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Profitability of organic cropping systems in southwestern Minnesota

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Abstract
In spite of concerns, Minnesota's dominant cropping system is the corn–soybean rotation using synthetic pesticides and chemically processed fertilizers. Using experimental data from 1990–99, this study compared the profitability of organic versus conventional strategies. Net return (NR) was calculated from actual yields, operations, inputs, prices and organic premiums. Yields and costs were lower for the 4-year organic strategy. With premiums, the 4-year organic strategy had NRs significantly higher than conventional strategies; without premiums, the NRs were statistically equal ($P = 0.05$). Thus, the 4-year organic strategy was not less profitable nor its NR more variable than the conventional strategies in this study.

Key words: net returns, Variable Input Crop Management Systems, high-purchased inputs, low-purchased inputs, organic inputs, cumulative distribution functions, organic premiums, risk, first-degree stochastic dominance, second-degree stochastic dominance

Introduction

By most measures, crop production systems are more efficient and productive today than at any time in the past. This is due, in large part, to improved crop varieties, improved farm equipment, better management skills, synthetic pesticides and chemically processed fertilizers. While the use of synthetic pesticides and chemically processed fertilizers has contributed significantly to gains in productivity, it has also raised concerns from the general public about food safety and adverse environmental quality effects. In addition, the current price and income situations have increased farmers' interest in organic production methods.

However, the vast majority of farmers in southwest Minnesota (and the Midwest) continue to produce crops with a traditional corn–soybean rotation using production practices that involve, at some level, chemical use and commercial fertilizers. Farmers' reasons for not changing from traditional cropping systems are as diverse as the farmers themselves. Some of the reasons include the uncertainty of the profitability of organic systems, increased labor that may be required by an organic system, lower yields with other systems, the cost in money and time to learn other systems, and the difficulty of finding markets for organic products.

Previous studies have analyzed the profitability, sustainability and yields of organic farming practices, and have shown generally that organic systems can be as, or more, profitable than conventional systems[1,2]. Although price premiums paid for organic products increase profitability and are highly sought after, Welsh found in his research review that they were 'not always necessary for organic systems to be competitive with or outperform conventional systems'[2]. However, these studies also found that organic systems were not necessarily without potential pitfalls and not necessarily for every farmer and farm site.

In response to the concerns about the impact of conventional farming practices, the University of Minnesota started the Variable Input Crop Management Systems (VICMS) study in 1989, to estimate and compare the agronomic and economic impacts of organic production methods in southwest Minnesota. To help decrease some of the uncertainty regarding profitability of organic production methods, this current study used data from the VICMS study to compare the profitability and riskiness of three different management strategies, two cropping sequences and three organic price scenarios. The value of this study comes from the use of a long-term study (10 years) in which each crop in each management strategy and each sequence is present and replicated three times in each year. Due to the continued dominance of conventional production systems, the current study's primary objective was to test the hypothesis that conventional systems were more profitable and/or had less risk than organic systems.

Background

Sales of organically grown products have increased steadily over the past two decades[3]. Even though the numbers are small relative to the entire food market, the number of organic products on grocers' shelves and the amount of grocery shelf space being devoted to organically produced products has increased. As consumers become more concerned about food and environmental safety, they also become more concerned about the practices and inputs being used to produce the food they consume. Since some consumers are willing to pay a premium for products produced by organic methods, there appears to be a separate demand for organic products in the marketplace. In addition, as Krissoff (1998)[4] notes, 'increasing farm, agribusiness, and food marketing investments in alternatively produced products suggest a responsiveness to the growing interest in the organic foods'.

In general, organic systems do not use synthetic pesticides and chemically processed fertilizers, and have longer crop sequences with a greater variety of crops being grown. However, the specific methods, certification of organic methods, and labeling of organic products were not uniform across the US until the National Organic Program (NOP) rules were finalized in December 2000, and fully implemented in October 2002. Under the NOP rules, all organically labeled products must be produced and processed using a set of specific standards, to ensure consistent practices nationwide. Organic producers must operate under an organic system plan approved by an accredited certification agency or agent. Under these standards, if a product is to be sold and labeled as organically produced, all materials used in production must be used in accordance with the National List of Allowed Synthetic and Prohibited Non-Synthetic Substances. Specifically, the NOP crop production standards[5] state that:

> Land will have no prohibited substances applied to it for at least 3 years before the harvest of an organic crop. The use of genetic engineering (included in excluded methods), ionizing radiation and sewage sludge is prohibited. Soil fertility and crop nutrients will be managed through tillage and cultivation practices, crop rotations, and cover crops, supplemented with animal and crop waste materials and allowed synthetic materials. Preference will be given to the use of organic seeds and other planting stock, but a farmer may use non-organic seeds and planting stock under specified conditions. Crop pests, weeds, and diseases will be controlled primarily through management practices including physical, mechanical, and biological controls. When these practices are not sufficient, a biological, botanical, or synthetic substance approved for use on the National List may be used.

Study Location and Design

The VICMS study was situated at the University of Minnesota's Southwest Research and Outreach Center near Lamberton, Minnesota, about 240 km southwest of Minneapolis-St. Paul. In this area of Minnesota, crop production began in the 1870s, with wheat grown almost exclusively. From the 1900s until the 1960s, corn, small grains and pasture predominated. Since the 1960s, this region has been farmed almost exclusively with corn and soybean. Recently, corn and soybean were grown on more than 90% of the cropped land in southwest Minnesota[6].

The data for this study were from part of the study called VICMS II, which had been cropped according to university recommendations since 1959, resulting in high soil fertility levels and low weed populations. Since the common soil condition in this part of Minnesota was high fertility and low weed pressure, the VICMS II data were important for producers interested in the transition from conventional practices to organic practices. Data from 1990 to 1999 were used in this study. Although they may differ from actual farm yields, the yields obtained in these research trials were considered the best comparison of different management strategies and cropping sequences, due to being obtained on the same location with all crops present in every year.

The three management strategies analyzed in this study used a low level of purchased inputs, a high level of purchased inputs and organic inputs. Both high and low levels were included, since the set of practices thought of as 'conventional' was similar to the high level of inputs at the beginning of the study, but had moved closer to the low level of inputs by 1999. A general description of each strategy is given below, with a general description of the production practices followed in each strategy listed in Table 1.

