for the OI 4-yr rotation.

In the case of the OI 4-yr rotation, yield penalties related to corn planting delay and alfalfa harvest delays are the most frequently binding constraints in the farm size model. Yield penalties due to soybean planting delay and delays in mechanical weed are less frequently binding with these machinery size groupings. In the HI 2-yr rotation, there are fewer field operations than in the OI 4-yr rotation and therefore there is less competition for limited labor and machinery time. Furthermore, because both corn and soybean are planted early in the spring

in the HI system relative to the OI system, and because the associated yield penalties are quadratic in nature, when there are planting delays, daily penalties are usually smaller in the HI system than in the OI system. Thus in most years planting can be delayed longer in the HI system without triggering the unacceptable 5% yield loss level. Late planting in organic management systems for the purpose of weed control may not only affect yield of late planted corn and soybean, but may also increase the probability of significant additional yield loss if weather precludes field work during this critical time.

### *Production Costs*

In both the HI 2-yr and the OI 4-yr rotations, per-acre machinery operating costs decrease as machinery size increases. Larger implements, able to complete field operations in less time than smaller implements, have lower per-acre labor. Machinery operating costs and purchased inputs for the OI 4-yr rotation averaged across all years and crops are \$137, \$127, and \$123 per-acre for machinery complements #1, #2, and #3, respectively. Similarly, average production costs for the HI 2-yr rotation are \$183, \$170, and \$165 per-acre for the same machinery complements. Though the organic system has requires more machinery passes per year than the conventional system when averaged over all crops in the rotations (Table 3), higher average weed control costs in the HI 2-yr rotation contribute to higher productions costs compared to the OI 4-yr rotation (Delbridge et al., 2011).

When machinery ownership costs, in the form of averages from the FINBIN database, are added to operating costs and input purchases, the difference in total production costs between the two rotations increases. The average cost of repairs, machinery depreciation and machinery leases on organic crop farms between 250 and 1000 acres in 2010 was \$59 per acre. This is compared to \$75, \$71 and \$77 per acre for conventional farms from 500 to 1000 acres, 1000 to

1500 acres, and 1500 to 2000 acres, respectively. This group of relatively small organic farms reported slightly lower per-acre costs for all three cost categories that make up the machinery ownership costs considered in this study than either of the three conventional farm size groupings.

### *Net Returns*

When full organic price premiums are considered, average whole-farm net returns to the OI 4-yr rotation are greater than the returns to the HI 2-yr rotation for each of the three machinery complements, despite the fact that the HI system has more crop acres in each scenario (Table 4). Returns to the HI system are also more variable than those to the OI system, as more crop acres result in larger swings in profits between years with strong yields and high prices and those without. When only half of the recorded organic price premiums from recent years are considered, the mean net revenue is higher for each of the machinery complement sizes under the HI 2-yr rotation than under the OI 4-yr rotation.

Stochastic dominance analysis of the six whole-farm scenarios shows that when full price premiums are taken into account, neither cropping system dominates by FSD when compared to the other system within machinery groups. However, when the analysis is extended to SSD, each of the OI 4-yr rotations dominates the HI 2-yr rotation within the same machinery group, despite having fewer crop acres. Perhaps more interesting is the comparison between farms of equal or similar size. The maximum farm size found for the OI rotation with machinery complement #2 is 560 acres, as is the maximum farm size for the HI rotation with machinery complement #1. Under these scenarios, the OI 4-yr rotation dominates by FSD under full organic premiums as well as under 50% of organic price premiums. Similarly, the largest farm within the OI system



(800 acres with machinery group #3) dominates the mid-size farm within the HI system (1120 acres with machinery group #2) by FSD with full organic premiums and by SSD with half of the organic premiums.

### Conclusions

While previous studies have used agricultural trial data to analyze the profitability of conventional and organic cropping systems in the Midwest, this study extends this line of research to account for likely differences in farm size between the two systems. Maximum farm sizes have been estimated for different machinery complements using historical data on suitable days for field work and data on field operations for an organically managed 4-yr crop rotation and a conventionally managed 2-yr rotation. These farm sizes have been used in the calculation of more accurate machinery operating costs than are possible without assumptions regarding farm and machinery sizes. Machinery operating costs, empirical machinery ownership cost averages, and trial production data have been joined to create distributions of possible whole-farm net return distributions for each cropping system.

