

Overview of the University of Minnesota Variable Input Crop Management Systems (VICMS) Trials

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X.1 Overview

Two Variable Input Crop Management Systems (VICMS) trials, initiated in southwestern Minnesota USA in 1989, evaluated the interactions of crop rotation length with various management strategies. Claims were being made that soils farmed with organic practices were more mellow, dried more slowly, and had more beneficial organisms than soils farmed with conventional practices using synthetic chemical inputs. We hypothesized that for crop yields there would be a rotation length by management strategy interaction when the crops were managed with organic and conventional management practices, and that these interactions could be explained in part by changes in soil properties and pest pressures.

Each trial evaluated two rotation lengths and four management strategies. Rotation lengths included a 2-yr maize-soybean rotation and a 4-yr maize-soybean-oat/alfalfa-alfalfa rotation. The four management strategies were conventional production (HI for high input), low purchased inputs (LI for low input), organic production (OI for organic input), and a system where fertility levels were not maintained (ZI for zero input). To avoid the confounding effect of growing season, each crop in each rotation was present each year.

One trial (VICMS1) began on land with a history of no fertilizer or pesticide application and where soil fertility levels, specifically P, had been depleted over time. The other trial (VICMS2) began on land with a history of conventional fertilizer and pesticide application and where soil fertility levels had been built up.

X.2 Origin of the VICMS trials

From 1986 to 1988 there was discussion between the University of Minnesota College of Agriculture and outside groups working on sustainable agricultural and environmental issues. The University had previously been approached by farmer and community groups with concerns about the University's restricted focus on conventional, chemically-dependent agriculture. The concern was

that the University was focusing on conventional or even corporate agriculture and wasn't considering more ecological approaches, organic methods, or how to sustain small farms and rural communities. In response, a series of meetings between University faculty and a "sustainers' coalition" led to the establishment of the Minnesota Institute for Sustainable Agriculture (MISA), a University - sustainers' coalition partnership.

The perspective of most of the agriculture faculty at the University at that time was that even though the sustainers were well-meaning people, they dealt with the sustainability issue somewhat like a religion. Their thinking and policies appeared to be based on what they felt in their gut, or what they were afraid of, or believed in deeply; and not on replicable research. The faculty concluded field research was needed to provide a statistically-valid means of evaluating claims that soils farmed with organic practices were more mellow, dried more slowly, had more beneficial organisms, eroded less, and sponsored fewer diseases. Consequently, a trial was designed that would allow a randomized replicated comparison over years; be large enough to accommodate field-scale equipment; accommodate considerable sampling and probing by researchers; and allow valid economic comparisons.

A 65-ha site adjacent to the Southwest Research and Outreach Center near Lamberton, now known as the Elwell Agroecology Farm (EAF), was considered an ideal location to conduct such a trial. It had been historically managed with no chemical and few fertility inputs. The University decided to acquire the site and do serious planning about how it could be 'recovered and managed.' Input was sought from organic and low-input researchers and spokespersons from around the country. Consideration was given to not using any chemicals in cleaning up the site so that its "organic" status would not be compromised. Some considered not using chemicals to be unwise because the weed presence was overwhelming. They considered using various herbicides to do some initial "cleaning up", and then starting an organic approach. The concern of some organic farmers was that any attempt to represent organic farming on the site would be so compromised by weeds that conclusions would be worthless even though they could be tested with statistics. In the end, the concept of using no chemicals for weed control on the site prevailed.

The initial design of the trial involved comparing 2- and 4-yr rotations under different management strategies. Some in the sustainers' coalition protested the 2-yr rotation. They stated that a 2-yr rotation was not organically certifiable, and couldn't properly engage organic principles and benefits. Since the 2-yr maize-soybean rotation represented most of the planted acreage in the

region, and since there was a desire to determine if the on-site measurable benefits of certifiable organic management (more mellow soil, fewer diseases, etc.) would show up in the 2-yr as well as the 4-yr rotations, it was decided to keep those treatments for comparison purposes.

A comparison trial, VICMS2, begun on land that had been managed with modern production practices by the Center for over two decades; it was intended to complement the VICMS1 trail. The plot size in VICMS2 was about one-tenth the plot size in VICMS1, and the trials were located approximately 1 km apart .

In the initial years there was a lot of publicity and the Elwell Farm was featured in all the summer field days at the Center. A sizeable grant helped fund the initial years of the trials. Since that time, funding from outside sources has been sporadic. So too has been the interest in maintaining the trials. The VICMS2 trial was terminated after the 2002 season, but the VICMS1 trial is ongoing. In the 15 plus years since the VICMS trials were established there have been numerous Center superintendents, heads of the Department of Agronomy and Plant Genetics, and Deans for the College. While there have been over a dozen faculty from various departments who have published research from the VICMS trials, these researchers have often been interested in – and have funding for – only specific aspects of the trials. This creates a situation where the long-term sustainability of the trials has been problematic.