Low purchased inputs (LI)

Chemical applications were minimized by banding of fertilizers, banding of post-emergent herbicides (if needed), utilization of mechanical weed control, use of insecticides only if prescribed and similar practices. A realistic yield goal was used to determine fertilizer rates. This realistic yield goal was based on soil type, water availability,

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Table 1. General description of the three management strategies: low purchased inputs (LI), high purchased inputs (HI), and organic inputs (OI)[1] for four crops.

	LI	HI	OI
Corn			
Prior fall tillage[2]	None	Chisel	Chisel
Spring tillage	Field cul. (2×)	Field cul. (2×)	Field cul. (2×)
Rotary hoeing	1–3× (as needed)	None	1–3× (as needed)[3]
Row cultivation	2–3×	1–3×	2–3×
Tillage after harvest	MB	MB	MB
Herbicides	Pre-e post.	Pre-e post.	Organic
Fertilizer application	Banded	Broadcast	Organic
Soybean			
Prior fall tillage	Soil saver	MB	MB
Spring tillage	Field cul./disk	Field cul./disk	Field cul./disk
Rotary hoeing	1–2×	None	1–2×
Row cultivation	2–3×	1–2×	2–3×
Tillage after harvest	None	Chisel	Chisel
Herbicides	Pre-e post.	Pre-e post.	None
Fertilizer application	Banded	Broadcast	Organic
Oat			
Prior fall tillage	None	Chisel	Chisel
Spring tillage	Field cul. (1×)	Field cul. (1×)	Field cul. (1×)
Rotary hoeing	None	None	None
Row cultivation	None	None	None
Tillage after harvest	None	None	None
Herbicides	None	None	None
Fertilizer application	Broadcast	Broadcast	Organic
Alfalfa			
Prior fall tillage	None	None	None
Spring tillage	None	None	None
Rotary hoeing	None	None	None
Row cultivation	None	None	None
Tillage after harvest	MB	MB	MB
Herbicides	None	None	None
Fertilizer application	Broadcast	Broadcast	Organic

Field cul., field cultivation; MB, moldboard plowing; Pre-e post., pre-emergent, post-emergent.

[1] Specific operations used each year may have been different.

[2] In the 4-year rotation the previous fall tillage was moldboard plowing (MB) of the alfalfa residue.

[3] For the OI strategy, the fertilization was with fall-applied, composted beef manure for the 4-year rotation, and spring-applied swine manure for the 2-year rotation.

growing season length and actual recorded yields in the past, not an optimistic view of the soil potential.

High purchased inputs (HI)

Chemical applications were not necessarily minimized. Broadcast (no banding) fertilizers and insecticides were used according to university recommendations. Pre-emergent herbicides were often used. Other practices were selected on the basis of what were considered the best conventional practices for this region. An optimistic yield goal was used to determine fertilizer rates. However, even this optimistic yield goal was 'realistic' in that it, too, was based on actual recorded yields in the past, not an optimistic view of the soil potential.

Organic inputs (OI)

No synthetic chemical applications were used. Organic sources of nutrients, such as manure, and mechanical weed control were utilized. The OI strategy incorporated the best organic practices for the region, based on practices approved by a designated certification organization recognized by the Minnesota Department of Agriculture. The OI crops were not certified under NOP rules, but could have been. Potential organic premiums were not applied until certification was possible under organic certification standards (i.e. the third crop) in the 4-year sequence.

These three management strategies were carried out in two cropping sequences: the popular two-year sequence (corn–soybean) and a four-year sequence (corn–soybean–

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Table 2. Typical harvest cash prices from the Southwestern Minnesota Farm Business Management Association (SW Ass'n) and all Minnesota (US$ Mg^{-1}).

Crop	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Corn										
SW Ass'n	78.75	82.69	70.87	88.59	70.87	108.28	94.50	94.50	68.91	68.91
Minnesota	81.11	84.66	75.21	83.47	75.60	100.41	102.77	92.53	68.12	59.85
Soybean										
SW Ass'n	211.31	92.94	192.94	220.50	183.75	211.31	257.25	238.87	189.26	189.26
Minnesota	212.78	199.92	193.67	216.09	198.45	212.41	264.60	234.46	182.65	158.02
Oats										
SW Ass'n	86.13	68.91	68.91	86.13	75.80	103.36	137.81	137.81	82.69	82.69
Minnesota	72.35	68.22	83.38	88.89	74.42	94.40	135.06	103.36	67.53	60.64
Alfalfa										
SW Ass'n	66.15	55.13	60.64	77.18	77.18	77.18	88.20	104.74	71.66	71.66
Minnesota	104.74	73.32	88.48	105.01	82.41	80.21	92.61	115.49	88.48	72.49
Oat straw (US$ $bale^{-1}$)										
SW Ass'n	1.00	1.00	1.00	1.50	1.50	1.75	2.00	2.00	1.00	1.50

Sources: Adapted from annual association reports [e.g., Olson et al. (1992)[7]] and annual *Minnesota Agricultural Statistics* [e.g., Minnesota Agricultural Statistics Service (2001)[6]].

oat/alfalfa–alfalfa). Rotation restrictions did not allow the certification of a 2-year corn–soybean sequence as organically produced so, even though an organic management strategy was followed, crops grown under the 2-year sequence did not receive an organic premium in any year. Every crop in each cropping sequence was grown every year under each management strategy, so all treatments were present each year. Each combination of strategy and sequence was replicated three times in each year.

Data Collection and Analysis Methods

Detailed records have been maintained on field operations, labor used, rainfall, plant growth, weed counts (broadleaf and grasses separately), earthworm species and counts, mycorrhiza in the soil and plants, and crop yield. Soil phosphorus (P) and potassium (K) fertility levels were determined in the fall, and soil nitrate levels were determined in 0.304-meter increments to 1.52 m following alfalfa and soybeans.