Results of stochastic dominance analysis indicate that an organically managed crop farm in the Upper Midwest would be preferred by risk averse individuals to a conventionally managed crop farm (i.e. SSD), even when fewer total crop acres are available. When comparing these cropping systems for farms of the same size, results indicate that the organic rotation, at least on smaller farms, dominates the conventional rotation by FSD, which holds for all individuals that prefer more to less. This result does not appear to hold when only half of the recent organic price premiums are applied to crops produced in the organic system.

An interesting implication of these results is that small conventionally managed farms may be able to earn greater net returns if transitioned to organic production. Higher prices for

organic crops and lower production costs in an organic system allow for higher per-acre net returns on organic crop farms than on conventional corn-soybean operations. However, increased management requirements, such as mechanical rather than chemical weed control, allow conventional rotations to be managed on larger areas with the same labor and machinery resources. Therefore, in cases in which crop land is limited, organic crop management may be more attractive.

There are a few issues that must be kept in mind when considering these results. It should be noted that the organic crop yields used in this study are derived from long-term agricultural trial yields that are somewhat higher than state average organic crop yields (Delbridge et al., 2010). While organic farmers in Minnesota can and do achieve yields comparable to those produced in the VICMS trial, organic systems are complex and a great deal of experience and expertise in managing organic rotations was present among trial managers. Additionally, the machinery required for corn-soybean-oat/alfalfa-alfalfa rotation is significantly different from that required to manage a corn-soybean rotation, in both size and machinery type. It would be inaccurate to suggest that growers using one system could simply “switch” to the other system without significant changes to their machinery fleet, in addition to the changes to management practices. Both of these aspects of transition impose a cost on the transitioning grower that is not considered in this study.

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Table 1. Sizes assumed for each of 3 machinery complements

Implement	Size #1	Size #2	Size #3
	-----ft.-----		
Chisel plow	15	23	57
Moldboard plow	9	12	12
Field cultivator	18	23	47
Row planter	15	40	60
Grain drill	16	20	30
Rotary hoe	21	40	40
Row cultivator	30	40	40
Manure spreader			
Corn head	15	20	30
Soybean head	18	30	35
Mower conditioner	9	12	12
Hay rake	20	25	32
Baler	12	20	20

Table 2. Maximum farm for each of 3 machinery complements.

Crop rotation	Machinery Implement Group		
	Size #1	Size #2	Size #3
OI 4-yr	320	560	800
HI 2-yr	560	1,120	1,520

Table 3. Average number of field passes per acre

Implement	HI 2-yr	OI 4-yr
Chisel plow	0.5	0.25
Moldboard plow	0.5	0.25
Field cultivator	2.09	1.68
Row planter	1	0.5
Grain drill	0	0.25
Rotary hoe	0.09	0.65
Row cultivator	0.68	1.16
Combine: corn head	0.5	0.25
Combine: soybean head	0.5	0.5
Mower-conditioner	0	0.75
Hay Rake	0	0.75
Hay Baler	0	0.75
Total	5.86	7.74

Table 4. Average net return to the high input (HI) 2-yr and organic input (OI) 4-yr crop rotation from 1993 to 2010 for each farm-size and pricing scenario.

Crop rotation	Farm size	<u>Conventional Prices</u>		<u>Half Premiums</u>		<u>Full Premiums</u>	
		Net return	SD	Net return	SD	Net return	SD
-----US \$-----							
HI 2-yr	560	71,874	61,645	-	-	-	-
	1120	165,281	123,344	-	-	-	-
	1560	220,434	167,450	-	-	-	-
OI 4-yr	320	27,211	21,200	70,565	28,852	113,919	38,914
	560	53,293	37,117	129,163	50,514	205,032	68,124
	800	79,391	53,069	187,776	72,203	296,160	97,355