X.3 Materials and methods

X.3.1 Experimental setup

The University of Minnesota Southwest Research and Outreach Center (SWROC) near Lamberton, MN (44°25'N, 95°32'W) was the location of the two VICMS trials. Being in the northwest section of the US Corn Belt, the predominant cropping system is the maize-soybean rotation. The mean annual precipitation is 666 mm and the average annual temperature is 7 C. Mean precipitation, growing degree units (gdu) and solar radiation from corn planting through September is 430 mm, 1 230 gdu, and 31 000 Watts m⁻², respectively

The treatments in the trials were finalized following lengthy discussions with organic farmers and researchers from several Land-Grant Universities and the Rodale Institute. Two crop rotations and four management strategies were established in the late 1980s. The two crop rotations included a 2-year maize-soybean rotation and a 4-year maize-soybean-oat/alfalfa-alfalfa rotation. The trials began in the spring of 1989 except for the 4-yr rotation in VICMS2, which

began in the spring of 1990. Each crop of each rotation was grown each year, which constituted six main plots for each of the three replicates, which were arranged in a randomized complete block design. The four management strategies, arranged as subplots of the crop rotation main plots, included zero inputs (ZI), low-purchased inputs (LI), high-purchased inputs (HI), and organic inputs (OI). Thus, when referring to yields, for both maize and soybean there were eight treatments (two crop rotation lengths each involving four management strategies), whereas for both oat and alfalfa there were four treatments (four management strategies).

In VICMS1, in addition to the two rotation lengths and three management systems, there was also a non-cropped prairie treatment associated with the ZI management strategy. This treatment allowed comparisons in soil dynamics between cropped and non-cropped soils. Each treatment was replicated three times, for a total of 90 plots [(4 cropped management levels plus the non-cropped prairie treatment) x 6 crops (4-yr + 2-yr rotations) x 3 replications], of which 72 are planted to crops every year. In VICMS2 there was no prairie treatment, and thus only the 72 cropped plots.

Subplot size was 54.9 m long by 30.5 m wide for VICMS1, and 19.8 m long by 9.1 m wide for VICMS2. A bare-fallow or grass border of 10 m surrounded each main plot, allowing for movement of farming equipment onto subplot experimental units. Row spacings were 0.76 m for maize and soybean (allowing for 40 and 12 rows per subplot in VICMS1 and VICMS2, respectively), and 0.19 m for oats. Alfalfa seed was broadcast.

X.3.2 Soils

Soil types at each location included a complex of Normania, Revere, Webster, and Ves clay loams (fine-loamy, mixed, mesic Aquic Hapludolls; fine-loamy, mixed, mesic Typic Calciaquolls; fine-loamy, mixed, mesic Typic Endoquolls; and fine-loamy, mixed mesic Calcic Hapludolls, respectively). Crop production in this region began in the 1870s with wheat as the major crop. From the 1900s until the late 1950s, small grains, maize and pasture predominated. Between 1959 and 1989, the land was farmed almost exclusively in a maize-soybean rotation, but management of the two sites was quite different. The VICMS1 site was managed without fertilizer or pesticide inputs, resulting in low productivity. By contrast, the VICMS2 site was managed for high productivity according to University of Minnesota recommendations, which included commercial fertilizer and pesticide applications. Soil fertility levels at the beginning of the trials in 1989 reflect the difference in the level of fertilizer applications

between the two trials. While both locations had organic matter contents ranging from 42 to 44 g kg⁻¹, the pH averaged 6.4 and 5.8, the Bray₁ P levels averaged 7 and 28 mg kg⁻¹, and the K levels averaged 168 and 160 mg kg⁻¹ for VICMS1 and VICMS2, respectively, in the top 30 cm of soil.

As is typical of most cropped soils in this region of the Midwestern United States, the sites were subsurface tiled drained: the VICMS2 site had been tiled drained for several decades prior to the start of the trial whereas the VICMS1 site was tiled at the initiation of the trial (which consumed a sizeable portion of the initial grant funds). At both sites there were no surface inlets; thus all drainage involved only subsurface tile drainage.

Particulate organic matter, microbial biomass carbon, mineralizable N, total organic carbon, and large stable aggregates were determined as referenced by Kuratomi (2003).

