Comparison of Risk Between Cropping Systems in Eastern Norway

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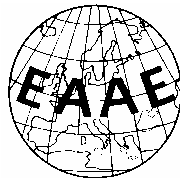
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COMPARISON OF RISK BETWEEN CROPPING SYSTEMS IN EASTERN NORWAY

Abstract

The aim of this study was to compare production and policy risk of organic, integrated and conventional cropping systems in Norway. Experimental cropping system data (1991-1999) from eastern Norway were combined with budgeted data. Empirical distributions of total farm income for different cropping systems were estimated with a simulation model that uses a multivariate kernel density function to smooth the limited experimental data. Stochastic efficiency with respect to a function (SERF) was used to rank the cropping systems for farmers with various risk aversion levels. The results show that the organic system had the greatest net farm income variability, but the existing payment system and organic price premiums makes it the most economically viable alternative.

Introduction

There is general agreement that sustainable agriculture refers to the use of resources to produce food and fibre in such a way that the natural resource base is not damaged, and the basic needs of producers and consumers can be met over a long term. Sustainable agriculture entails ecological, social and economic aspects (Yunlong and Smit, 1994). The choice of cropping system is an important issue since different systems have different environmental, agronomic and economic consequences.

Comparing different cropping systems requires a system context or whole-farm approach (and not partial analysis), since factors interact. A cropping systems project with the aim of studying environmental issues, yield and economy of different cropping systems was initiated in 1989 at Apelsvoll Research Centre in the eastern part of Norway. Yield and yield quality results for the first 8 years were presented by Eltun and Nordheim (1999), and results on nutrient balance by Korsaeth and Eltun (2000). Eltun et al. (2002) compared environmental, soil fertility, yield and economic effects between the cropping systems. However, the economic analysis ignored the effects of risk on the selection of cropping systems.

There are reasons to believe that different cropping systems behave differently given the same weather situations and thus have different impacts on income risk for a farm. For example, restrictions on pesticide and fertiliser use may give rise to different production risk in organic farming than in conventional farming. Additionally, smaller organic markets may mean greater price fluctuations.

These types of risks should be considered when comparing economic viability between cropping systems, because most farmers are risk-averse, and there is a need to account for downside risk (Hardaker et al., 2004a). In other words, only comparing the expected value (mean) of the expected profitability between cropping systems will often be too simple. Within a whole-farm framework, where the problems investigated normally involve more than one uncertain quantity, the stochastic dependency between variables becomes an important, but often neglected, aspect (e.g., Reutlinger, 1970; Richardson et al., 2000; Hardaker et al., 2004a). Experimental data, as in this study, often implies sparse data. To obtain more refined probability estimates and more trustworthy analysis, the sparse data should be supplemented with subjective judgments, expert advice and adjustment of irregularities by using some smoothing methods (Schlaifer, 1959, 1969; Anderson, 1974; Anderson et al., 1977).

Some studies have compared differences in productivity between cropping systems, without dealing with their economic consequences (e.g., Stanhill, 1990). Roberts and Swinton (1996) reviewed economic studies comparing alternative crop production systems. Several alternative economic methods for comparing alternative crop production systems exist (enterprise budgets, whole-farm budgeting, mathematical programming, biophysical simulation, dominance, etc.) Most studies looked exclusively at expected profitability by analyzing average net farm income. However, expected profitability is an insufficient criterion as it ignores likely differences in the riskiness of net income between cropping systems.

Two alternative methods for incorporating effects of profit (in)stability are risk programming and stochastic simulation (Hardaker et al., 2004a). As far as we know, no studies have used risk programming to compare cropping systems. Mahoney et al. (2004), Smith et al. (2004), and Ribera et al. (2004) all used stochastic simulation within a stochastic dominance framework on experimental data to analyse income risk differences between crop systems in the United States. In general, optimal crop rotation choices depended on output levels, price premiums and farmer's degree of risk aversion.

In our study we expand on the procedure used by Ribera et al. (2004). Our empirical goal is to compare the distributions of returns between conventional, integrated[1] and organic cropping systems in eastern Norway, and to quantify the importance of specific organic area payments and price premiums on economic viability.

It is hard to find relevant and reliable data to compare differences for the distributions of returns between cropping systems. One option is to use non-experimental farm-level panel data, i.e., repeated observations over time on the same farms. There are two main problems with non-experimental farm-level panel data for comparing risk between cropping systems: 1) sufficient data for two or more farming systems on the same farm grown over the same years are very hard (if not impossible) to find; 2) unless sufficient data from a single farm is available, comparative data from different farms would include noise, such as different climate, soil and growing conditions, disease and weed stress, topology conditions, and farm management practice, that have little to do with differences in risk between the cropping systems.

An alternative to farm-level panel data is to use yield data from verified scientific experiments. Then most of the problems mentioned in point 2 above can be avoided. The problems with using experimental data are: 1) we usually have few observations; 2) farm practices and results from experimental conditions may differ from what is obtained on real farms; and 3) data are often only from one site (usually an experiment station).

This last point reduces the generality of the results. However, some general implications may be drawn from such information, since it is the differences in risk between cropping systems that is the focus of this study. Moreover, for our study where Apelsvoll experimental cropping data are supplemented with budget data, the experimental practice and yields were quite close to what is the typical for crop farms in eastern Norway. Our approach to deal with the problem of sparse data is discussed in the "The simulation procedure" section.

Methodically, compared to earlier studies we illustrate a whole-farm simulation model used in a stochastic efficiency framework that incorporates three advances that often are of importance in cases with sparse data:

- The procedure for simulating the multivariate empirical probability distribution using a kernel estimator to smooth out irregularities in the sparse data set.
- The concept of sensitivity elasticity to determine which exogenous variables affect the key output variables most is described and used.
- The yield data is supplemented with subjective judgements about the upper and lower bounds of the distributions to deciding where the cumulative distribution functions (CDFs) meet zero and one probability bounds.

