Organic and Conventional Production Systems in the Wisconsin Integrated Cropping Systems Trial: II. Economic and Risk Analysis 1993–2006

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ABSTRACT

This article, the second in a series looking at the Wisconsin Integrated Cropping Systems Trial (WICST), reports on the profitability of six conventional and organic systems, with a focus on net returns and associated risk exposure. Several pricing scenarios were compared to evaluate the impact of government programs and organic price premiums. When net return estimates are made using only neighboring elevator prices (no government programs or organic price premiums), we found that the no-till corn-soybean system [*Zea mays* L. and *Glycine max* (L.) Merr.] was the most profitable grain system, and management intensive rotational grazing (MIRG) the most profitable forage system. When government programs and organic price premiums are included, returns increased by 85 to 110% for the organic grain system (corn-soybean-wheat + red clover (*Triticum aestivum* L. + *Trifolium pratense* L.) and 35 to 40% for the organic forage system [companion seeded alfalfa with oat + field pea (*Medicago sativa* L., *Avena sativa* L., and *Pisum sativum* L.), hay, and then corn]. This places both organic systems with higher returns than any of the Midwestern standards of no-till corn-soybean, continuous corn, or intensive alfalfa production. Also, the results indicate how risk exposure varied across systems. Interestingly, taking risk into consideration did not drastically affect the ranking among those systems. Our analysis shows that, under the market scenarios that prevailed between 1993 and 2006, intensive rotational grazing and organic grain and forage systems were the most profitable systems on highly productive land in southern Wisconsin.

MUCH RESEARCH has focused on the management of agroecosystems. While technological progress in agriculture has been rapid, concerns have been raised about the sustainability and environmental implications of current management practices. This has stimulated interest in low-input, diversified, and organic farming systems (Clark et al., 1999; Goklany et al., 2002; Lotter, 2003; Lu et al., 2003; Pimentel et al., 2005). In the first article of this series (Posner et al., 2008), we reported on the productivity of a range of cropping systems in the WICST including organic systems. Our findings indicated that diverse, low-input cropping systems can be as productive per unit of land as conventional systems. However, these systems were associated with more variability in yields, primarily due to the difficulty of mechanical weed control in wet springs. In this article we are looking at the profitability of these same systems, with a focus on net returns and associated risk exposure.

A number of studies have shown that more diverse crop rotations, often due to higher yields and somewhat lower input costs, result in higher net returns than, for example, continuous corn and sometimes corn-soybean rotations (Liebman et al., 2008; Singer et al., 2003; Singer and Cox, 1998). An exception was a recent article by Stanger et al. (2008), who reported on a 15-yr study of seven rotations in southwestern Wisconsin and found that the highest net returns were found in the no-till corn-soybean and continuous corn rotations, and not the longer rotations including alfalfa hay phases. When organic systems are included in the experiment, although yields tend to be lower, input costs are much lower, making these systems competitive with conventional systems sometimes, even before including organic price premiums. Welsh (1999) reviewed six long-term studies in the Midwest. Without premiums, in three of the studies the more diverse organic systems were as profitable as the conventional systems and in three they were less profitable. However, with premiums, in all six studies the organic systems had higher net returns. More recently, Mahoney et al. (2004) found in southwestern Minnesota that a four-phase organic rotation (corn-soybean-oat-alfalfa-alfalfa) had equal net returns to a two-phase conventional rotation (corn-soybean)—even before organic corn and soybean price premiums were included. Delate et al. (2003), working in Iowa with the same two systems, had similar results. And Pimentel et al. (2005) reported that in the Rodale study in Pennsylvania, a three-phase organic legume based system [corn-soybean-wheat+hairy vetch (*Vicia villosa* Roth.)] had similar net returns as the conventional corn-soybean rotation, again before organic price premiums were factored in. In this current study, a wider array of system diversity is compared, ranging from continuous corn to rotational grazing, and includes two organic systems.

What is relatively rare in this economic literature however, is a careful study of risk exposure. Risk exposure in this paper is analyzed through both the variance and skewness of returns. While the variance provides a traditional measure of risk, the

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Abbreviations: CC, counter cyclical (payment); CE, certainty equivalent; CRRA, constant relative risk aversion; DP, direct payment; LDP, loan deficiency payment; MIRG, management intensive rotational grazing; WICST, Wisconsin Integrated Cropping Systems Trial.

skewness captures exposure to downside risk (e.g., the probability of crop failure). As documented by Antle (1987), Chavas (2004), and Gollier (2001), most decision makers are averse to risk and especially downside risk. Here, "downside risk" means exposure to unanticipated low outcomes (e.g., crop failure). In this context, a model was developed to evaluate the cost of risk bearing as measured by a risk premium. This supports an economic analysis of each system based on a certainty equivalent (CE) defined as mean expected return (M) minus the risk premium.

Therefore, in this article we address two issues: (i) What is the effect of government payments and organic price premiums on the economics of crop system diversity? And (ii) how important is risk exposure in evaluating the relative ranking of net returns from the WICST project?