X.3.3 Management strategies

Detailed descriptions of the management strategies are summarized in Porter et al. (2003) and reported in more detail by Klossner et al. (1995 and 1998), Klossner and Porter (1999), and Perillo et al. (1996 and 1997). Each of the four strategies was managed independently of the others (Table X.1). In general, the ZI strategy involved no purchased inputs other than seed: there were no fertilizers or pesticides of any kind applied in this strategy throughout the course of the trials. Both the ZI and OI strategies utilized delayed planting as one technique for weed control. Fertilizer or manure was applied to the remaining three strategies according to University of Minnesota Soil Testing Service recommendations to achieve moderate maize and soybean yield goals. The HI strategy assumed a 10% higher yield goal than the LI strategy, and fertilizer rates were adjusted accordingly. These recommendations provided for fertilizer application based on soil organic matter, cropping history, crop to be grown, and yield potential for the crop. Average fertilizer application rates were reported in Porter et al. (2003). The LI and HI strategies involved the use of commercially available fertilizers and pesticides. Whereas the LI strategy relied principally on banded applications, inputs were broadcast in the HI strategy. Details of the pesticides applications were reported by Kurle and Pflieger (1994). The OI strategy involved practices acceptable for organic certification: the use of manure for fertilization and no synthetic pesticides, including using untreated seed. For the OI strategy, solid beef manure was fall-applied prior to maize in the 4-yr rotation and liquid swine manure was spring-applied prior to maize in the 2-yr rotation. The use of the two manure

sources reflects the presence of alfalfa in many dairy and beef operations, but not in most swine operations. The N, P₂O₅, and K₂O composition of the solid beef manure averaged 12.2, 5.4, and 13.3 g kg⁻¹ respectively, whereas the N, P₂O₅, and K₂O composition of the liquid swine manure averaged 8.0, 5.3, and 3.3g kg⁻¹, respectively. Since the beef manure contained greater amounts of N, typically the swine manure was applied at a higher rate. Beginning in 1998, solid beef manure has been applied to both trials. Under organic certification guidelines, the 2-yr OI strategy would not be certifiable due to the requirement for a broader crop rotation. Nonetheless, an evaluation of the 2-yr OI strategy with other management strategies (the 2-yr LI and HI strategies in particular) could demonstrate the results of lowering synthetic inputs for conventional growers.

Tillage varied among management strategies: the ZI and OI strategies relied on rotary hoeing and row cultivation to a greater extent than the LI and HI strategies, while the LI strategy relied on less intensive tillage than the HI strategy. For the 2-yr rotation, soybean residue was chisel plowed in the HI, OI and ZI strategies, whereas there was no fall tillage in the LI strategy; and maize residue was moldboard plowed in the HI, OI, and ZI strategies, whereas in the LI strategy the maize residue was worked with a soil saver.

Table X.1. General description of the management strategies in the VICMS trials (see text for references to more detailed descriptions).

	HI	LI	OI	ZI
Fertilizer source	Synthetic chemicals	Synthetic chemicals	Manures	None
Fertilizer amount	Yield goal plus 10%	Yield goal	Yield goal	--
Fertilizer application	Broadcast	Banded	Broadcast	--
Insecticide application	As needed	As needed	None	None
Herbicide application	As needed	As needed	None	None
Planting date	- (Timely, as recommended) -		- (Delayed planting) -	
Tillage	- (Varied by crop, but generally relatively aggressive) -			

X.3.4 Planting and harvest operations

Maize and soybean planting date depended on management strategy. To better manage weeds without herbicides, maize in the ZI and OI management

strategies was usually planted in mid- to late-May, approximately 10 to 14 days later than maize in the LI and HI management strategies. Soybean planting usually occurred in late-May for the ZI and OI management strategies, and 7 to 10 days later than for the LI and HI management strategies. Oats and alfalfa were planted on the same date for all management strategies, typically in mid- to late-April.

Each year crop cultivars were the same for all rotations and management strategies in VICMS1 and VICMS2. Seeding rate was approximately 64 000 to 80 000 seeds ha⁻¹ for maize, 370 000 to 400 000 seeds ha⁻¹ for soybean, 81 kg ha⁻¹ for oats, and 12 kg ha⁻¹ for alfalfa over the duration of the trial. Details of cultivars planted, soil and weed samplings, harvest techniques, grain sample preparation, and grain yield analysis through 1999 were provided by Porter et al. (2003). Kuratomi (2003) reports details of soil quality analysis procedures for soil samples taken in 2000 and 2001 from VICMS1. Details of the economic analysis were provided by Mahoney et al. (2004) for VICMS2, and for both trials by Huggins et al. (1994). Oat straw was baled and removed from the plot area, except in 1989 in VICMS1, when oat was green chopped and no grain yields were obtained. Alfalfa harvest did not occur in the year it was underseeded in oat, but in the following year harvest occurred on at least three dates throughout the growing season depending on weather conditions and suitability for harvest.

X.4 Results and discussion

X.4.1 Soil chemical properties in the first decade

Porter et al. (2003) reported the changes in soil pH, P, K, and organic matter from soil samples obtained in 1992 and 1998. When averaged across all treatments, soil pH did not change between 1992 and 1998. In 1998 the pH levels averaged 6.7 and 6.0 in VICMS1 and VICMS2, respectively. Rotation length had no significant effect on soil pH. By 1998, management strategy influenced soil pH in both VICMS1 and VICMS2, with the OI and ZI strategies having slightly greater soil pH levels than those in the HI strategy (0.2 pH units).