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[1] See Morris and Winter (1999) for a description of the origin and basic principles of integrated farming systems.

Materials and methods

Method

A stochastic simulation model for the hypothetical farm is used to estimate the empirical probability distribution for annual net farm income $\left(\tilde{I}\right)$. The model used to simulate the three alternative cropping systems can be described as:

$$\tilde{I} = \sum_{j=1}^{k} \left[A_j \left(\tilde{Y}_j \times \tilde{P}_j + AP_j - \tilde{C}_j \right) \right] - FC \tag{1}$$

where

A_j is the area in hectare of crop *j* in the cropping system, so $\sum_{j=1}^{k} A_j$ is total farm land

$\tilde{Y}_j$ is the per-hectare stochastic yield of crop *j*

$\tilde{P}_j$ is the per-kg stochastic or deterministic price for crop *j*

AP_j is the per-hectare area payment for crop *j*

$\tilde{C}_j$ is the per-hectare stochastic or deterministic variable cost for crop *j*

FC is the fixed costs

The simulation procedure

The experimental sample yield data consisted of nine annual observations. In simulation, sample data can be used to fit a parametric distribution (such as the normal). Parametric probability distributions are often inadequate because they are not flexible enough to accurately simulate the sparse data. An alternative is to let the "data speak" by using the empirical distribution. However, empirical distributions do not allow one to simulate beyond the range of observed data, which could bias the results if indeed values could extend beyond the observed minimum or maximum. This problem is especially relevant when the data are sparse, as in this case.

A better option when using sparse data is to apply a smoothing method to the empirical distribution. Irregularities in an empirical distribution are usually a result of sampling from the true distribution and reflect sampling error. It is usually reasonable, therefore, to assume that the population follows a smooth distribution, implying that the irregularities should be eliminated in fitting a distribution (Schlaifer, 1959, 1969; Anderson, 1974; Anderson et al., 1977). Moreover, supplementary information that can make the sparse data more reliable should be considered when smoothing. For example, the upper and lower bounds of a true underlying continuous distribution would often be more extreme than those observed from a sparse data set. Judgments from experts can be used to estimate such bounds.

Figure 1 illustrates the empirical and a smoothed CDF (cumulative density function) of organic barley yields in the Apelsvoll experiment. The experimental barley yield distribution was smoothed using a Gaussian kernel density function with the addition of minimum and maximum values specified by a panel of experts.
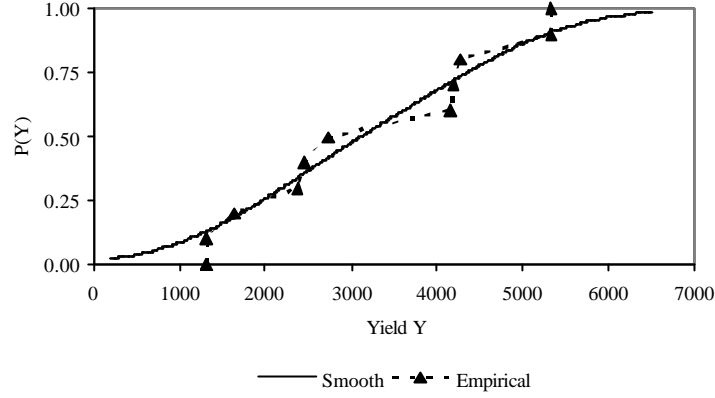
Figure 1. Empirical and smoothed CDF for organic barley yield per ha.

In this paper, stochastic yields and prices were simulated using a more general version of the multivariate empirical (MVE) distribution described by Richardson et al. (2000). This procedure uses a kernel density estimation (KDE) function to smooth the limited sample data for yields and prices. The resulting stochastic procedure is denoted as the multivariate kernel density estimate (MVKDE) of a random vector.

Parameters for the MVKDE procedure are: the sample mean or estimated central value for each random variable; estimated deviations and fractional deviations from the sample mean; a sample correlation matrix to model the dependencies among the random variables; and the kernel density transformation of the fractional deviations from the mean for each of the random variables. The steps for parameterize a MVKDE distribution for k random variables, $\tilde{X}_j$, (as yield, $\tilde{Y}_j$, and price, $\tilde{P}_j$) are described below.

1. The means, $\overline{X}_j$, are calculated for each of the k random variables.

2. Deviations from the mean are calculated for each observation, $i = 1,...,n$, for each of the variables, $j = 1,...,k$:

$$\tilde{e}_{ij} = \tilde{X}_{ij} - \overline{X}_j \tag{2}$$

3. The correlation matrix used to quantify the historical correlation among the variables is calculated using the $\tilde{e}_{ij}$ values as:

$$\mathbf{P_{k \times k}} = \begin{bmatrix} 1 & r_{12} & \cdots & r_{1k} \\ r_{21} & 1 & \cdots & \vdots \\ \vdots & \vdots & \ddots & r_{(k-1)k} \\ r_{k1} & \cdots & r_{k(k-1)} & 1 \end{bmatrix} \tag{3}$$

where r_{ij} is the sample correlation coefficient between the vectors $\underline{\tilde{\mathbf{e}}_i}$ and $\underline{\tilde{\mathbf{e}}_j}$ for $i, j = 1,...,k$. The r_{ij} coefficients can be either product-moment or rank correlations.

4. The correlation matrix is factored by the Cholesky decomposition:

$$\mathbf{R_{k \times k}} \text{ such that } \mathbf{P = RR^T} \tag{4}$$

5. Deviations from the mean, $\tilde{e}_{ij}$, are divided by their respective means to produce the fractional deviations from the mean and are then ordered from minimum to maximum:

$$\text{let } d_{ij} = \tilde{e}_{ij}/\overline{X}_j \text{ and } d_{(i)j} = \tilde{e}_{(i)j}/\overline{X}_j \tag{5}$$

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where $d_{(i)j}$ is the ith ordered value for the jth variable.