The net return (NR) was calculated as gross income from the crops produced minus the direct production costs for each management strategy, cropping sequence and year. NR was expressed as the return per one hectare averaged over either two or four crops. The value of corn and soybean was included in NR for the 2-year sequence, and the value of corn, soybean, oat, oat straw, and alfalfa was included for the 4-year sequence. The gross income of each crop was calculated by multiplying the actual crop yield by the typical harvest cash price plus a potential organic premium (if applicable). The yield was the average of three replications. Typical harvest cash prices were those reported annually by the Southwestern Minnesota Farm Business Management Association (SWMFBMA, Table 2). Harvest prices were used (versus annual average prices) to account for the value of production only and not for marketing skill. These SWMFBMA prices were used since they were considered to reflect more accurately the prices faced by farmers close to the VICMS study site, compared to using an overall Minnesota average price. Except for alfalfa and the oat price in later years, the SWMFBMA prices followed the annual levels and patterns of average harvest-time prices in Minnesota. Direct production costs were determined by the actual operations, input levels used and local input prices. The costs for land, management and indirect costs (farm insurance, marketing and so on) were not subtracted from the gross value of the crops because they would not vary between strategies and sequences. Thus, NR was the net return to land, management, indirect labor and other indirect costs for each management strategy and cropping sequence.

Production costs were estimated for each year using the actual cultural operations, equipment and inputs used, as listed in the research field records for each strategy and sequence. The cost of each operation was calculated using the University of Minnesota Extension Service's annual estimates of machinery costs, which included fuel, maintenance, repairs, operator labor and overhead costs of the machinery[8]. Each strategy and sequence was charged the same cost per pass for the same operation (cultivating, for example), but the total cost per hectare varied when the number of passes varied (two cultivations versus one cultivation, for example). Labor costs for machinery operations were included in extension's estimates, but since no records were kept to show differences in time required for pest scouting, managing, marketing and other indirect labor use, these labor costs are not included in the calculation of NR. Manure application costs were included in the organic systems, but no manure purchase cost was included. Local market prices were used for inputs except for seed and herbicide. Seed costs were taken from annual SWMFBMA records[7]. Herbicide prices were taken from University of Minnesota Extension Service's annual weed control report[9]. Total crop production costs were the sum of tillage, planting, fertilizer, pest control, harvesting and hauling costs.

Due to insufficient annual information on organic premiums in Minnesota (and the US) for 1990 through 1999, potential organic premiums were estimated for corn, soybean and oat using information compiled by Dobbs and Pourier for 1995 through 1998[10] (Table 3). Over these 4 years, the average price for certified organically produced corn was 160% of the average US cash price for non-organic corn; that is, the average premium for organic corn was 60% over the average non-organic corn. The average price for certified organically produced soybean was 236% of the average US cash price for non-organic soybean; that is, the average premium for organic soybean was 136% over non-organic soybean. The average price for certified organically produced oat was 163% of the average US cash price for non-organic oat; that is, the average premium for organic oat was 63% over the average non-organic oat. In the absence of reliable annual data on organic prices, these average organic premiums were applied to the typical harvest cash prices for corn, soybean and oat in the 4-year OI strategy, starting in 1992, the third year of production and the first that could be certified as organic. Production in 1990 and 1991 did not receive an organic premium because the land had not been in a certified organic production system for the required 36 months. This pattern of not applying organic premiums in the first 2 years but then applying them to eligible production in the third and following years simulated the transition a conventional farmer would have to go through to sell organically produced crops as certified organic. Due to lack of data, no price premium was considered for either organic alfalfa or organic oat straw. Because it would not meet NOP rules for certification, crops grown under the 2-year sequence did not receive organic premiums in any year, even though all other organic practices were followed. Using the same average organic premium for all years reduced the potential variability of NRs; however, the alternative of using annual premiums based on very little data seemed much less desirable.

Potential organic premiums vary from year to year and are also dependent on each individual producer's marketing strategies and abilities. To reflect this variability, three organic price scenarios were evaluated as well as the sensitivity to the oat straw price. In the first scenario (as discussed in the previous paragraph), corn, soybean and oat grown under the 4-year, OI strategy received the full historical average organic premium starting in the third year, i.e., 1992. The second price scenario was more conservative and assumed that eligible crops received only half of the historical average organic premiums starting in 1992 (or that only half of the eligible production received the historical average). The third price scenario contained no organic premiums even for certified organic production; every crop in every management strategy and sequence received the typical harvest cash prices reported earlier. This last price scenario was useful to evaluate the situation that may occur if a farmer could not obtain the organic premium or if the supply of organic production increased faster than the demand and put downward pressure on the organic premium. In all three price scenarios, non-organic crop production from the 2-year OI strategy and both sequences of the HI and LI strategies received only the typical harvest cash prices in every year. To evaluate whether the straw value would affect a farmer's choice of production method, the oat straw price was set to zero and NRs recalculated in a subsequent evaluation for all three scenarios.

Table 3. Average organic price premium ratios based on organic price quotes and US cash prices.

Year	Corn	Soybeans	Oats
1995	1.35	2.14	1.35
1996	1.43	1.85	1.59
1997	1.73	2.41	1.73
1998	1.88	3.02	1.83
Average ratio	1.60	2.36	1.63
Average premium	60%	136%	63%
Half of the average premium	30%	68%	31.5%

Source: Dobbs and Pourier (1999)[10].
Note: Due to insufficient data on organic prices for alfalfa and oat straw, no organic premiums were estimated for these two crop products.

Risk, that is, the variation in NR, was analyzed using stochastic dominance. Cumulative distribution functions (CDFs) of NRs were calculated based on the yields, market prices, input costs, potential organic premiums, correlations between crop yields and correlations between crop yield and market price. The CDFs were calculated using a program called Crystal Ball© (CB), which is an add-in program that functions within Microsoft's Excel©. Crystal Ball© was used to develop a probability distribution of net returns based on the averages and distributions of yields and market prices, average input costs, average potential organic premiums, correlations between crop yields, and correlations between crop yields and market prices. The distribution assigned to each individual crop yield within each strategy and sequence was based on actual recorded yield data, with the Kolmogrov–Smirnov (KS) test used to determine the best fitting distribution. Eleven distributions (Normal, Lognormal, Weibull, Triangular, Uniform, Beta, Exponential, Gamma, Logistic, Pareto, and Extreme Value) were considered. The top three best-fitting distributions (based on the KS test) were compared visually to the distribution of the actual yields as a visual check of their goodness-of-fit. For crop yields, 30 yield observations (3 replications/crop for 10 years) from each crop were used in fitting the distributions; if available, 33 observations from

Table 4. Price/yield correlations for each crop in each cropping sequence and management strategy from 1990 through 1999 in the VICMS II study.