At the beginning of the trials in 1989, the soil P level was considered to be yield-limiting in VICMS1 but not in VICMS2 (Porter et al., 2003). In VICMS1, the ZI strategy soil P level averaged 4.2 mg kg⁻¹ in 1998 and 3.8 mg kg⁻¹ in 2001, essentially the same as when the trial began. In VICMS2 however, soil P level in the ZI strategy continued to drop from about 28 mg kg⁻¹ in 1990 and

17 mg kg⁻¹ in 1992, to 13 mg kg⁻¹ in 1998, and 10 mg kg⁻¹ in 2001 (Kuratomi, 2003). The decline in soil P levels in the ZI strategy in VICMS2 represents the draw-down of the soil P fertility due to the absence of P fertilizer application. In both trials there was a significant rotation length x management strategy interaction for soil P level in 1998. Soil P levels in the 4-yr rotation were less than those in the 2-yr rotation, especially in the OI strategy. This was probably due to differences in P applications from the different manure types and fertilizer sources. For the 4-yr OI strategy the manure source was solid beef manure, while for the 2-yr OI strategy the manure source was liquid swine manure. By 2001, 2-yr OI strategy P levels were about twice the 4-yr OI strategy P levels in both VICMS1 and VICMS2 because the N:P ratio in beef manure (5.1) was greater than that of swine manure (3.5), and more units of N had to be applied because of the lack of alfalfa in the 2-yr rotation.

At the beginning of the trials, the soil K level was considered high enough (>140 mg kg⁻¹) in both VICMS1 and VICMS2 to be non-limiting for crop production (Porter et al., 2003). By 1998, this was still the case, even in the ZI strategy where no K fertilizer was applied. In both VICMS1 and VICMS2, soil K levels were greatest in the OI strategies, especially in the 4-yr rotation. Again, the differences observed between the 4-yr and 2-yr OI strategies with respect to soil P and K levels were most likely due to the differences in manure type. The liquid swine manure had less K and N relative to P compared with the solid beef manure.

By 1998, a decade after the trials began, rotation length and management strategy had no effect on soil organic matter (Porter et al., 2003). The soil organic matter averaged 44 and 42 g kg⁻¹ in VICMS1 and VICMS2, respectively. Similar values were observed at the start of the trials.

X.4.2 Soil physical properties and microbiota

A number of soil characteristics in both VICMS1 and VICMS2 were analyzed for samples obtained in 2000 and 2001 as reported by Kuratomi (2003) and Kuratomi et al., (2004). Indicators of soil quality measured included particulate organic matter, microbial biomass carbon, mineralizable N, total organic carbon, and large stable aggregates. Comparing management systems, the OI system had the greatest overall soil quality as seen in the greater areas delineated by both the 2 and 4-yr rotation lines (Fig. 1). The LI system had levels of aggregation, microbial biomass, and total carbon levels comparable to the OI system. The ZI and HI systems, which had the lowest soil quality, showed the greatest positive response to the extended rotations as shown by

the larger area encompassed by the solid lines in those graphs compared to the dashed lines (Fig. 1).

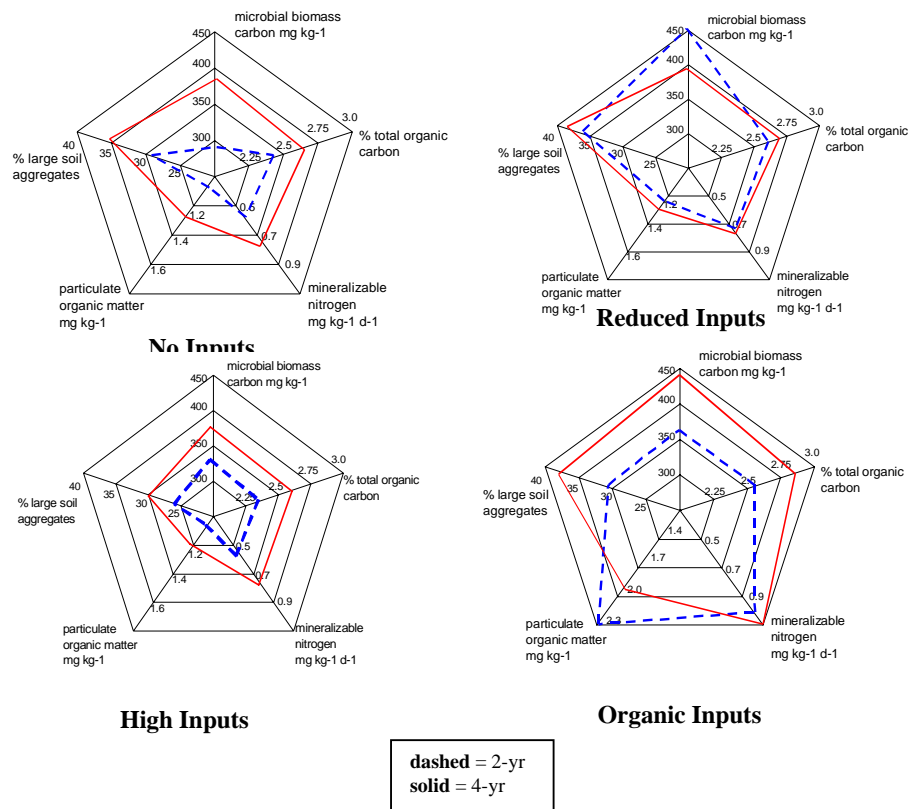


Fig. X.1. Effect of rotation length in the four different management strategies in VICMS1 on different soil quality indicators from samples taken in 2000 and 2001. The greater the area outlined by either the dashed or solid line the better the overall soil quality for the system examined.