6. Multivariate kernel density estimation (Silverman, 1986) was the method used to smooth the empirical distribution functions. For the jth random variable, the smoothed percentile is evaluated at a given point d_j^*:

$$\hat{F}\!\left(d_j^*\right)=\frac{1}{nh_j}\sum_{i=1}^{n}K\!\left[\frac{\left(d_j^*-\tilde{d}_{ij}\right)}{h_j}\right]$$

(6)

where $K(\cdot)$ is the cumulative kernel function associated with a continuous kernel density $k(\cdot)$ such that $K(x)=\int_{-\infty}^{x}k(t)dt$. The kernel function is commonly selected from a class of symmetric kernel densities such as the Gaussian, Epanechnikov, biweight, etc. The bandwidth associated with each variable, h_j, is the parameter that influences what degree each data point has on smoothing the CDF. In this study, we used a Gaussian kernel density function, and Silverman's formula (1986) is a suitable associated choice used for the estimation of the bandwidth for a given variable.

The MVKDE of the random vector is simulated as follows for each iteration or sample of the possible states of nature:

1. Generate a k-vector, $\underline{\mathbf{z}}_{\mathbf{k \times 1}}$, of independent standard normal deviates (ISNDs).
2. Pre-multiply the vector of ISNDs by the factored correlation matrix to create a k-vector, $\underline{\mathbf{z}}_{\mathbf{k \times 1}}^{*}$, of correlated standard normal deviates (CSNDs):

$$\mathbf{z}_{\mathbf{k \times 1}}^{*}=\mathbf{Rz}$$

(7)

3. Transform each of the j CSNDs to correlated uniform standard deviates (CUSDs) using the error function:

$$CUSD_j=\boldsymbol{p}_j=ERF\!\left(z_j^*\right)$$

(8)

The error function, $ERF(z)$, is the integral of the standard normal distribution from negative infinity to z, which is the z-value from a standard normal table. The result of the function will be a value between zero and one.

4. The quantile from the jth smoothed empirical distribution function is found by applying the inverse transform method through an iterative bisection optimization procedure. Given the CUSD, $\boldsymbol{p}_j$, the quantile is approximated by

$$\tilde{d}_{\boldsymbol{p}_j}\approx\hat{F}_j^{-1}\!\left(\boldsymbol{p}_j\right)$$

(9)

where $\hat{F}_j^{-1}(\cdot)$ is the approximate inverse smoothed empirical distribution such that $\hat{F}_j\!\left[\hat{F}_j^{-1}(\boldsymbol{p}_j)\right]-\boldsymbol{p}_j\approx 0$, within a pre-specified level of tolerance.

5. Simulate the correlated stochastic value for the jth random variable, recalling that the $\tilde{d}_{\boldsymbol{p}_j}$ values are fractional values of their respective means, as:

$$\tilde{X}_j=\overline{X}_j*\left(1+\tilde{d}_{\boldsymbol{p}_j}\right)$$

(10)

where $\overline{X}_j$ is considered to be the deterministic portion of the modelled random variable and $\tilde{d}_{p_j}$ is the stochastic element. The resulting stochastic vector has interrelated elements based on the selection of the correlated uniform standard deviate, p_j, impacting the $\tilde{d}_{p_j}$ elements. In other words, the resulting random variables are appropriately correlated based on their historical relationship and are coefficient of variation stationary so alternative means can be used without significantly impacting the relative variability (Richardson, 2004).

The SERF procedure

We do not know the decision maker's (DM's) utility function, and some efficiency criteria, which allow a partial ordering of the risky alternatives when the exact degree of risk aversion is not known, must be used. A much used efficiency criterion given risk aversion is second-degree stochastic dominance (SSD). SSD assumes that the DM prefers more income to less and is not risk preferring, i.e., that the risk aversion bounds are $0 \leq r < +\infty$. However, in empirical work it is often found that SSD is not discriminating enough to yield useful results (King and Robison, 1984; Anderson and Hardaker, 2003).

An alternative to SSD is stochastic dominance with respect to a function (SDRF) (Meyer, 1977). In SDRF risk aversion bounds are reduced to $r_L \leq r \leq r_U$, and ranking of risky scenarios is defined for all decision makers whose risk aversion coefficients lie anywhere between the lower and upper bounds r_L and r_U, respectively.

In this paper we apply a more straightforward, and potentially more discriminating method called stochastic efficiency with respect to a function (SERF) (Hardaker et al., 2004b). The SERF method works as follows. For each risky alternative and for a chosen form of the utility function, the subjective expected utility hypothesis means that the utility for net income can be calculated depending on the degree of risk aversion, r, and the distribution of the net farm income, I (Note, for simplicity of the presentation, the $\tilde{I}$ is assumed further to be given by I):

$$U(I,r) = \int U(I,r) f(I) dz \approx \sum_{l=1}^{L} U(I_l, r) P(I_l) \tag{11}$$

where U is evaluated for selected values of r in the range r_L to r_U. The second term represents the continuous case and the third term is the discrete approximation for computational purposes. $P(I_l)$ is the probability for iteration l in the Monte Carlo simulation and we run L iterations (in this study the probability of each of the 1000 iterations in the SERF analysis was the same).

Partial ordering of alternatives by utility values is the same as partial ordering them by certainty equivalents (CEs). For convenience, we chose to convert the utilities to CEs by taking the inverse of the utility function:

$$CE(I,r) = U^{-1}(I,r) \tag{12}$$

CEs are readily interpreted because, unlike utility values, they are expressed in money terms. For a risk-averse decision maker (the normal case), the estimated CE is typically less than the expected money value (EMV). The difference between the EMV and the CE is the risk premium (Hardaker et al., 2004b).

The general rule for SERF analysis for the given assumptions is that the efficient set contains only those alternatives that have the highest (or equal to highest) CE for some value of r in the relevant range.