MATERIAL AND METHODS

The Model

Consider a farming system involving the production of m outputs $y = (y_1, ..., y_m)$, using n inputs $x = (x_1, ..., x_n)$. The production technology is represented by the feasible set $F(\mathbf{v})$, where $\mathbf{v}$ is a vector of noncontrollable inputs (e.g., weather effects). Thus, $(x, y) \in F(\mathbf{v})$ means that it is feasible to produce outputs y using inputs x under weather condition $\mathbf{v}$. At planting time, $\mathbf{v}$ is a random vector representing production uncertainty (e.g., due to unpredictable weather effects). Different farming systems are associated with different choices of inputs x and outputs y. Each farming system generates return

$$\pi = \sum\nolimits_{j=1}^{m} p_j y_j - \sum\nolimits_{i=1}^{n} w_j x_j,$$

where $(x, y) \in F(\mathbf{v})$, p_j is the price of the jth output, and w_i is the price of the ith input. Because it takes time to produce, output prices $p = (p_1, ..., p_m)$ are typically not known at planting time. It follows that production uncertainty $\mathbf{v}$, as well as output prices p, are uncertain at the time farming system decisions are made. This means that returns $\pi\,(x, y, \varepsilon)$ depend, in general, on the production system (x, y) as well as the uncertain variables $\varepsilon = (\mathbf{v}, p)$. Treating ε as a random vector with a given probability distribution implies that $\pi\,(x, y, \varepsilon)$ is also a random variable. Evaluating the economic implications of alternative farming systems can be done through the evaluation of the moments of π (x, y, ε). We start with its mean:

$$M(x, y) = E[\pi(x, y, \varepsilon)] \qquad [1]$$

where E is the expectation operator based on the probability distribution of ε. The mean return $M(x, y)$ varies with (x, y) and can be used to rank alternative farming systems according to their expected economic payoff. However, most farmers also worry about their risk exposure. This can be measured by the second and higher moments of the distribution of $\pi(x, y, \varepsilon)$. The second moment is the variance of $\pi(x, y, \varepsilon)$ given by

$$V(x, y) = E\{[\pi(x, y, \varepsilon) - M(x, y)]^2\} \qquad [2]$$

And the third moment is the skewness of $\pi(x, y, \varepsilon)$ given by

$$S(x, y) = E\{[\pi(x, y, \varepsilon) - M(x, y)]^3\} \qquad [3]$$

In general, both the variance $V(x, y)$ and skewness $S(x, y)$ can vary across production systems. For example, from Eq. [2], the ith input can be variance increasing, variance neutral, or variance decreasing as $\partial V/\partial x_i > 0, = 0$, or < 0, respectively. Similarly, from Eq. [3], the ith input can be skewness increasing, skewness neutral, or skewness decreasing as $\partial S/\partial x_i > 0$, $= 0$, or < 0, respectively. Note that Eq. [3] goes beyond the standard mean-variance approach that has been commonly used in the literature (e.g., Just and Pope, 1978 and 1979). This appears relevant in situations where exposure to downside risk is a concern and skewness effects are important.

A farming system that generates a higher variance means that it creates greater risk exposure. Most farmers being risk averse would see this high variability as undesirable. The skewness measures the asymmetry of the probability function around its mean, with a negative (positive) skewness implying a probability function skewed to the left (to the right). It means that a lower (higher) skewness generates a greater (lower) exposure to "downside risk" (e.g., to risk crop failure). Since most farmers are averse to downside risk (Binswanger, 1981; Antle, 1987; Chavas, 2004), farm managers see higher skewness as desirable.

These arguments suggest that it would be useful to incorporate risk exposure in the economic analysis of farming systems. This raises two challenges: First, we need a methodology to estimate all the relevant moments of the distribution of returns; and second, we need to translate the estimates of variance and skewness into a measure of the "cost of risk" with a monetary interpretation that makes it comparable with the mean return $M(x, y)$ in Eq. [1]. These two challenges have been addressed in previous literature. The approach proposed by Antle (1987) on both the estimation of the relevant moments of $\pi(x, y, \varepsilon)$ and their translation into measuring the cost of risk will be followed. In the economic literature, the cost of risk has been called the "risk premium" (Pratt, 1964). Following Antle (1987), the risk premium (R) can be approximated as follows:

$$R = 1/2\, r_2\, V + 1/6\, r_3\, S \qquad [4]$$

where r_2 and r_3 are parameters reflecting the nature of risk preferences. The R in Eq. [4] has a standard monetary interpretation: it measures the decision maker's willingness-to-pay to eliminate risk. According to expected utility theory, risk preferences are represented by a utility function $U(\pi)$, satisfying

$$\partial U/\partial\pi > 0 \text{ and } \partial^2 U/\partial\pi^2 \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0 \text{ under } \begin{Bmatrix} \text{risk aversion} \\ \text{risk neutrality} \\ \text{risk loving} \end{Bmatrix}$$