Strategy	Corn 2-year	Soybean 2-year	Corn 4-year	Soybean 4-year	Oat 4-year	Alfalfa 4-year	Oat straw 4-year
LI	–0.847	0.059	–0.700	0.049	–0.252	–0.020	–0.525
HI	–0.683	–0.127	–0.734	–0.024	–0.341	–0.004	–0.525
OI	–0.197	–0.226	–0.557	–0.260	–0.314	0.091	–0.537

Source: Estimated from actual VICMS II experiment yield data and the prices listed in Table 2.
LI, low purchased inputs; HI, high purchased inputs; OI, organic inputs.

Table 5. Yield correlations for each crop in each cropping sequence and management strategy from 1990 through 1999 in the VICMS II study.

Strategy	Corn/SB 2-year	Corn/SB 4-year	Corn/oat 4-year	Corn/alfalfa 4-year	SB/oat 4-year	SB/alfalfa 4-year	Oat/alfalfa 4-year	Oat/oat straw 4-year
LI	0.643	0.558	0.369	–0.127	0.401	–0.479	–0.672	1.000
HI	0.713	0.456	0.353	–0.163	–0.080	–0.259	–0.570	1.000
OI	0.338	0.038	0.069	–0.180	0.328	–0.166	–0.667	1.000

Source: Estimated from actual VICMS II experiment yield data.
LI, low purchased inputs; HI, high purchased inputs; OI, organic inputs.

11 years were used. Using the same methods as for yields, crop price distributions were estimated using data from 1990 through 1999.

The total input cost of each crop in the risk analysis of the study was assumed to be constant, based on the actual historical 10-year average of input costs. Average projected costs were used since historical input prices, actual yields and field operations were used in the calculation of the yearly input costs. By using the 10-year average of input costs, it more accurately reflects the relationships and actual decisions made historically. Input costs in this part of the analysis were held constant because this is most likely the way individual farmers would represent their own costs in a similar forecasting or budgeting scenario. Potential organic premiums (i.e., ratios of organic prices to US cash prices) were also considered constants due to the lack of adequate data to estimate a sound distribution based on the historical data.

Correlations between crop yield and price were calculated using actual crop yields and their respective crop prices (Table 4). Correlations between crops were also calculated, using the actual recorded crop yields from the VICMS II data correlating the corn yield to other crops in the sequence (i.e., soybeans in the 2-year sequence and soybeans, oats and alfalfa in the 4-year sequence; Table 5).

Using the assigned distributions of crop yields and crop market prices, CB calculated 500 different possible random draw combinations of crop yields and prices. Using these 500 possible outcomes of yield and price, in addition to input costs and potential organic premiums, 500 possible outcomes of NR for each input strategy and cropping sequence were also calculated. The 500 estimated NRs for each cropping sequence and input strategy were then used to develop their respective CDFs.

First-degree stochastic dominance (FSD) and second-degree stochastic dominance (SSD) were used to determine farmers' potential risk preferences between input strategies and cropping sequences[11].

Results

Annual corn and soybean yields in the 4-year sequences under the LI, HI and OI strategies tend to be equal to, or better than, the corn and soybean yields in the 2-year HI and LI strategies (Figs. 1 and 2). However, the average yields were not substantially different, except for the 2-year OI strategy, which had lower yields (Table 6). Although they are not shown, annual oat and alfalfa yields in all strategies followed very similar patterns. Only in 4-year OI corn could a potential transition period be seen due to its lower yields relative to other strategies (except 2-year OI); however, this period was uncertain, due to all strategies and sequences having lower yields in the fourth, extremely wet year. For other crops, the 4-year OI yields follow the annual patterns similar to other strategies (Figs. 3 and 4). Annual VICMS yields for all crops follow a similar pattern compared to the average yields reported for this part of Minnesota by the USDA. In most years, VICMS yields were higher than the USDA averages, with two exceptions. First, the organic yields (especially the 2-year rotation) were lower than average yields in this area. Secondly, the VICMS alfalfa yield was obviously higher in most years

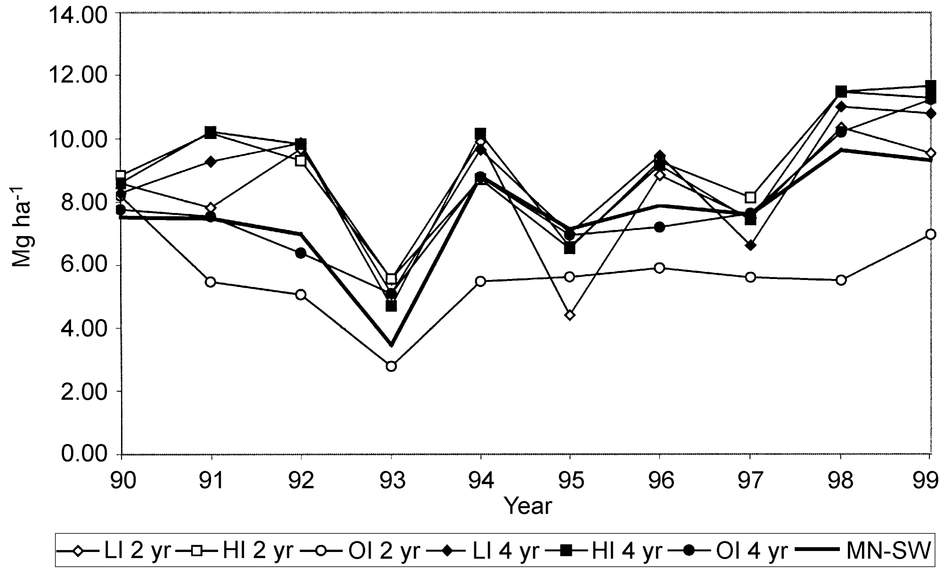

Figure 1. Corn yield by cropping sequence and management strategy, 1990–1999. LI, low purchased inputs; HI, high purchased inputs; OI, organic inputs; MN-SW, southwest Minnesota.