In SERF, any convenient form of utility function can be used. We used the negative exponential function:

$$U = 1 - \exp(-r_a(I) \times I) \tag{13}$$

where $r_a(I)$ is a non-negative parameter representing the coefficient of absolute risk aversion with respect to net income I, $U'(I) > 0$, and $U''(I) < 0$. This function exhibits constant absolute risk aversion (CARA), which is a reasonable approximation in this study, since we compare annual net farm income that normally is small relative to the farmer's wealth (Hardaker et al., 2004b).

The range of risk aversion used in the SERF analysis is crucial. Anderson and Dillon (1992) proposed a classification of degrees of risk aversion, based on the relative risk aversion with respect to wealth $r_r(W)$ in the range 0.5 (hardly risk-averse at all) to about 4 (very risk-averse). If the coefficient of absolute risk aversion with respect to wealth $r_a(W)$ is needed, we can use $r_a(W) = r_r(W)/W$ (Pratt, 1964; Arrow, 1965).

In this paper, we are not considering utility and risk aversion in terms of wealth, but in terms of income. Since we want to examine a range of relative risk aversion with respect to wealth, $r_r(W)$, from 0 to 4.0 and use a negative exponential function in terms of income, we need relations between $r_r(W)$ and $r_a(I)$. Assume a rational farmer makes the same choice whether the risky outcomes are expressed in terms of wealth or transitory income (i.e. we assume asset integration). We can define W as uncertain wealth, W_0 as initial wealth and I as uncertain transitory income and let $W = W_0 + I$. Then the choice problem can equivalently be expressed in terms of W and I, given W_0 is non-stochastic or I is stochastically independent of W_0. If we do not want preferences to change whether we express outcomes in terms of W or I, we can assume that $r_a(W) \cong r_a(I)$. Then, it follows that (Hardaker et al., 2004a):

$$r_a(I) = r_r(W)/W \qquad (14)$$

Thus multiplying $r_a(I)$ by W for $r_r(W)$ in the range from 0 to 4.0 will yield the approximately corresponding range expressed in $r_a(I)$. In this study, the typical level of a farmer's wealth, W, was assumed to be NOK (Norwegian kroner, €1≈NOK 8.00) 1 350 000. According to equation (14) a value of $r_a(I)$ in the range 0 to 0.000003 corresponds to $r_r(W)$ in the range 0 to 4, which was used as the risk aversion bound in the SERF analysis.

Scenario analysis

The model was used to analyse three different scenarios. First, given prevailing payment system and organic price premiums comparison of the three cash-cropping systems: CON – conventional cash-crop production without farmyard manure; INT – integrated cash-crop production without farmyard manure; and ORG – organic cash-crop production with farmyard manure were investigated.

To encourage crop farmers for converting to and continue organic farming practices, the Norwegian government introduced area payments for producing organic field crops in the mid 1990's. The farmers consider the organic area payment as risky and they fear this payment will decrease (Koesling *et al.*, 2004). In scenario two, therefore, the area payment for organic farming is removed. The ORG producers are then assumed to receive the same area payments as CON and INT producers.

The price premium may decrease as more farmers convert to organic production. Hence, in scenario three, both the organic payments and the organic price premiums are removed. Scenario three illustrates the economic viability of the ORG system without any price premiums or organic support payments. For this last scenario, input prices for organic seeds are reduced almost to the prices of conventional seeds.

Sensitivity elasticity

A sensitivity elasticity (SE) was used to determine which exogenous variables affected net farm income (I) the most. Reutlinger (1970) was the first to use the concept of a SE to quantify the sensitivity of key output variables for a stochastic model. For this study the SEs of net farm income with respect to several exogenous variables are calculated during the simulation process: 1) simulate the model for the base situation and record I for each iteration, 2) increase an exogenous variable by 5 percent and simulate the model and record I for each iteration, 3) repeat step 2 for each exogenous

variable tested for sensitivity, 4) calculate the ES for each iteration, l, across all exogenous variables, s, or:

$$ES_{ls} = \left[\frac{I_{Base,l} - I_{Exog,l}}{I_{Base,l}} \right] / 0.05 \qquad (15)$$

The average $ES_{.s}$ is the sensitivity elasticity for variable s and is interpreted as the percentage change in net farm income, I, for a one percent change in the exogenous variable, s.

Stochastic variables

Most of the stochastic variables used in this study were based on the experimental cropping data from Apelsvoll Research Centre. The field experiment started in 1989, but because it takes some time to get a system established, the data used in this study are based on the results for 1991-1999. The period 1991-1999 was fairly representative of the normal annual variation in growing conditions at the site (Eltun and Nordheim, 1999). For the whole project the experimental units include six types of cropping systems, three cash-crop systems and three forage crop systems. In this paper only the three cash-cropping systems CON, INT and ORG are included. Each cropping system in the experiment was studied on two model farms, each of 0.18 ha. More detailed description of the experiment design, management of individual cropping systems and soil conditions on the model farms are described in Korsaeth and Eltun (2000) and Eltun et al. (2002).

Table 1. Characteristics of the cropping systems at Apelsvoll Research Centre, eastern Norway 1991-1999.

Management	Cropping system[a]		
	Conventional (CON)	Integrated (INT)	Organic (ORG)
Crop rotation	Barley[b]	Barley[b]	Barley[c]
	Winter wheat[d]	Winter wheat[d]	Annual grass-clover
	Oats	Oats	Spring wheat[e]
	Barley	Barley	Potatoes
	Potatoes	Potatoes	Barley[c]
	Spring wheat	Spring wheat	Annual grass-clover
	Oats	Oats	Winter wheat[d, e]
	Barley	Barley	Oats[e]
Fertiliser	Yes	Yes[f]	No
Slurry	No	No	Yes
Soil tillage	Spring ploughing[g]	Spring harrowing	Spring ploughing
Crop protection	Chemical	Integrated[h]	Mechanical

[a] The proportion of cropland is equally devoted to each of the eight crops for each of the three rotation systems.
[b] Early potatoes in the period 1991-1994.
[c] With undersown crop (timothy, red clover and alsike clover).
[d] For CON and INT spring wheat in the period 1998-1999. For ORG spring wheat in 1994-1995 and 1998-1999.
[e] With undersown crop (annual ryegrass and white clover).
[f] Less use of mineral fertilisers compared to the CON system.
[g] Autumn ploughing in the period 1991-1994.
[h] Less use of pesticides compared to the CON system, mechanical weed control in potatoes.