(Pratt, 1964). In this context, r_2 in Eq. [4] is the Arrow-Pratt absolute risk aversion parameter satisfying $r_2 = -(\partial^2 U/\partial\pi^2)/\partial U/\partial\pi)$. And following Antle (1987), r_3 in Eq. [4] is the downside risk aversion parameter satisfying $r_3 = -(\partial^3 U/\partial\pi^3)/\,\partial U/\partial\pi)$. Under risk aversion, $\partial^2 U/\partial\pi^2 < 0$ and r_2 is positive (Pratt). This gives the intuitive result that any increase in variance V increases the cost of risk in Eq. [4]. Similarly, under downside risk aversion, $\partial^3 U/\partial\pi^3 > 0$ and r_3 is negative (Menezes et al., 1980; Antle, 1987). This gives the intuitive result that an increase in skewness S (i.e., a decrease in down-side risk exposure) reduces the cost of risk in Eq. [4]. Below, we will consider the case of a logarithmic utility function $U(\pi) = \ln(\pi)$, where $r_2 = 1/\pi$ and $r_3 = -2/\pi^2$ with $\pi > 0$. This utility function belongs to the class of risk preferences exhibiting constant relative risk aversion (CRRA), with an Arrow-Pratt relative risk aversion parameter equal to 1,

$$-\frac{\partial^2 U/\partial\pi^2}{\partial U/\partial\pi}\pi = 1$$

(Pratt, 1964). The CRRA preferences are commonly used in economics, as they seem to provide a good representation of risk preferences for many decision makers. A CRRA parameter of 1 corresponds to a moderate level of both risk aversion and downside risk aversion (Gollier, 2001, p. 31).

Equation [4] provides the basis to empirically investigate the role of risk exposure across farming systems. Furthermore, it can be used to evaluate the relative importance of the variance effect versus skewness effect in the valuation of the cost of risk. Indeed, Eq. [4] decomposes the R into two components:

$$R = R_V + R_S \qquad [5]$$

where $R_V = 1/2\ r_2$, V is the variance component, and $R_S = 1/6\ r_3$ S is the skewness component. As mentioned above, we consider the case of a logarithmic utility function $U(\pi) = \ln(\pi)$. Evaluated at mean return $M > 0$, this implies that $r_2 = 1/M > 0$, and $r_3 = -2/M^2 < 0$. A monetary measure that incorporates risk exposure is the CE:

$$CE = M - R \qquad [6]$$

The certainty equivalent CE in Eq. [6] is defined as expected returns (M) minus the cost of risk (R). It provides a single measure that combines both mean returns and an economic evaluation of risk exposure. It can be used to compare the economic performance (including risk) of alternative farming systems.

Econometric Implementation

Equations [1–3] need to be estimated. Following Antle (1987), this can be done as follows: First, consider that the mean function (Eq. [1]) takes the parametric form $M(x, y, \boldsymbol{\beta}_1)$, where $\boldsymbol{\beta}_1$ is a vector of the parameter to be estimated. Estimate the regression model

$$\pi = M(x, y, \boldsymbol{\beta}_1) + u_1 \qquad [7]$$

where u_1 is an error term with mean zero. Equation [7] satisfies $E(\pi) = M$, as expected. Estimating Eq. [7] yields $\boldsymbol{\beta}_1^e$, a consistent estimator of $\boldsymbol{\beta}_1$, and the associated error term u_1^e: $u_1^e = \pi - M(x, y, \boldsymbol{\beta}_1^e)$.

Second, consider that the variance and skewness functions (2) and (3) take the parametric form $V(x, y, \boldsymbol{\beta}_2)$ and $S(x, y, \boldsymbol{\beta}_3)$, respectively, where $\boldsymbol{\beta}_2$ and $\boldsymbol{\beta}_3$ are parameter vectors to be estimated. Consider the regression models

$$(u_1^e)^2 = V(x, y, \boldsymbol{\beta}_2) + u_2 \qquad [8]$$

$$(u_1^e)^3 = S(x, y, \boldsymbol{\beta}_2) + u_3 \qquad [9]$$

where u_2 and u_3 are error terms each with a mean of zero. Equations [8–9] satisfy $E[(u_1^e)^2] = V$ and $E[(u_1^e)^3] = S$, as expected. Estimating the regression Eq. [8–9] generates consistent estimators of the parameters $\boldsymbol{\beta}_2$ and $\boldsymbol{\beta}_3$, respectively (Antle, 1987). However, note that the variance of u_1 in Eq. [7] is $V(x, y, \boldsymbol{\beta}_2)$, and the variance of u_2 and u_3 in Eq. [8–9] are not constant (Antle, 1987). For example, Eq. [8] implies that the variance of u_1 is $V(x, y, \boldsymbol{\beta}_2)$ which in general varies with (x, y). It follows that Eq. [7–9] exhibit heteroscedasticity, which needs to be taken into consideration in the estimation of the parameters. Heteroscedasticity suggests using a weighted regression approach to capture efficiency gains, where the optimal weights are given by the inverse of the variance of the error terms. This provides the basis for the hypothesis testing reported below.