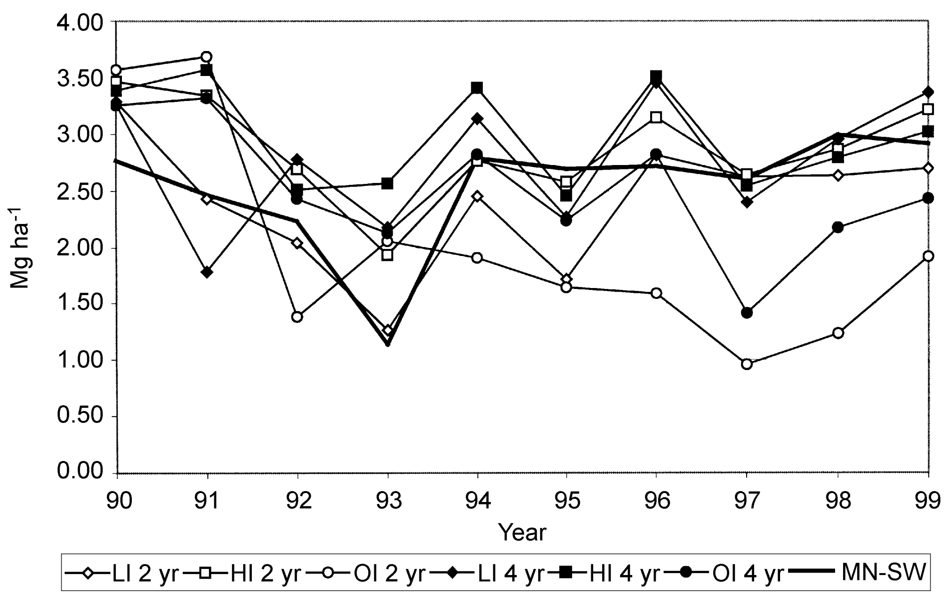

Figure 2. Soybean yield by cropping sequence and management strategy, 1990–1999. LI, low purchased inputs; HI, high purchased inputs; OI, organic inputs; MN-SW, southwest Minnesota.

than the USDA average. The higher alfalfa yields may be due to the VICMS study site being on better soils than most alfalfa fields in southwest Minnesota, and/or due to more management time spent on alfalfa within VICMS than an average farmer would spend. Porter et al. (2003)[12] provided a more detailed analysis of the agronomic results in the VICMS study.

Relative to the yields under conventional management, VICMS organic yields were similar to those obtained in other studies in the Midwest. In the VICMS II study, the 4-year OI corn yield was 89% of the 2-year HI corn yield, and the 4-year OI soybean yield was 86% of the 2-year HI soybean yield. In a study at Iowa State, the 10-year average organic corn yield was 81% of the conventional corn yield; soybean was not included in the organic rotation[2]. In Nebraska, the 8-year average organic corn yield was 85% of the conventional corn yield, and the 8-year average organic soybean yield was 84% of the conventional soybean yield[2]. In South Dakota State, the 7-year average organic corn yield was 84% of the conventional corn yield

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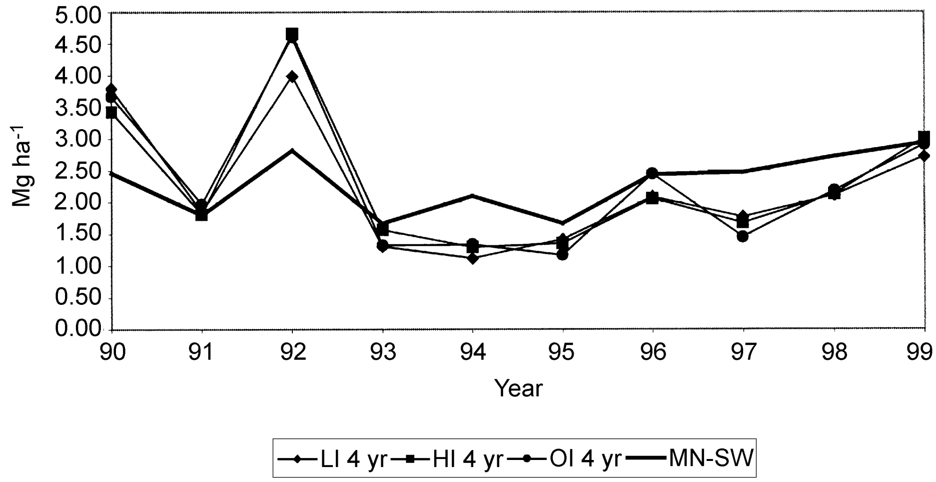

Figure 3. Oat yield by cropping sequence and management strategy, 1990–1999. LI, low purchased inputs; HI, high purchased inputs; OI, organic inputs; MN-SW, southwest Minnesota.

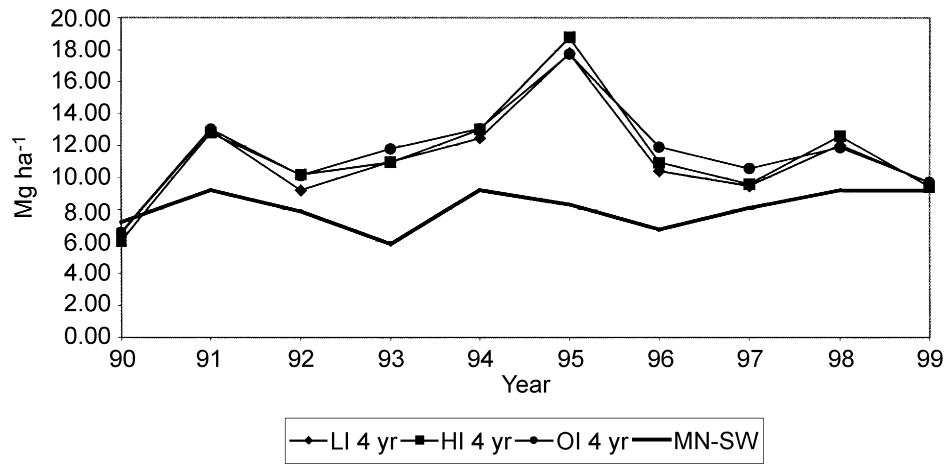

Figure 4. Alfalfa yield by cropping sequence and management strategy, 1990–1999. LI, low purchased inputs; HI, high purchased inputs; OI, organic inputs; MN-SW, southwest Minnesota.