Inspection of the experimental data allowed to collapsing some of the crops within a rotation without significantly reducing the information from the experiment. There were two reasons for doing this. One, some of the crop rotations showed very similar yield distributions over the sample period, and the same level of inputs were applied. Second, to account for stochastic dependency between the stochastic variables, we needed to factorize the crop yields correlation matrix for crop rotation, which requires a positive definite matrix. By reducing the number of highly correlated variables, the matrix factorization was possible. The consolidation resulted in six crops in the CON and INT systems and seven crops in the ORG

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systems. Table 2 shows the descriptive yield statistics and elicited expert judgments (prepared by an expert group of crop researchers) about minimum and maximum yield levels for the individual crops in the cropping systems.

Table 2. Descriptive yield statistics and subjective judgments of minimum and maximum yields for the individual crops in the cropping systems, 1991-1999.

Cropping system	Barley I[c] (kg ha^{-1})	Barley II[c] (kg ha^{-1})	Oats[d] (kg ha^{-1})	Potato (kg ha^{-1})	Spring wheat (kg ha^{-1})	Winter wheat (kg ha^{-1})	Grass-clover (kg DM ha^{-1})
Conventional							
Mean	5018	5665	5394	30839	5903	5867	
CV[a]	27.8	15.9	16.4	23.3	15.9	26.0	
Minimum,o[b]	2718	4053	3812	19500	4290	4229	
Maximum, o	6871	7124	6897	42650	7224	8171	
Minimum, s[b]	1600	1600	1800	15000	1800	1800	
Maximum, s	8700	8700	8600	49000	8600	9000	
Integrated							
Mean	4496	4908	4816	27749	4943	5299	
CV	30.1	19.1	21.9	21.4	10.9	25.5	
Minimum, o	2800	3915	2718	22310	4150	4053	
Maximum, o	6212	6506	6159	40910	5982	7565	
Minimum, s	1600	1600	1800	15000	1800	1800	
Maximum, s	7100	7100	7000	47000	6800	8300	
Organic							
Mean	3165	3823	3415	21103	3422	3734	8939
CV	43.3	35.3	44.1	43.6	18.0	16.1	22.7
Minimum, o	1320	1320	0	7100	2120	3012	6309
Maximum, o	5329	6306	4900	36670	4194	4471	11774
Minimum, s	0	0	0	0	0	0	3000
Maximum, s	6900	6900	5400	42500	4600	4900	13000

[a] CV = coefficient of variation, defined as standard deviation divided on mean yield.
[b] o = observed value from the experiment, s = subjective extreme values given by an expert group.
[c] Barley I and Barley II represent two different varieties of barley.
[d] For CON and INT the two oats experiment (cf. Table 1) results (same varieties) were combined in one variable.

Compared to the CON system, the average yields were lower for all individual crops in the INT system, and lowest in the ORG system. Stanhill (1990), Offermann and Nieberg (2000), Mäder et al. (2002) and Mahoney et al. (2004) have reported similar results. The relative variability in yields, expressed by the coefficient of variation (CV) were, in general, highest for ORG, second highest for INT, and smallest for the CON cropping system. However, for potatoes and spring wheat production, the INT rotation system showed the smallest relative variation, while for winter wheat the ORG system showed the smallest CV.

It is well known that the experimental yield typically exceed the response achieved under workaday farm conditions (e.g., Dillon and Anderson, 1990). But these yield effect should not affect the comparisons of the systems, since all yield data were experimental. The soil at Apelsvoll Research Centre is nutrient-rich (Korsaeth and Eltun, 2000), so the yield level for the ORG system shows the potential for fertile soils under Nordic weather conditions.

In Norway, target (maximum) prices and support payments are determined in annual negotiations between the farmers' unions and the government, so grain prices are non-stochastic. The potato price has been quite unpredictable, and was specified as stochastic. Deflated (to 2004-money value) historical potato prices in NOK per kg for 1991-1999 from the Agricultural Price Reporting Office (LP, 2000) were used to specify the empirical potato price distribution. Based on organic potato price premiums in Norway 2003/2004 and price premiums for organic potatoes in other European countries (Offermann and Nieberg, 2000), we assumed organic potatoes sold at prices 50% above conventional prices, and with the same absolute variability.

Even if the basis price for wheat can be regarded as deterministic, the quality parameters such as falling number and protein content will cause a stochastic farm-gate price. These quality parameters were registered in the experiment and were used to specify stochastic wheat prices. Table 3 shows the descriptive product price statistics for wheat and potato. For all crop products, prices at harvesting were used (versus annual average prices) to account for the value of production only and not for storage and marketing strategies.

Table 3. Descriptive product price statistics in NOK (€1≈NOK 8.00) kg^{-1} for spring wheat, winter wheat and potato. Year 2004 price level.

Cropping system	Potato	Spring wheat	Winter wheat
Conventional			
Mean	1.66	2.04	1.97
CV[a]	21.10	8.82	9.25
Minimum	1.18	1.56	1.56
Maximum	2.19	2.10	2.05
Integrated			
Mean	1.66	1.97	1.97
CV	21.10	11.94	9.25
Minimum	1.18	1.56	1.56
Maximum	2.19	2.10	2.05
Organic			
Mean	2.49	3.18	2.92
CV	14.07	5.15	7.47
Minimum	2.01	2.76	2.76
Maximum	3.02	3.30	3.17

[a] CV = coefficient of variation.

The experimental site was irrigated in cases of moderate or extreme moisture deficit, with the same amount of water to all crops. Variable costs of irrigation were estimated for each year based on the water used and the actual rounds of irrigation. Cost of water was calculated based on energy costs per mm water per hectare. Costs of an irrigation round included labour and tractor costs.