Data

The empirical analysis in this study is based on a large scale (plots = 0.3 ha), and long-term study entitled the WICST. It was initiated on two experimental farms located in southern Wisconsin: Arlington and Elkhorn, and has been reported on in some detail by Posner et al. (1995, 2008). Both locations are on prairie-derived soils (Mollisols). A major difference between the two sites is soil drainage: Arlington has well-drained soils, while Elkhorn has somewhat poorly drained soils. Both locations had been in a dairy cropping system of corn and alfalfa with manure returned to the land for at least the 20 yr before establishing the trial in 1990. As a result, both locations have very fertile soils with initially high organic matter levels (47 g kg^{-1} at Arlington and 52 g kg^{-1} at Elkhorn). In this paper we are reporting on the data collected for the period 1993–2002 at Elkhorn and 1993–2006 at Arlington.

The WICST experiment consists of six cropping systems, replicated four times. Within each of the two principal enterprise types in southern Wisconsin (cash grain and livestock), an array of cropping systems was designed going from monocropping to more diverse systems. The experiment involves three cash-crop systems: continuous corn (S1); no-till corn-soybean (S2); an organic grain system with corn, soybean, and winter wheat with interseeded red clover (S3). The experiment also involves three forage systems: an intensive (high input) system with 3 yr of alfalfa and 1 yr of corn (S4); an organic forage system with companion seeded alfalfa with oat and field pea, hay, and then corn (S5); a MIRG system seeded with a mixture of red clover and several cool-season grasses: timothy (*Phleum pratense* L.), smooth bromegrass (*Bromus inermis* L.), and orchardgrass (*Dactylis glomerata* L.), and reed canarygrass (*Phalaris arundinacea* L.) at Elkhorn; along with Holstein dairy heifers (*Bos taurus*) (S6). Table 1 includes a description of the inputs associated with each system. More agronomic details are available from Posner et al. (1995, 2008) and the WICST technical reports (WICST, 2008).

Input use (e.g., fuel, fertilizer, and chemical inputs), yields, input prices, and output prices were recorded either at the time of purchase or measured by local prices prevailing at harvest time (no storage fees or future options were used). Elevator prices for conventionally grown corn ranged from \$0.06–0.12 kg^{-1} (\$1.43–2.94 bu^{-1}), for soybean from

Table 1. The six cropping systems of the Wisconsin Integrated Cropping Systems Trials.

			Input summary			
	System	**Crop rotation**	**Machinery use**	**Input use (fertilizer)**	**Pesticide use†**	**Crop diversity**
			Cash-grain systems			
S1	continuous corn	corn-corn-corn	annual fall tillage; seedbed preparation; often one cultivation	starter fertilizer & N sidedressing	high	low
S2	no-till	corn-soybean	planting but no tillage or cultivations	starter fertilizer & modest N-sidedressing only on Corn	medium	medium
S3	organic grain	corn-soybean-wheat+red clover	annual fall tillage, seed bed preparation & several mech weed control passes during corn & soybean phases	no fertilizer inputs between 1990–2006‡, N supplied by red clover & soybean residue	none	high
			Forage-based systems			
S4	intensive forage	corn-alfalfa-alfalfa-alfalfa	seed bed preparation & fall tillage (corn) only seed bed preparation (alfalfa) Harvest 4× yr^{-1}	starter fertilizer for corn and some potassium fertilization, N supplied by manure & alfalfa residue	high	low
S5	organic forage	corn-oat+alfalfa-alfalfa	seed bed preparation & fall tillage (corn) only seed bed preparation (alfalfa) Harvest 3× yr^{-1}	no fertilizer inputs between 1990–2006‡, N supplied by manure & alfalfa residue	none	medium
S6	rotational grazing	pasture	occasional haying of some paddocks and clipping of others; biennial inter-seeding of red clover	occasional N additions in early spring	low (spot spraying for thistle)	high

† Includes herbicides and insecticides.

‡ Some plots have required the purchase of organically certified potassium fertilizer since 2006.

$\$0.15–0.26$ kg^{-1} ($\$4.03–7.16$ bu^{-1}), and for wheat from $\$0.05–0.15$ kg^{-1} ($\$1.40–4.08$ bu^{-1}). Forage prices for large square bales were collected from Wisconsin hay quality-tested auctions based on forage quality classes and ranged from $\$35–150$ Mg^{-1} ($\$32–136$ ton^{-1}). During this same period of study, local elevator prices for organic feed grain at harvest ranged from $\$0.15–0.20$ kg^{-1} ($\$3.75–5.00$ bu^{-1}) for corn, $\$0.27–0.44$ kg^{-1} ($\$7.50–12.00$ bu^{-1}) for soybean, and $\$0.15–0.20$ kg^{-1} ($\$3.75–5.00$ bu^{-1}) for wheat. Feed-grade premiums were used in this analysis to eliminate the requirement of estimating the dockage fees (penalties for discolored seed, foreign matter, weed seed content, etc.) associated with higher food-grade standards and premiums. During the period of this analysis, there was no established market for organic hay, so S5-hay does not have an organic price premium. However, the corn phase of S5 has a feed-grade premium. Since 1996 for example, organic price premiums increased revenues by $\$361$ ha^{-1} for the organic grain rotation (S3) and $\$189$ ha^{-1} for the organic forage rotation (S5) at the Arlington location. The value of the output of rotational grazing dairy heifers (S6) was difficult to measure. We decided to use a payment rate of $\$1.39$ head^{-1} d^{-1} as a custom heifer raiser contract (Wolf, 2003; Rudstrom et al., 2005). Our target was a 0.82 kg d^{-1} weight gain and that was achieved through grazing and minimal supplemental grain. In the two forage systems that received manure (S4 and S5), fuel cost for spreading was charged to the system, while the nutrient content in the manure was not, since it was a by-product from the dairy system.