In a study conducted from 2002 through 2004 that assessed soil physical properties and the amount and quality of subsurface drainage of the 65 ha EAF (which includes the 15 ha VICMS1 study) with an adjacent 65 ha site on the SWROC farmed in a conventional maize-soybean rotation, Rolf (2005) showed farming practices on the EAF enhanced soil physical properties and decreased the amount and rate of water movement to and through subsurface tile drains. Predictably, drainage and nutrient leaching depended heavily on precipitation. The results showed that the alternative farming practices on the EAF reduced subsurface drainage between 32% and 40% in 2002 and 2003 and nitrate-nitrogen leaching between 59% and 62% in 2002 and 2004 compared with conventional practices. There were no differences between drainage from the two sites in 2004 or between nitrate-nitrogen leaching from the

two sites in 2003. The results are useful to water resources managers as they determine the best methods to achieve total maximum daily loads in surface waters (Oquist et al., 2006).

Brodeen (2004) quantified the emissions of greenhouse gasses [carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)] from soils in the Prairie, HI and OI management strategies in the VICMS1 trial. The soils were incubated, and emitted gas was analyzed for CO_2 , CH_4 , and N_2O , using gas chromatography. Three studies were performed: soils incubated with no manipulations (field soil study), soils incubated with the addition of water to simulate rainfall (wet soil study), and soils incubated with the addition of fertilizer (fertilized soil study). Global warming potentials for each management strategy in each study were calculated by multiplying the mass of total gas exchange by a global warming potential in CO_2 equivalents. The results of the field and wet soil studies suggested decomposition rates were higher in the Prairie and OI soils compared with HI soils. Prairie soils had the lowest global warming potential across all three studies. In the field and fertilized soil studies, the OI soils had higher global warming potential than the HI soils. In the wet soil study, HI soils had the highest global warming potential. The addition of fertilizer raised the amount of global warming potential of all three soils by three orders of magnitude. These considerations may assist in efforts to minimize the impacts of land management systems on greenhouse gas emissions.

In a greenhouse study, De Bruin et al. (2006) examined how rye responded to soil microbiota from soil samples collected in the fall of 2001 and 2002 from various VICMS1 treatments. Rye growth of three cultivars was measured and colonization by arbuscular-mycorrhizal fungi (AMF) was determined before and shortly after a vernalization period. Although generally not a strong host, rye cultivars differed in their response to soil microbiota and their ability to host AMF. At final sampling, rye shoot biomass in the 2-yr rotations was 17% greater than in 4-yr rotations, suggesting that microbial populations selected for by 4-yr rotations may be more deleterious or pathogenic than those selected for by 2-yr rotations. They found no evidence that the OI strategy increased the beneficial effects of soil microbiota on rye growth, relative to the ZI and HI strategies.

Arbuscular-mycorrhizal fungi (AMF) spore populations and root colonization by AMF in the 2-yr maize-soybean rotations were monitored in the initial years (1989 through 1991) of both VICMS1 and VICMS2 (Kurle and Pflieger, 1994). They reported AMF colonization percentages were not correlated with AMF

spore populations and did not appear to be influenced by the management strategies established within each trial. Management strategies, however, appeared to influence AMF spore populations by their effect on weed population.

X.4.3 Crop yields in the first decade

The decision-making process on when and how to conduct certain field operations proved to be very challenging in these trials. Management of the experimental plots was complicated by some of the same issues producers face. Portions of the land would be optimum for specific field operations while other areas would be too wet. Some areas would be infested with weeds while other areas would not. Weed growth, development and management, one of the biggest issues in organic production systems, was also a function of fertility - which varied greatly across the rotation lengths and management strategies. The logistical complications of when to plant, rotary hoe and cultivate were enhanced by the number of crops and management strategies involved. Timeliness of field operations was often weather-dependent, and greatly influenced production.

An interpretation of yield results through 1999 is reported by Porter et al. (2003 and 2004). Predictably, year-to-year variation in weather influenced how the crops responded to rotation length and management strategy (Fig. 2). Weed control, especially in the OI and ZI strategies, was greatly influenced by early-season climatic conditions. In some years, such as 1993, 1996 and 1997, rainfall events precluded timeliness and effectiveness of rotary hoeing and cultivation. Lack of adequate weed control one season negatively influenced crop productivity that particular year as well as influenced weed pressure and crop productivity in subsequent years. The OI strategy required increased management skills compared with the three other management strategies. The ZI strategy included similar weed control methods to those of the OI strategy, but because of no fertilizer input, weed growth was considerably slowed, allowing for better weed control.