Deterministic variables

The farm in this study was constructed to have 40 ha of arable land, a typical crop farm size in the region. The farms with CON and INT cropping system cultivated 15 ha barley, 10 ha oats, 5 ha spring wheat, 5 ha winter wheat, and 5 ha potatoes. The ORG crop systems consisted of 10 ha barley, 5 ha oats, 5 ha spring wheat, 5 ha winter wheat, 5 ha potatoes, and 10 ha clover grass.

The price of silage made from grass-clover was treated as deterministic, as were input prices and prevailing area payment schemes (2004/2005). These deterministic data, which were taken from NILF (2004a), are shown in Table 4.

Inputs such as seed, fertilizer/manure, pesticides, and machinery operations were identical to the experiment. The costs of machinery operations, based on prevailing rented cost in the market, exclusive of operator labour, were based on typical mechanization for 40 ha farms. European studies show labour use in organic crop farming 10-20% higher than comparable conventional systems (Offermann and Nieberg, 2000). We assumed the additional labour requirement in ORG to be 15% more than the 2000 hours of labour for CON. The INT system was assumed to use 20 hours less labour per year than CON because of the less labour intensive tillage system. INT fixed cost was estimated at NOK 160 000, based on the Norwegian farm accounting survey (NILF, 2004b). The extra labour cost for CON resulted in fixed cost of NOK 162 684, for the ORG system NOK 205 284.

Table 4. Deterministic product prices in NOK kg^{-1}, and area payments and variable costs (VC) in NOK ha^{-1} for each individual crop and cropping system. Year 2004 price level.

Cropping system	Barley I	Barley II	Oats	Potato	Spring wheat	Winter wheat	Grass-clover
Conventional							
Product price[a]	1.64	1.64	1.41	1.66[b]	2.04[b]	1.97[b]	
Area payment	3300	3300	3300	2500	3300	3300	
Seeds	782	871	752	4850	1083	950	
Fertilisers	1023	1023	986	2470	1509	1602	
Pesticides	819	729	509	1819	1168	1235	
Machinery[c]	3142	3142	3142	14071	3247	3247	
Others[d]	295	295	295	3295	295	295	
Sum VC	6061	6061	5684	26505	7302	7329	
Integrated							
Product price[a]	1.64	1.64	1.41	1.66[b]	1.97[b]	1.97[b]	
Area payment	3300	3300	3300	2500	3300	3300	
Seeds	782	871	752	4850	1083	950	
Fertilisers	744	744	744	1581	905	1046	
Pesticides	379	69	69	632	619	619	
Machinery[c]	2249	2249	2249	15202	2606	2606	
Others[d]	295	295	295	3295	295	295	
Sum VC	4449	4229	4109	25560	5508	5516	
Organic							
Product price[a]	2.79	2.79	2.36	2.49[b]	3.18[b]	2.92[b]	1.43[f]
Area payment[e]	5800	5800	5800	5000	5800	5800	3540
Seeds	2399	2399	2052	5850	2624	2420	1335
Manure	500	500	500	1000	500	500	
Machinery[c]	3128	3128	3296	16365	3296	3128	2296
Others[d]	295	295	295	3295	295	295	295
Sum VC	6322	6322	6143	26510	6715	6343	3926

[a] Product prices net of yield dependent haulage cost for grain and potatoes and silage making costs for annual grass-clover.
[b] Stochastic variables are specified in Table 3.
[c] Cost of all machinery operations.
[d] The expected value of the stochastic specified irrigation cost is included here, in addition to miscellaneous cost in potato production.
[e] Included the specific organic area payments of NOK 2500 ha^{-1} for grains and potatoes and NOK 550 ha^{-1} for grasslands.
[f] Product price for annual grass-clover is in NOK (kg DM)$^{-1}$.

Results and discussion

Existing Norwegian price and public payment system
Results of simulating the three alternative crop systems given existing payment system and organic price premiums in Norway are presented as CDFs of annual total net farm income in Figure 2.
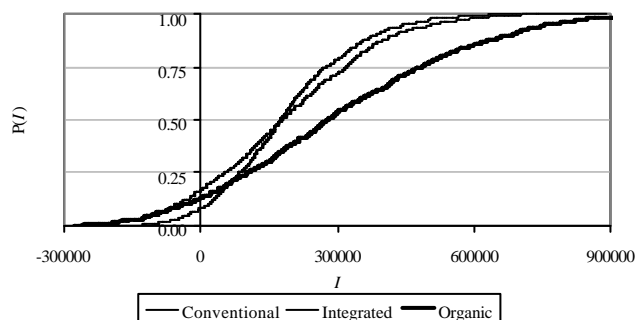

Figure 2. Simulated CDFs of annual total net farm income, *I*, in NOK under CON, INT and ORG cropping systems. Farm size 40 ha.

Three observations can be drawn from Figure 2. First, the ORG system in general shows a higher net farm income than the CON and INT systems. Second, the net income from the ORG system can be described as the one with the most uncertain income, since the CDF for ORG is less steep than the CDFs for CON and INT. Moreover, the ORG CDF has a lower minimum and a larger maximum than either of the other CDFs. The relative uncertainty for yields is generally highest for the ORG system (Table 2). In addition, the high yield uncertainty combined with the organic price premium has a multiplicative effect on the uncertainty of net farm income for the ORG farming system. Third, under the existing payment schemes, all of the crop systems show some probability of generating negative net farm income. For example, the CON system is associated with an 18 percent chance of experiencing a negative annual net farm income, while the corresponding chance is about 14 percent for the ORG system.

The expected annual net farm income for the simulated ORG system is NOK 300 000, for INT NOK 188 000, and for CON NOK 187 000. In other words, the CON and INT systems were found to have the almost same expected income. Crop yields were higher under the high input CON strategy, but were offset by cost savings for the INT system because of lower costs for tillage, fertiliser, and pesticides. Comparison of CDFs for the CON and INT crop systems shows that they have a slightly different risk profile, where the INT system has the lowest uncertainty. The alternative cropping system a farmer would prefer depends on his/her degree of risk aversion.