During the course of this trial, farmers have been receiving price support payments under three farm bills. The first was *The Food, Agriculture, Conservation, and Trade Act of 1990*, which covered the time period from 1990–1995. The 1990 Farm Bill had price supports for corn and wheat, but not soybean. In addition to a loan deficiency payment (LDP) subsidy on corn and wheat, farmers were paid to take land out of production under the set-aside program. A charge for seeding and mowing was added to cover these costs at $\$83.41$ ha^{-1}.

During *The Freedom to Farm Act of 1996*, which spanned the period 1996–2002, farmers were again paid an LDP on 85% of their planted corn, wheat, and now occasionally soybean acres, depending on the year. For both farm bills, the average county yield was used in payments where USDA assigned yields. The third farm bill (2003–2007) was named *The Farm Security and Rural Investment Act of 2002.* Under this bill, Congress set a target price (per bushel) for corn, soybean, and wheat. When local prices didn't meet the target prices, government subsidies covered the difference. The payments were composed of three parts: Direct payment (DP), counter cyclical (CC) payment, and LDP. The DP was fixed and came every year and were paid on 85% of base acres and based on historical county yields. The CC payments are based on 100% of a farmer's acres and on recent 3-yr average yields (1999, 2000, 2001), while the LDP is on 100% of a farmer's acres for actual bushels produced that year.

To facilitate the analysis, all government payments have been paid in the same cropping year as the program year and payments were only given to S1, S2, and S3. The forage systems were not given government payments since these farmers would grow most of the crops for feed and probably didn't enroll in the federal programs. Under the three farm bills at the Arlington site, for example, government payments ranged from $\$116$ to $\$245$ ha^{-1} for continuous corn (S1), $\$59$ to $\$165$ ha^{-1} for the two-phase corn-soybean (S2), and $\$62$ to $\$118$ ha^{-1} in the three-phase corn, soybean, and wheat system (S3). The impact of government payments will be further discussed below.

The net returns (defined as crop value minus cost of variable costs such as farm inputs like seed, fertilizer, fuel) were calculated using Agriculture Budgeting Calculation Software (Frank and Gregory, 2000). Farm size and machinery complement were chosen for each of the six enterprises to represent local farm conditions. The continuous corn (S1) and no-till corn-soybean (S2) systems were designed to represent a 480-ha farm. The organic grain system (S3) was chosen to represent a 240-ha farm. And the three forage systems were designed to represent a 60-ha farm. All farms were family farms relying mostly on family labor. The net return provides a measure of economic return to land, capital, and family labor. All empirical analyses presented below are conducted on a per-hectare basis. Thus, we implicitly assume constant returns to scale for each farming system.

Econometric Analysis

As each farming system is held fixed over time and across locations, the inputs-outputs (x, y) in Eq. [7–8] reduce to dummy variables for the six farming systems: $S_j = 1$ for the jth system and 0 otherwise. The effect of these dummy variables is expected to vary across locations and over time. As a result, the systems dummies $\{S_j: j = 1, ..., 6\}$ are specified to interact with a location dummy {L = 0 for Arlington and 1 for Elkhorn} and a time trend variable t capturing long-term changes in profitability for each system. From Eq. [7–8], this generates the following specification for the jth system in location L at time t:

$$\pi_{j\mathrm{Lt}} = \alpha + \alpha_{\mathrm{T}}\mathrm{t} + \alpha_{\mathrm{L}}\mathrm{L} + \sum\nolimits_{j=2}^{6} \alpha_j \mathrm{S}_j + \beta_{\mathrm{TL}}\mathrm{tL} + \sum\nolimits_{j=2}^{6} \beta_{\mathrm{T}j}\mathrm{tS}_j + \sum\nolimits_{j=2}^{6} \beta_{\mathrm{L}j}\mathrm{LS}_j + u_{1,j\mathrm{Lt}} \qquad [10]$$