Table 6. Average crop yields for each crop in each cropping sequence and management strategy from 1990 through 1999 in the VICMS II study (Mg ha^{-1}).

Strategy	Corn 2-year	Soybean 2-year	Corn 4-year	Soybean 4-year	Oats 4-year	Alfalfa 4-year
LI	8.22 (1.95)*	2.42 (0.58)	8.72 (1.92)	2.75 (0.57)	2.22 (1.00)	11.2 (2.01)
HI	8.90 (1.88)	2.89 (0.45)	8.97 (2.21)	2.96 (0.46)	2.29 (1.08)	11.4 (3.36)
OI	5.64 (1.38)	2.02 (0.93)	7.90 (1.79)	2.49 (0.57)	2.29 (1.14)	11.6 (2.91)

* Standard deviations are in parentheses.

and the 7-year average organic soybean yield was 99% of the conventional soybean yield[2].

In both the 2- and 4-year sequences, the HI strategy had the highest average direct production costs compared to the LI and OI strategies (Table 7). The OI strategy had the lowest costs. Direct production costs for corn in the 2-year sequence averaged US$116 higher per hectare under the HI strategy than under the OI strategy. In the 4-year sequence, the production costs for corn averaged US$89 higher under the HI strategy than under the OI strategy. The variation between years was also higher for all crops under the HI strategy, as shown by

Table 7. Average crop production costs (US$ ha^{-1}) for each crop in each cropping sequence and management strategy from 1990 through 1999 in the VICMS II study.

Strategy	Corn 2-year	Soybean 2-year	Corn 4-year	Soybean 4-year	Oats 4-year	Alfalfa 4-year
LI	291 (28.7)*	190 (16.3)	294 (28.7)	190 (18.0)	205 (32.1)	247 (41.7)
HI	358 (39.0)	203 (18.3)	351 (47.7)	217 (27.9)	222 (35.1)	257 (55.3)
OI	242 (16.5)	180 (24.0)	262 (13.8)	185 (14.3)	170 (16.5)	225 (35.3)

* Standard deviations are in parentheses.

Table 8. Average net returns for each crop in each cropping sequence and management strategy from 1990 through 1999 in the VICMS II study.

Strategy and pricing alternative	2-year sequence (US$ ha^{-1})	4-year sequence (US$ ha^{-1})
LI	339.4 (120.8)[b,c]	426.3 (91.1)[b]
HI	378.4 (108.4)[b]	423.9 (80.5)[b]
OI with average OP	–[1]	667.4 (188.2)[a]
OI with half the average OP	–[1]	550.1 (130.4)[a]
OI with no OP	227.7 (121.5)[c]	433.0 (84.5)[b]

OP, organic premiums.
[1]Since the 2-year OI strategy did not meet the organic certification rules, it could not receive organic premiums.
Standard deviations are in parentheses.
Different letter superscripts indicate statistically significant differences between means ($P = 0.05$).

the higher standard deviations. The lower costs for the OI strategy were primarily due to no expenditures for synthetic pesticides and chemically processed fertilizers, even though this strategy did pay more for additional mechanical weed control.

When full historical average organic price premiums (starting in the third year according to NOP rules) were applied to corn, soybean and oat grown under the 4-year OI strategy, the 10-year average NR was US$667 per hectare (Table 8). This was significantly ($P = 0.05$) higher than the HI and LI strategies in both the 2- and 4-year sequences. The 4-year HI strategy had an average NR of US$424 ha^{-1}, and the 4-year LI strategy had an average NR of US$426 ha^{-1}. The 2-year HI strategy had an average NR of US$378 ha^{-1}, and the 2-year LI strategy had an average NR of US$339 ha^{-1}. Although they look different, the average NRs for the 4-year HI and LI strategies were not significantly ($P = 0.05$) different from the 2-year HI and LI strategies.

The 2-year OI strategy did not meet NOP rules for certification and, thus, could not receive any organic premiums in any year. Its average NR was US$227 ha^{-1}, which was significantly ($P = 0.05$) lower than any other strategy and sequence except for the 2-year LI strategy.

If only half the historical average organic premiums were received (or half of the production received the historical premium), the average NR for the 4-year OI strategy was US$550 ha^{-1}. This was statistically equal to the 4-year OI strategy when it received the full historical organic premium, but significantly ($P = 0.05$) higher than all other strategies and sequences.

If the 4-year OI strategy did not receive any organic premiums, its average NR was US$433 ha^{-1}. This was not significantly ($P = 0.05$) different from the 4-year HI and LI strategies, and seemingly higher but not significantly ($P = 0.05$) different from the NRs received from the 2-year HI and LI strategies.

The annual movements in the NR echo the similarities and differences noted in the averages just discussed. For clarity in the graph, only selected strategies and sequences were chosen to highlight the annual patterns (Fig. 5). The effect of starting to receive the organic premium in the third year was obvious as the annual NRs are substantially higher for the 4-year OI strategy compared to the other NRs. The higher levels of NR for the 4-year sequences can also be seen compared to the 2-year HI strategy.