Table 5. Detrended crop yields from the Variable Input Crop Management

Systems (VICMS) trial for the high input (HI) 2-yr and organic input (OI) 4-yr

Year	CI 2-yr crop rotation		OI 4-yr crop rotation				crop rotations from 1993 to 2010.
	Corn Bu/A	Soybean Bu/A	Corn Bu/A	Soybean Bu/A	Oat Bu/A	Alfalfa Tons/A	
1993	117.4	45.4	116.6	39.6	33.5	5.4	
1994	220.7	49.0	189.1	53.0	88.2	4.9	
1995	138.9	48.8	138.6	52.1	38.0	4.5	
1996	194.9	56.0	168.1	53.1	62.2	4.9	
1997	150.1	47.8	131.2	23.7	47.2	4.6	
1998	216.4	49.7	204.4	29.8	48.6	5.0	
1999	197.4	52.1	190.2	44.8	80.9	5.0	
2000	185.8	47.3	181.8	27.4	74.2	5.5	
2001	171.9	46.7	177.0	45.4	75.6	6.7	
2002	147.3	44.1	179.1	46.9	42.7	4.5	
2003	160.4	25.9	144.6	22.6	63.6	4.2	
2004	178.8	56.0	174.0	22.8	50.2	4.6	
2005	184.5	45.1	190.4	32.0	44.7	5.4	
2006	198.2	52.5	188.8	28.4	113.6	5.5	
2007	153.2	49.4	159.9	37.5	129.5	6.4	
2008	133.6	42.7	124.1	24.3	136.7	5.3	
2009	175.4	44.7	165.0	20.2	123.9	4.7	
2010	196.8	59.2	185.0	40.5	84.3	4.6	
Mean	173.4	47.9	167.1	35.8	74.3	5.1	
SD†	29.0	7.1	25.8	11.5	32.9	0.6	

† SD, standard deviation.

Figure 1. Cumulative distribution function for the high input (HI) 2-yr and organic input (OI) 4-yr crop rotations, considering 100% of organic price premiums and each farm-size scenario.

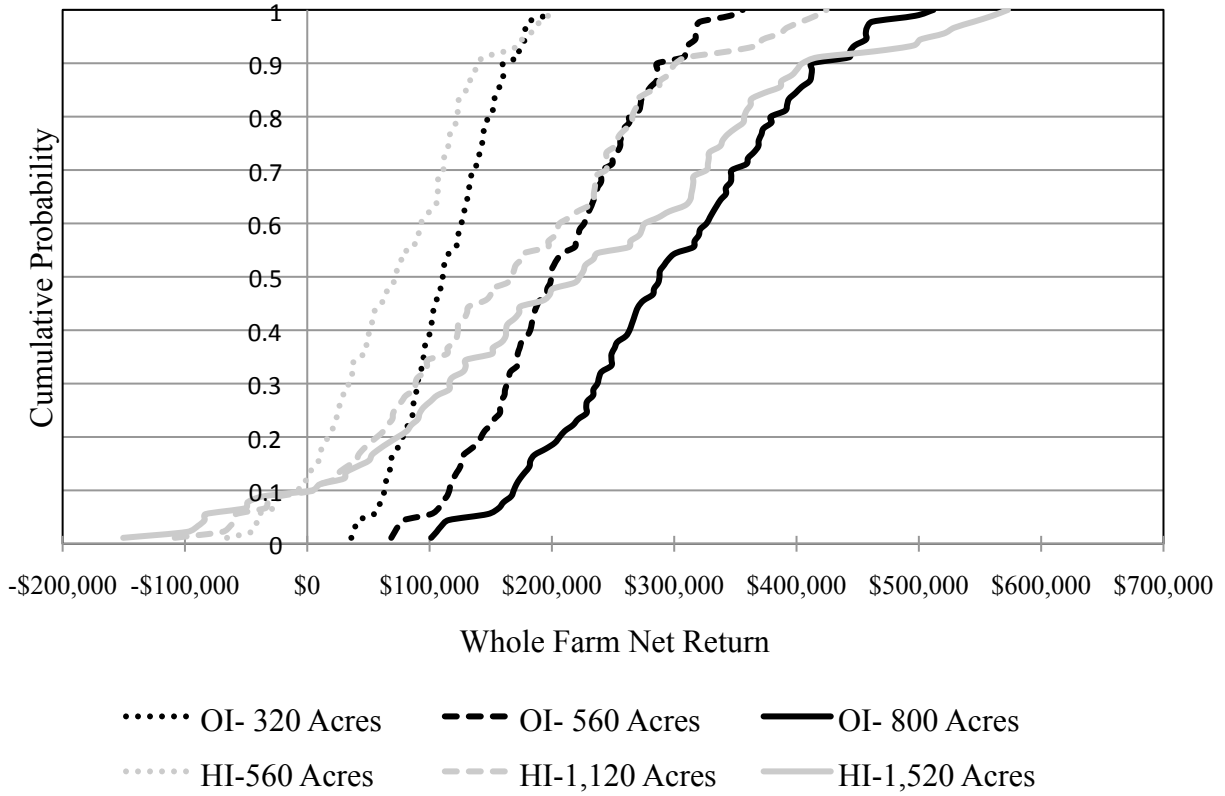


Figure 2. Cumulative distribution function for the high input (HI) 2-yr and organic input (OI) 4-yr crop rotations, considering 50% of organic price premiums and each farm-size scenario.