$$(u_{1,j\mathrm{Lt}})^i = \alpha_i + \alpha_{\mathrm{T}i}\mathrm{t} + \alpha_{\mathrm{L}i}\mathrm{L} + \sum\nolimits_{j=2}^{6} \alpha_{ji} \mathrm{S}_j + \beta_{\mathrm{TL}i}\mathrm{tL} + \sum\nolimits_{j=2}^{6} \beta_{\mathrm{T}ji}\mathrm{tS}_j + \sum\nolimits_{j=2}^{6} \beta_{\mathrm{L}ji}\,\mathrm{LS}_j + u_{1,j\mathrm{Lt}} \qquad [11]$$

where $i = 2$ corresponds to the variance equation, and $i = 3$ corresponds to the skewness equation. Equation [10] provides a basis for evaluating the mean for each system at each location. The interaction effects in Eq. [10] allow the returns to vary across systems, across locations, as well as over time. Equation [11] provides a basis for evaluating the variance and skewness of returns. Again, the interaction effects in Eq. [11] allow these to vary across systems, across locations, as well as over time. Equations [10–11] are estimated using the WICST data.

In summary, for Systems 1–5 the results are based on 56 and 36 observations for Arlington and Elkhorn, respectively. For the grazing system (S6), there was a single herd grazing the four replicate pastures at each site, so there were only 14 and 8 yr of observations for Arlington and Elkhorn, respectively. Although there are fewer observations for this system, it was felt that the number of years was adequate, so the grazing system was kept in the analysis. As discussed above, the error terms in Eq. [10–11] are expected to be heteroscedastic (with their variance varying across systems, across locations and over time), thus requiring the use of weights in the estimation method. Equations [10–11] are estimated by generalized least squares, generating unbiased and efficient parameter estimates.

RESULTS AND DISCUSSION

The results from the weighted regression equation are presented in Table 2, including mean return effects, variance effects, as well as skewness effects. Given the presence of unpredictable weather effects, the models have reasonably good explanatory power, with $R^2 = 0.562$, 0.208, and 0.325, respectively for the mean, variance, and skewness equations. Many parameters are found to be statistically significant. The parameters will be used to estimate the effect of alternative pricing scenarios on system net returns as well as the importance of risk premiums. Mean returns (using market prices, government programs, and organic price premiums) across locations were not significantly different for the three conventional systems of continuous corn (S1 is the intercept, \$539.90 ha^{-1}), the no-till corn-soybean (S2, +\$33.42 ha^{-1}) and the intensive alfalfa (S4, −\$5.18 ha^{-1}), and significantly less than the two organic systems (S3, +\$243.97 ha^{-1} and S5, +\$177.66 ha^{-1}) as well as the MIRG (S6, +\$194.60 ha^{-1}). Also, at this level of analysis, variance was significantly greater for the two organic systems (S3 and S5), as well as conventional alfalfa (S4) than the other three systems. We observed some variation in skewness of returns across systems. Returns averaged \$340 ha^{-1} less at Elkhorn than at the better-drained Arlington site, and that site had significantly higher variance of net returns. This is a similar finding to our earlier work, with individual crop yields that showed that the primary effect of location was not in the ranking of yields, but in their magnitude (Posner et al., 2008). This general similarity in rankings for net returns suggests that this analysis can be applied to farms in the Upper Midwest on prairie-derived soils. However, due to the differences and heterogeneity of errors, the two locations were handled separately.

Using our econometric model, we compared three scenarios (see Table 3).

Scenario 1: Elevator prices (i.e., no government payments or organic premiums).

Scenario 2: Government payments without organic price premiums (government payment only; this was the situation until 1996).

Scenario 3: The full market price plus government programs (government payment + organic premium).

Returns are constant under the three scenarios for the intensive alfalfa system (S4) and the rotational grazing (S6) because neither of these two systems benefit from government payments or organic price premiums. The organic grain system (S3) does benefit from government programs (when in program crops) (Scenario 2) and, along with the corn phase in the organic forage system (S5), they both also benefit from organic price premiums, as shown in Scenario 3.

Scenario 1 represents returns when only yield, cost of inputs, and elevator prices for grain and auction prices for hay are used. These results show that the no-till grain (S2) and rotational grazing (S6) systems were both highly productive and offer the highest returns at both locations. Once government programs are introduced (Scenario 2), returns climb in the systems with program crops and this is especially obvious in the continuous corn system (S1) where returns increased by 47% at Arlington and 190% at Elkhorn. Under Scenario 2, the less-diverse grain

Table 2. Econometric estimates of mean, variance, and skewness of return.