When the oat straw price was set equal to zero for all 4-year sequences, the general level of NR decreased, but only one change in significance occurred. The only change was for the 4-year OI strategy with half of the historical organic premium, the NR of which became statistically ($P = 0.05$) the same as the 4-year OI strategy with no premium and the HI and LI strategies in both the 2-year and 4-year sequence. Even with an oat straw price of zero, the NR for the 4-year OI strategy with the full historical premium remained

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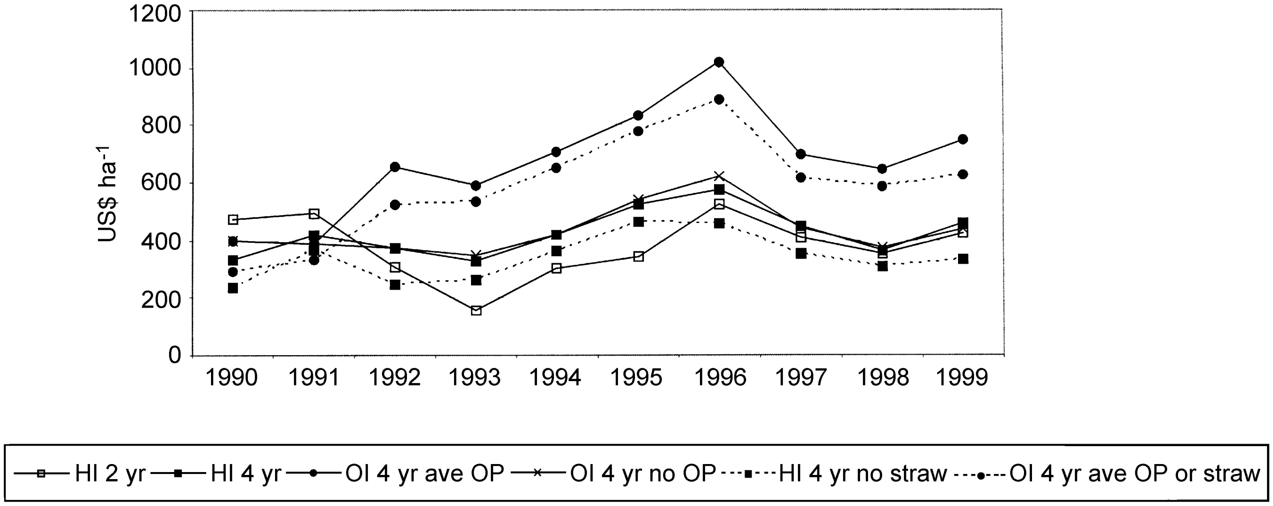

Figure 5. Annual net returns, selected strategies and sequences, 1990–1999. HI, high purchased inputs; OI, organic inputs; OP, organic premiums; ave, average.

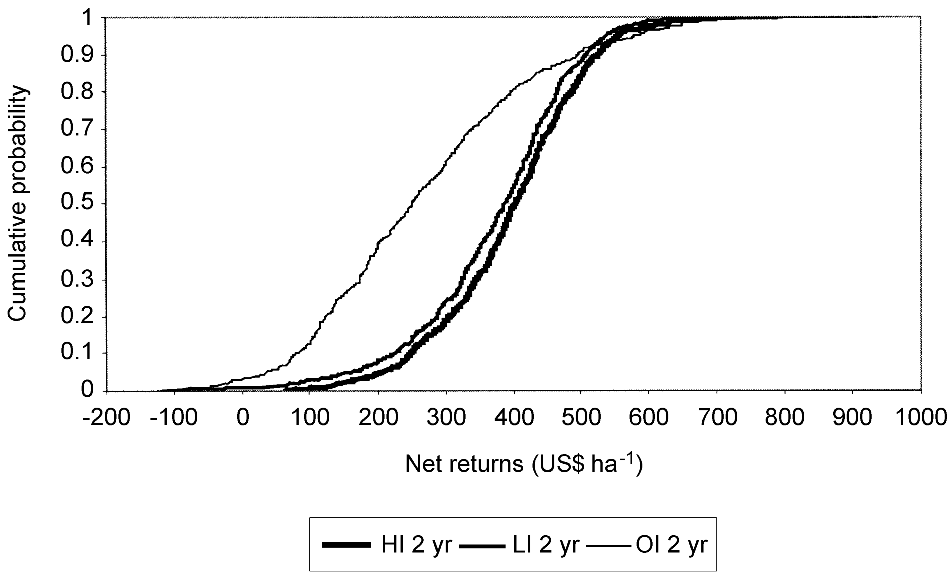

Figure 6. Cumulative distribution functions of net returns for low purchased input (LI), high purchased input (HI) and organic input (OI) strategies, 2-year sequence with conventional market prices.

significantly ($P = 0.05$) higher than all other strategies and sequences.

When all input strategies received conventional prices in the 2-year sequence, both the HI and LI strategies dominated the OI strategy by SSD, and the HI strategy dominated the LI strategy by FSD (Fig. 6). Therefore, under the 2-year sequence, with all input strategies receiving the same market prices, the HI strategy would be preferred over the OI and LI strategies.

With all input strategies receiving the same conventional market prices (including the initial positive straw prices) under the 4-year sequence, the CDF of the OI strategy was equal to, or strictly below and to the right of, the CDF of the HI strategy, thus dominating the HI strategy by FSD under the 4-year sequence (Fig. 7). Under the 4-year sequence there was no FSD or SSD between the OI and LI strategies. Although it is not clearly visible in Figure 7, the LI strategy had a lower NR than the HI strategy at a probability level of 1% or less (i.e., the CDF of the LI strategy begins to the left of the CDF of the HI strategy), therefore there was neither FSD nor SSD between the LI and HI strategies. However, starting at a probability level below 5%, the LI strategy had a higher NR at all probability levels.

With conventional market prices, the LI and OI 4-year strategies would be preferred to the 2-year HI strategy

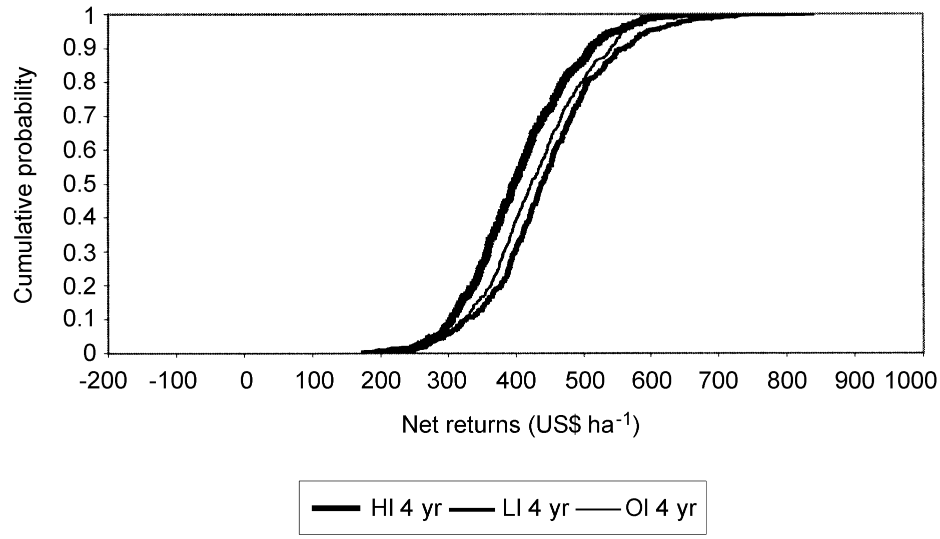

Figure 7. Cumulative distribution functions of net returns for low purchased input (LI), high purchased input (HI) and organic input (OI) strategies, 4-year sequence with conventional market prices and no organic premiums.