Averaged across the 7-yr time frame from 1993 through 1999, maize yields in the 4-yr OI strategy were 91% and 93% of the 2-yr HI strategy for VICMS1 and VICMS2, respectively (Table X.2). Soybean yields in the 4-yr OI strategy across that same time frame were 81% and 84% of the 2-yr HI strategy for VICMS1 and VICMS2, respectively. Maize yields were 8.11 and 8.13 Mg ha⁻¹, and soybean yields were 2.36 and 2.29 Mg ha⁻¹ for the 4-yr OI strategies in VICMS1 and VICMS2, respectively. The data show a larger reduction in yield

from organically produced soybean relative to maize in a 4-yr maize-soybean-oat/alfalfa-alfalfa rotation compared with yields in a conventional 2-yr maize-soybean rotation. This may have been due in part to decreased weed seed production in the OI strategy during the oat/alfalfa-alfalfa phase of the cropping sequence in the 4-yr rotation followed by increased weed pressure during the maize phase. Because soybean followed maize in the rotation, soybean was subjected to a greater weed pressure than the maize.

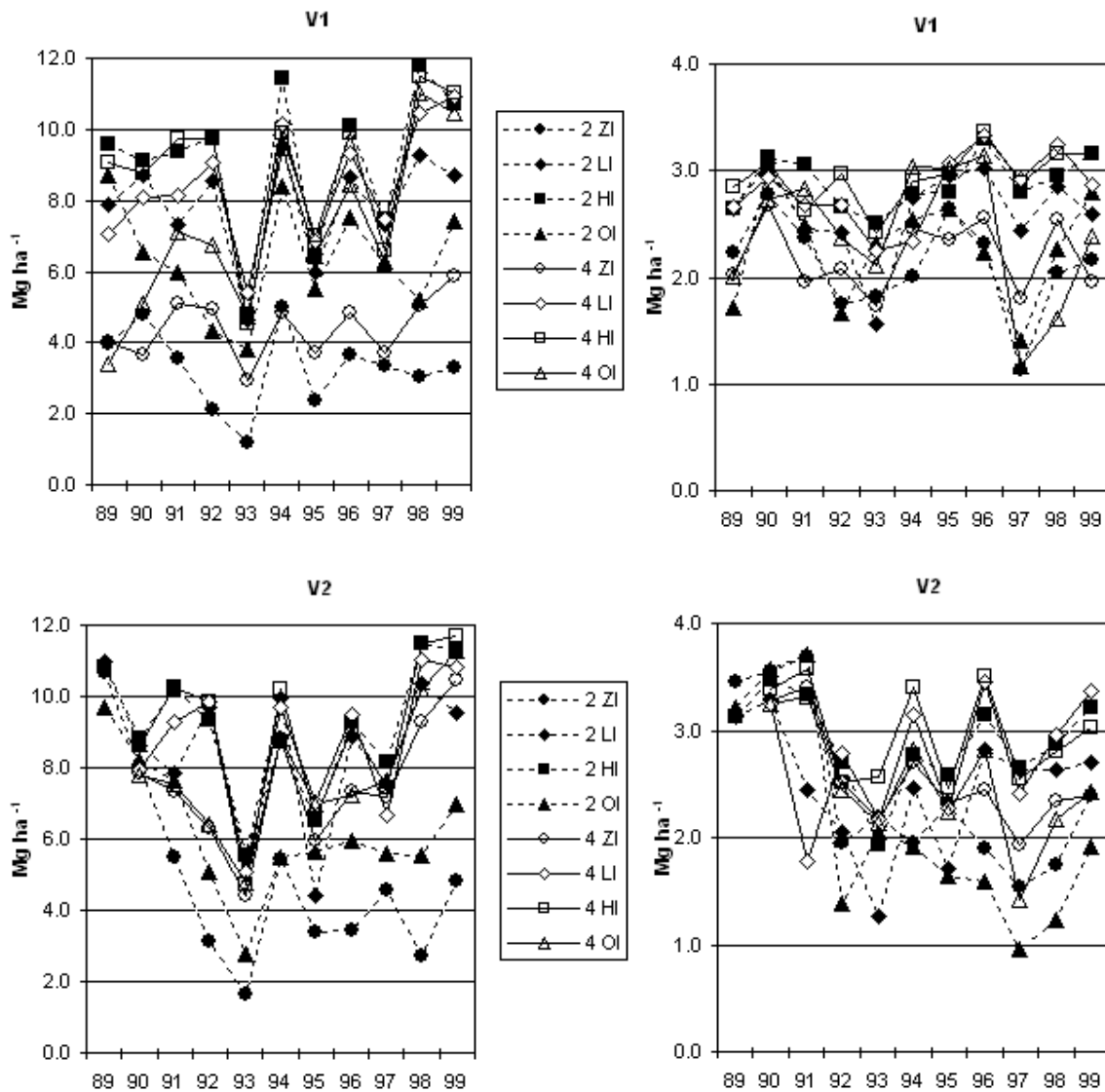


Fig. X.2. Maize and soybean grain yields in the VICMS1 (V1) and VICMS2 (V2) trials involving two rotation lengths (2 or 4 yr) and four management strategies [zero inputs (ZI), low purchased inputs (LI), high purchased inputs (HI), and organic inputs (OI)] at Lamberton, MN.