A SERF analysis of the three risky alternative cropping systems is summarized in Figure 3. At all risk aversion levels, from risk-neutral to highly risk-averse, farmers would prefer the ORG farming system over the INT and CON systems. A risk-neutral farmer would rank the CON and INT cropping systems equally. The INT cropping system would be slightly more preferred than the CON system for farmers with some degree of risk aversion, because INT has higher CEs than the CON for all degrees of risk aversion, $r_a(I)$.
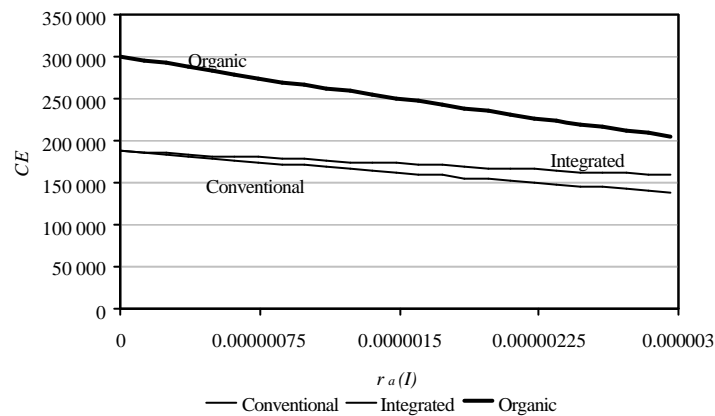

Figure 3. CEs for annual net farm income in NOK for the CON, INT and ORG crop systems. $r_a(I)$ in the range 0 to 0.000003 corresponds approximately to $r_r(W)$ in the range 0 to 4.

The experimental data used reflect fertile soils and relatively good growing conditions. In Norway, nitrogen supply is the major factor limiting plant growth in organic cropping systems (Haraldsen et al., 2000). Under less fertile soil conditions yield differences between organic and conventional crops may be higher. However, a mean yield decrease in the ORG production of 10%, ceteris paribus, did not change the preference of ORG over CON and INT for all values of risk aversion tested.

Effects of removing organic area payments

The presiding results may be sensitive to changes in the existing payment system. If the area payments for organic farming are removed and the ORG producers are assumed to receive the same area payments as CON and INT producers the net farm income distribution for ORG are changed (Figure 4).
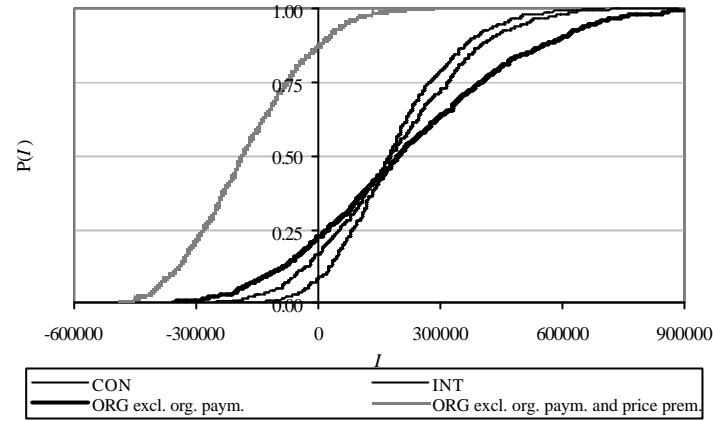
Figure 4. Simulated CDFs of annual total net farm income, *I*, in NOK if organic area payments are removed for the ORG system (bold line) and if organic area payments and price premiums are removed for the ORG system (shaded bold line).

Comparing Figure 4 with Figure 2 shows a negative shift in the ORG system's CDF of annual total net farm income when existing organic area payments were removed (the bold curve for ORG). The expected mean annual net farm income for ORG dropped from NOK 300 000 with organic area payments to NOK 220 000 without the organic support payments. Figure 5 shows for this scenario the normative rank of cropping systems for different degree of risk aversion.
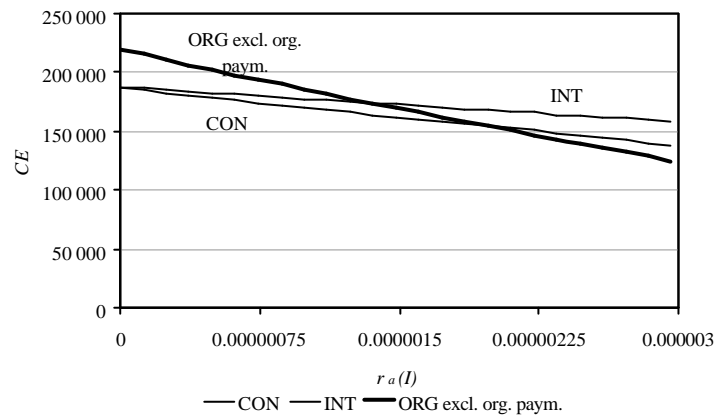

Figure 5. Scenario with no area payments for organic farming. CEs for annual net farm income in NOK for the CON, INT and ORG (without organic area payments) cropping systems.

Under these circumstances the ORG systems seems to be most preferred for farmers with absolute risk aversion levels, $r_a(I)$, less than 0.0000015 $\left(\approx r_r(W) = 2\right)$ and the INT systems may be considered as more efficient for farmers with absolute risk aversion levels greater than 0.0000015.

May be more interesting is to analyse how large the organic area payment should be, under prevailing market prices, to make the ORG systems from the farmers' point of view economic equivalent with the CON and INT system. Subtracting the CE for a less preferred alternative from the dominant alternative, yields a utility weighted risk premium (Hardaker et al., 2004b). Table 5 shows the risk premiums between the modified ORG and the INT and CON crop systems for different degrees of risk aversion.