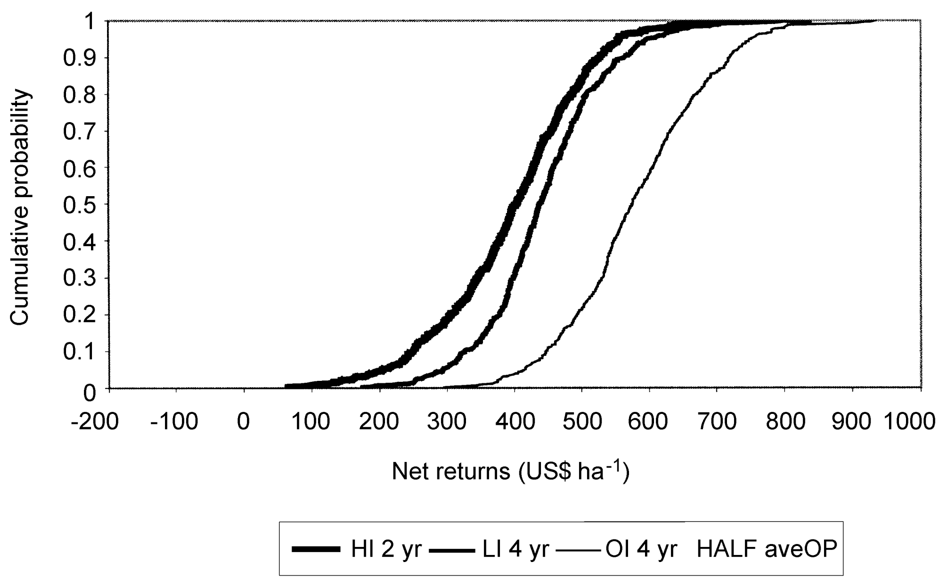

Figure 8. Cumulative distribution functions of net returns for 2-year high purchased input (HI) strategy and 4-year low purchased input (LI) strategy with conventional market prices and 4-year organic input (OI) strategy with half of the historic organic premiums (OP).

because they dominated the 2-year HI strategy by FSD and SSD, respectively. There was neither FSD nor SSD between the 4-year LI and 4-year OI strategies.

When the full organic premium for the OI strategy was added to the risk analysis under the 4-year sequence, the results of the OI strategy changed dramatically. The CDF of the OI strategy shifted notably to the right, and thus the OI strategy dominated the LI and HI strategies by FSD. The LI and HI strategies did not change since they were still receiving conventional prices, and thus there was still no FSD or SSD between the LI strategy and the HI strategy. Adding the full organic premium to the 4-year OI strategy clearly made it the preferred strategy over all other input strategies and crop sequences.

Applying half of the historical average organic premiums to the OI crop in the 4-year sequence also resulted in the OI CDF moving notably to the right (Fig. 8). The 4-year OI strategy was again clearly below and to the right, and thus preferred to both the LI 4-year and HI 2-year strategies when applying half the premium to the 4-year OI strategy. In other words, the 4-year OI strategy with half of the historical average organic premiums had a higher NR at all probability levels than the 2-year HI and 4-year LI strategies with conventional market prices.

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Conclusions

This research has shown the long-term impact on net returns of organic cropping strategies compared to conventional strategies. Even though crop yields were lower under the 4-year OI strategy, so too were its production costs. As a result, the 4-year OI strategy was able to produce NRs per acre statistically equal to the NRs under LI and HI strategies without any organic premiums, and significantly higher NRs when it received either full or half of the historical organic premiums. When the variability of NRs was analyzed using stochastic dominance, the 4-year OI strategy (with either full or half of the historical organic premiums) dominated all other strategies and sequences. When no organic premiums are applied, the 4-year LI strategy had higher NRs except at low probability levels (i.e., below 5%) although the CDFs are close visually. Based on these per-acre results, the original hypothesis of this study, that conventional agriculture (as represented by the HI and LI strategies) was more profitable and/or involved less risk than a 4-year OI strategy, must be rejected for this part of Minnesota.

This result, that conventional agriculture is not obviously more profitable or less variable on a per acre basis, supports the continuance of the current programs supporting organic farming, such as production research (including crop insurance coverage), market information and development, and policies at the federal and state levels. Policies that include subsidizing farmers for the environmental benefits of organic production methods warrant further development and refinement. Companies in the food-supply chain can continue to make investments to increase their capacity to handle organic products. Farmers and their advisors can be more confident in the potential benefits of investing the time and costs to learn the skills needed to grow and market certified organic products and to control potential problems.

Therefore, using the data from this study and the resulting profitability and risk analysis, the perception that conventional agriculture is more profitable, and/or involves less risk than a 4-year organic strategy, is not true for this part of southern Minnesota.

However, further research is still needed in several areas. This current study should be extended to include the VICMS trials that started on land with low fertility and high weed seed counts as well as the data from recent and future years. The NRs at the whole-farm level (versus the per-hectare calculations in the current study) should also be evaluated to estimate the impact of higher labor needs with organic methods. Further work is needed on the impact on crop prices and organic premiums of a substantial shift from the dominant corn–soybean sequence to longer cropping sequences. While considerable work has been done on consumer demand for organic products, more work is needed on the entire supply chain for organic products. Research is also needed on the feasibility of smaller livestock production units on organic farms, as well as the availability and associated costs of obtaining organic manure from larger livestock units. Additional research is needed on organic production methods, including the feasibility of including green manures in the cropping system, organic weed control and cropping sequences other than those included in VICMS.

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