Table X.2. Maize and soybean yield of the 4-yr OI strategy (and as a percentage of the 2-yr HI strategy) in the VICMS1 and VICMS2 trials.

	1993	1994	1995	1996	1997	1998	1999	Mean '93-'99
	----- Mg ha ⁻¹ -----							
<u>Maize</u>								
VICMS1								
	4.75	9.45	6.43	8.43	6.27	11.02	10.43	8.11
	(99%ns)	(83%)	(100%ns)	(83%)	(84%)	(94%ns)	(97%ns)	(91%)
VICMS2								
	4.77	8.80	6.95	7.24	7.66	10.21	11.26	8.13
	(86%)	(101%ns)	(106%ns)	(78%)	(94%ns)	(89%)	(100%ns)	(93%)
<u>Soybean</u>								
VICMS1								
	2.11	3.05	3.01	3.14	1.17	1.61	2.39	2.36
	(84%)	(110%ns)	(108%ns)	(95%ns)	(42%)	(54%)	(75%)	(81%)
VICMS2								
	2.13	2.83	2.24	2.83	1.41	2.17	2.43	2.29
	(110%ns)	(102%ns)	(87%)	(90%ns)	(53%)	(76%)	(76%)	(83%)

ns = difference between the two treatments was not significantly different at P>0.05)

Maize yield in the 4-yr OI strategy compared with the 2-yr OI strategy was 29% greater in VICMS1 and 50% greater in VICMS2. Maize yield in the 4-yr ZI strategy compared with the 2-yr ZI strategy was greater by 41% in VICMS1 and 106% in VICMS2. Soybean yield in the 4-yr OI strategy compared with the 2-yr OI strategy was not different in VICMS1 and greater by 42% in VICMS2. Soybean yield in the 4-yr ZI strategy compared with the 2-yr ZI strategy was greater by 10% in VICMS1 and 17% in VICMS2. These results indicate external inputs of fertilizer and pesticides mask the true value of crop rotation. These results support the concept that one way to reduce the amount of external inputs (and associated costs) in a cropping system is to expand the crop rotation into a more diversified crop sequence pattern, thereby taking full advantage of the benefits of crop rotation.

Averaged across the same 7-yr time frame, oat yields were similar when produced in the 4-yr OI strategy and the 4-yr HI strategy in both VICMS1 and VICMS2. Alfalfa yield in the 4-yr OI strategy was 92% that of the 4-yr HI strategy in VICMS1, whereas in VICMS2, the yields were the same. We suspect the reason alfalfa yield in the 4-yr OI strategy was lower than the 4-yr

HI strategy in VICMS1 was related to the lower soil P levels in VICMS1 relative to VICMS2.

X.4.4 Economic analysis in the first decade

Mahoney (2001) analyzed the profitability and risk of three of the management strategies (HI, LI, OI) from the VICMS2 study from 1990 through 1999. Net returns were based on the actual yields, operations, inputs, prices and organic premiums. Risk, that is, the variation in net return, was analyzed using stochastic dominance. Cumulative distribution functions (CDFs) of net returns 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.

Even though crop yields were lower under the 4-yr OI strategy, so too were its production costs. The average production costs for maize and soybean was 358 ± 39 and 203 ± 18 US\$ ha⁻¹ in the 2-yr HI strategy compared with 262 ± 14 and 185 ± 14 US\$ ha⁻¹ in the 4-yr OI strategy. As a result, the 4-yr OI strategy was able to produce net returns equal to the net returns under LI and HI strategies without any organic premium, and higher net returns when it received either full or half of the historical organic premiums (Mahoney et al., 2004a and 2004b; Olson et al., 1999). The net returns for the 2-yr HI strategy was 378 ± 108 US\$ ha⁻¹ compared with net returns for the 4-yr OI strategy of 433 ± 85 US\$ ha⁻¹ with no organic premiums and 550 ± 130 US\$ ha⁻¹ with half the organic premiums. When the variability of net returns was analyzed using stochastic dominance, the 4-yr OI strategy with either full or half of the historical organic premiums dominated all other strategies and sequences (Fig. 3). The results document that conventional maize-soybean production practices as represented by the HI and LI strategies were not more profitable and did not involve less risk than the 4-yr OI strategy. This observation supports the continuance of programs supporting organic production, and suggests that 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. The economic analysis is consistent with research at other U.S. land-grant universities (Welsh, 1999) which reported a range of responses to organic production systems, from lower yields and economic returns to comparable yields and greater returns.