Variables	Mean function M Parameter estimate	 SD	Variance function V Parameter estimate	 SD	Skewness function S Parameter estimate	 SD
	$ ha^{-1}					
Intercept	539.90**	13.65	26.69**	8.29	−639.90**	73.95
Year	13.72**	2.75	1.95	2.17	200.96**	20.51
Location	−339.94**	46.29	156.40**	40.39	421.28	2351.29
System2	33.42	20.50	11.02	11.97	849.24**	117.11
System3	243.97**	39.97	217.60**	49.37	965.87	2771.84
System4	−5.18	28.12	82.96**	24.83	1068.05	1060.57
System5	177.66**	40.73	237.87**	56.95	878.58	3201.85
System6	194.60**	58.89	92.04	52.14	1367.84	786.55
Year × L	−33.41**	5.12	−13.38**	4.51	227.51**	50.79
Year × System 2	−10.31*	4.35	−5.47	2.85	−175.62**	28.85
Year × System 3	−0.69	8.27	7.37	9.91	−121.60	524.88
Year × System 4	−37.09**	6.06	−12.65*	5.43	−623.63**	128.30
Year × System 5	0.59	7.53	−2.99	7.45	−372.06**	73.07
Year × System 6	−25.98*	11.35	−11.23	9.91	−266.59	141.31
Location × System 2	182.75**	51.11	−140.70**	42.39	−1088.75	2353.70
Location × System 3	138.33	74.98	−151.46	79.81	592.26	4420.30
Location × System 4	16.82	59.08	−161.33**	49.13	−834.56	2586.40
Location × System 5	150.17*	64.19	−339.65**	70.04	−411.21	3972.24
Location × System 6	197.19**	73.16	−230.67**	62.78	−1387.37	2448.76
			Fit statistics			
R^2	0.562		0.208		0.325	
Adjusted R^2	0.545		0.177		0.298	
F statistic with 18 and 462 df	32.99		6.73		12.33	

* Significant at the 0.05 level.

** Significant at the 0.01 level.

systems (continuous corn and corn-soybean) were economically superior to the diverse three-phase organic rotation at Arlington. At Elkhorn, the three-phase organic grain system was intermediary between continuous corn and the corn-soybean systems. Government programs had no effect on profitability among the forage-based systems since they were not applied to these systems.

The impact of the organic price premiums is large (Scenario 3). Returns increased by 85 to 110% for the organic grain system (S3) and, since only one phase of the organic forage system (S5) benefited from organic price premiums, increases were more modest (35–40%). Under this, the prevailing scenario, the diverse, three-phase organic grain system (S3) shows greater profitability than the two conventional systems (S1 and S2) at both locations. Although beyond the scope of this article, good November grain prices in 2007 and 2008 (approximately \$0.14 kg^{-1} for corn, 0.35 kg^{-1} for soybean, and \$0.20 kg^{-1} for wheat) more than doubled the net returns per hectare for the three grain systems under Scenario 1 (under no government payments nor organic premiums) compared with 2000, and markedly reduced the importance of government programs (about \$60 ha^{-1}). Organic feed grain price premiums were also very high (\$0.40 kg^{-1} for corn, \$0.72 kg^{-1} for soybean, and \$0.36 ha^{-1} for wheat). This has resulted, for the moment, in net returns for the organic grain system (S3) of \$3000 ha^{-1} and only \$1000 ha^{-1} for the no-till corn-soybean system (S2). Among the forage systems, premiums during the corn phase make the organic forage system (S5) more profitable than the conventional forage system (S4), and nearly equivalent to the rotational grazing system (S6). Overall, this shows the importance of organic markets in rewarding and stimulating a move toward more diverse cropping systems.

Table 3. Economic mean returns under alternative scenarios in the Year 2000.

System	Arlington No government payment or organic premium (Scenario 1)	 Government payment only (Scenario 2)	 Government payment + organic premium (Scenario 3)	Elkhorn No government payment or organic premium (Scenario 1)	 Government payment only (Scenario 2)	 Government payment + organic premium (Scenario 3)
	$ ha^{-1}					
S1 Continuous corn	365d†	540c	540b	69d	199d	199c
S2 No-till corn-soybean	465c	574b	574b	361b	416b	416b
S3 Organic grain corn-soybean-wheat	335d	423d	784a	212c	275d	581a
S4 Intensive alfalfa	535b	535c	535b	212c	212d	212c
S5 Organic forage	528bc	528c	717a	376b	376c	528a
S6 Rotational grazing	735a	735a	735a	592a	592a	592a

† Within a scenario (column), numbers followed by a different letter are significantly different at the 0.05 level.

Table 4. Risk Premium and Certainty Equivalent estimates for Wisconsin Integrated Cropping Systems Trials systems in Year 2000 at prevailing market prices.

	System					
	S1	S2	S3	S4	S5	S6
Arlington			$\$\ \text{ha}^{-1}$			
Mean return	540.11	573.51	783.95	535.15	717.49	734.83
SD	13.41	15.07	37.71	24.65	38.40	56.97
Risk variability†	6.10	8.12	38.49	25.31	45.54	19.96
Risk skewness‡	4.46	−1.29	−1.08	−3.04	−0.94	−2.74
Risk premium§	10.56	6.83	37.41	22.27	44.60	17.21
Certainty equivalent¶	529.55	566.68	746.55	512.88	672.89	717.61
Elkhorn						
Mean return	199.46	416.15	581.31	211.68	527.96	591.94
SD	43.55	13.43	50.14	26.85	22.81	22.70
Risk variability	113.37	15.85	52.95	61.10	19.02	9.28
Risk skewness	11.17	5.38	−8.06	−0.68	−1.81	1.38
Risk premium	124.54	21.23	44.89	60.43	17.20	10.66
Certainty equivalent	74.92	394.91	536.43	151.25	510.76	581.28

† Risk variability is the traditional measure of risk.