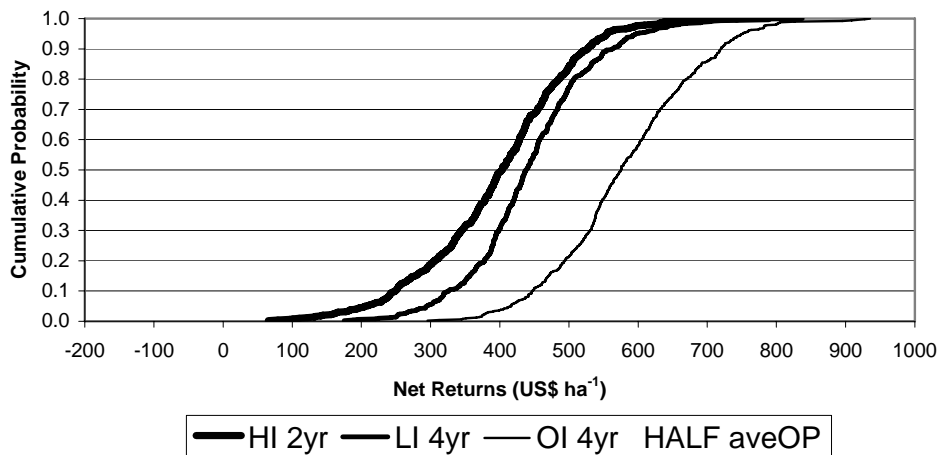


Fig. X.3. Cumulative distribution functions of net returns in VICMS2 for the 2-yr HI and the 4-yr LI strategies with conventional market prices and the 4-yr OI strategy with half of the historic average organic premiums (OP). When half and full organic premiums were applied, the net returns were largest for the OI strategy. When no organic premiums were applied, the analysis showed essentially no difference in net returns between the three treatments.

X.5 On-going research

In the fall of 2002 modifications in the VICMS1 trial were initiated to identify the costs and benefits associated with integrating additional crops and management practices into both rotation lengths (2- and 4-yr) of the OI strategy. One management system involves use of cover crops, compost, primary tillage in the spring, and the 'WeedCast' model for timing of postemergence tillage. The other management system involves no cover crop, heap manure instead of compost, primary tillage in the fall, and use of calendar day for timing of postemergence tillage. Cover crops consist of winter rye following maize and a red clover / hairy vetch mixture following soybean.

In addition, green foxtail seedbanks in all VICMS1 treatments were assessed in the spring of 2004 and 2005 in order to identify the implications of each rotation length and management strategy on the persistence of that species. Green foxtail was chosen as a model weed because of its moderate seed production and relatively-uniform distribution within plots.

As differences in soil quality, profitability, pest populations and crop yield between conventional and organic cropping systems become more widely acknowledged, the future of VICMS1 becomes more uncertain. The interaction of organic systems with their surrounding landscapes (for example, implications for beneficial predator migration) is an understudied topic; the

VICMS1 plot size, however, may be too small for this type of research. In addition, the size of VICMS1 plots limits the extent to which they can be divided into sub-treatments. Future research, thus, may focus on relating treatment differences to soil properties that have occurred under each management system.

Based on differences in soils quality indicators, further studies of carbon and nitrogen storage and losses in the VICMS1 plots are on-going (Allan et al., 2005). The objectives of this work are to measure storage and turnover of C and N in active and stable organic matter pools using ^{13}C and ^{15}N labeled inputs, and to measure C and N transport and losses via nitrate leaching and gaseous emissions of CO_2 , CH_4 , and N_2O . As a baseline measure for this study, gas flux measurements were begun in 2003 (King et al., 2004).

X.6 Challenges and lessons learned

The VICMS1 trial conducted on the Elwell Agroecology Farm (EAF) is multi-disciplinary in scope and inter-disciplinary in practice. Several dozen University researchers have been involved in studies conducted on the EAF, which since 1997 has maintained 45 hectares of certified organic production. The research is intended to be long term, but the historical pattern of funding reductions at both the state and national levels raises fears that the site may not be supported over the long term. Even though the short-term outputs from VICMS1 and other experiments there have been substantial, and a few have led directly or indirectly to shifts in farming practice, funding for maintaining VICMS1 and initiating new experiments has been insecure and unpredictable.

Research conducted at the EAF investigates the processes that explain the relationships between living organisms and their environment in agricultural systems with various levels of disturbance. Many fundamental processes in agroecosystems occur over relatively long periods of time. For example, weed seed dynamics may occur rapidly with one season of poor weed management, while processes that influence the health of the soil may require many years. Thus, ecological processes, consisting of both organisms and their environment, are driven by dynamics with periodicities and durations spanning many time and space scales.

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