‡ Risk skewness captures exposure to downside risk (e.g., the probability of crop failure).

§ Risk premium = risk (variability) + risk (skewness).

¶ Certainty equivalent = mean return − risk premium.

In Table 4, the profitability of six farming systems is evaluated based on Eq. [5–6]. The risk premium represents the cost of risk associated with variance and skewness, while the CE is the system's mean return (for the Year 2000) corrected for the risk premium. The results reported are obtained under Scenario 3 (i.e., in the presence of government payments and organic price premiums). It is found that the cost of risk is often dominated by its variance component compared with its skewness component. Certainty equivalents, measured as mean return minus the risk premium, were highest in the organic grain system (S3), rotational grazing (S6), and organic forage (S5) at both Arlington and Elkhorn. While these results point to the superior performance of the organic systems, note that the analysis did not consider the time and learning costs of farming organically (Boerngen and Bullock, 2004) nor the potential saturation of organic markets. It seems possible that, in the medium run, the organic price premiums will settle to cover the higher cost of organic production. Under such a scenario, agriculture and markets may evolve toward an equilibrium where organic agriculture and conventional agriculture are about equally profitable. A final point to note is that we are reporting on returns per hectare. Labor requirements are higher on organic farms and in general, organic inspectors have observed that family-run organic grain farms rarely are larger than 250 ha, while conventional grain producers frequently farm two or three times that area.

The worst performance comes from continuous corn (S1) and the intensive forage (S4), both in Arlington and in Elkhorn. The no-till standard of the Midwest (S2) is intermediary. This provides strong evidence against overspecialization and in favor of more diversified farming systems.

Table 4 shows that the cost of risk can have adverse effects on the relative desirability of a particular system. For example, the risk premium is $\$124\ \text{ha}^{-1}$ in Elkhorn under system S1. Comparing mean return versus CE, the cost of risk does not significantly change the relative rankings among systems. In some cases, however, it expands the difference between systems. The organic systems (S3 and S5) did have the highest risk premiums at Arlington, but they ultimately represented <5% of the value of the mean returns. At Elkhorn, due to the more poorly drained soils, risk premiums were generally higher than at Arlington, especially for continuous corn (S1) and intensive forage (S4). Corn yields were frequently low [<6.3 Mg ha^{-1} (100 bushels acre^{-1}) 40% of the time] at the Elkhorn site due to delayed planting and often poor weed control. The waterlogged soils, which likely encouraged seedling diseases and winterkill, resulted in poorer alfalfa stands in S4, where frequent replanting was required. In 8 out of 10 yr, seeding-year alfalfa yields were <3.4 Mg ha^{-1} (1.5 ton acre^{-1}) at the Elkhorn site. At both sites, the no-till corn-soybean rotation (S2) and MIRG (S6) had the lowest risk premiums. The rotational grazing was the economically strongest system at Elkhorn. At this wetter location, a highly palatable variety of reed canary grass was the basis of the pasture mix and held up well to animal traffic. The key to the success of this system at both sites was feeding only a modest amount of a low-cost grain supplement to ensure the expected weight gain and maximizing days on pasture assuring reduced feeding/housing costs.

CONCLUSIONS

Using an econometric model, with data collected at two locations in southern Wisconsin, we analyzed the profitability of alternative cropping systems under alternative scenarios. When net return estimates are made using only market prices (no government programs or organic price premiums), we found that the no-till corn soybean system (S2) was the most profitable grain system, and rotational grazing (S6) the most profitable forage system. Once government programs are included, returns did increase for all the cash grain systems, especially continuous corn with increases of 50 to 190%. At the highly productive Arlington location, the diverse three-phase organic system, without premiums was less profitable than the two conventional systems. And at Elkhorn, the organic grain system was more profitable than continuous corn, but still less profitable than the corn-soybean rotation. When organic price premiums are included with the government payment, returns to the organic grain system (S3) increased by 85 to 110% and in the forage system by 35 to 40%, placing both of them with higher returns than any of the Midwestern standards of no-till corn-soybean (S2), continuous corn (S1), or intensive alfalfa production (S4).

Our analysis explores the role of risk exposure and of its associated cost (as measured by a risk premium) across systems. The more diverse rotations were found to generate moderate risk exposure, with risk premiums rarely more than 5% of returns or significantly different among those systems. This indicates that the management practices associated with the lower input or organic systems are, overall, no less effective than those associated with high input systems. The two systems that had high-risk premiums were at the more poorly drained location (Elkhorn) and were the two high-input monocropped systems of continuous corn (S1) and intensive alfalfa (S4).

A glance at 2007 and 2008 suggests that under high grain prices and therefore lower government programs, if organic price premiums remain high, the spread among grain systems will increase to the advantage of organic grain and organic forage production. One option we have observed in response to this changing market is that of parallel production. Under this system, some growers are converting a farm to organic while also maintaining their conventional production system on other farms.

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