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Table 5. Risk premiums between the ORG system without area payment for organic farming and the INT and CON crop systems for different degrees of risk aversion.

Crop system	Unit	Coefficient of risk aversion		
	$r_a(I)\times10^{-5}$	0	0.15	0.3
	$\approx r_r(W)$	0	2	4
ORG vs. CON	NOK×1000	32	8	-13
ORG vs. INT	NOK×1000	32	-3	-34

In general, the risk premium between the different cropping systems and coefficient of risk aversion are fairly low (between NOK 32 000 and NOK -34 000), which imply that the three crop systems should normatively be considered not very different with respect to economic viability by farmers with different degrees of risk aversion. As an example, a highly risk-averse CON farmer $(r_r(W) \approx 4)$ that receives an annual risk premium of NOK 13 000 (for example as area payment) would consider the economic viability in ORG production equal to the CON system. A risk-neutral farmer would consider ORG farming as the most economically viable alternative, and a CON or INT producer will "get" a risk premium of NOK 32 000 by converting to ORG production.

Effects of removing organic area payments and organic price premiums
Comparing the shaded bold CDF in Figure 4 with the bold CDF in Figure 2 shows a dramatic negative shift in the ORG system's CDF of annual total net farm income if both the organic area payments are removed and the organic price premiums erodes. At any degree of risk aversion, the CON and INT production systems were more economically efficient than ORG farming. The expected mean annual net farm income for ORG dropped to NOK -176 000 for the scenario without organic support payments and price premiums. Figure 4 shows an 87% chance that the ORG system will generate a negative annual net farm income.

Sensitivity elasticity
The sensitivity elasticities presented in Table 6 are based on the following aggregated exogenous variables under the prevailing payment system (results presented in the subsection "Existing Norwegian price and public payment system" before): mean product prices, public area payments, and variable cost. Individual elasticities for barley price, public area payments for wheat land, etc. are not reported. Since yields and prices enter the net farm income formula the same way, they have the same sensitivity elasticities.

Table 6. Sensitivity elasticity of net farm income with respect to product prices, area payments and variable costs for three crop systems.

Exogenous variables	Conventional		Integrated		Organic	
	Mean	Std. dev.[a]	Mean	Std. dev.	Mean	Std. dev.
Product prices	3.15	27.53	3.09	25.69	2.65	17.85
Area payments	0.69	8.86	0.81	10.25	1.02	11.14
Variable costs	-1.93	24.76	-1.86	22.69	-1.63	17.56

[a] Std. dev. = standard deviation.

The product price affected the net farm income most, independently of cropping system. All other things unchanged, one percent change in all product prices, in e.g. the CON cropping system, would increase the net farm income more than three percent. The second most sensitive of the analyzed exogenous variables was variable costs, with the ORG system as the least sensitive. For the CON and INT systems, one percent change in area payments would increase the net farm income less than one percent. The ORG system had the highest sensitivity elasticity for area payments (1.02).

Concluding comments

Many decision problems in agriculture involve situations where data are too few to provide a good basis for probability assessment. Then there is both scope and need for inventiveness to get better analyses for these types of investigations. The simulation procedure that uses a multivariate kernel estimator seems to be a useful methodical advance to smooth out irregularities in sparse data set. Many other issues than analysed in this study could have been evaluated with a similar method. The SERF method seems to be a useful and easily understood tool to assist policy makers, advisers as well as farmers on similar problems as in this paper.

The results show that the organic cropping system currently stands out as the most economically viable alternative and the most preferred alternative for risk-averse producers, even though annual net farm income is more uncertain. Without area payments for organic farming and organic price premiums, the other two cropping systems would be preferred by all farmers, regardless of degree of risk aversion.

Although the results are site specific for eastern Norway, the differences in performance between cropping systems may not be very different on other sites with similar weather and growing conditions.

A farmers' choice of cropping systems could include other concerns than economics (e.g., Gasson et al., 1988). Policy makers have also several objectives to consider when developing their policies, and some trade-offs have to be made. For example, which farming methods best contribute to food safety, product diversity, environmental and social benefits, economic viability, and consumers demand is a complex question, often with conflicting objectives. Based on results from the same experiment as used in our study Eltun et al. (2002) ranked ORG first, INT second and CON third with respect to environmental effects such as nutrient runoff, soil erosion and pesticide contamination, but for the ORG system the nutrient balance showed a considerable deficit. Other studies have found enhanced soil fertility and higher biodiversity in organic fields (Mäder et al., 2002; Hole et al., 2005). One way to weight the wide range of effects against, e.g., economic aspects could be some form of multi-attribute analysis, but that is left for further research.

References

Anderson, J. R. (1974). Sparse data, estimational reliability and risk-efficient decisions. *American Journal of Agricultural Economics* 56: 564-572.

Anderson, J. R. and Dillon, J. L. (1992). *Risk Analysis in Dryland Farming Systems*. Farming Systems Management Series No. 2. Rome: FAO.

Anderson, J. R. and Hardaker, J. B. (2003). Risk aversion in economic decision making: Pragmatic guides for consistent choice by natural resource managers. In Wesseler, J., Weikard, H-P. and Weaver, R. (eds), *Risk and Uncertainty in Environmental Economics*. Cheltenham: Edward Elgar, 171-188.

Anderson, J. R., Dillon, J. L. and Hardaker, J. B. (1977). *Agricultural Decision Analysis*. Ames, IA: Iowa State University Press.

Arrow, K. J. (1965). *Aspects of the Theory of Risk-Bearing*. Helsinki: Yrjö Jahnssonin Säätiö, Academic Bookstore.

Dillon, J. L. and Anderson, J. R. (1990). *The Analysis of Response in Crop and Livestock Production, 3rd edn*. Oxford: Pergamon.

Eltun, R. and Nordheim, O. (1999). Yield results during the first eight year crop rotation of the Apelsvoll cropping system experiment. In Olesen, J. E., Eltun, R., Gooding, M. J., Jensen, E. S. and Köpke, U. (eds), *Designing and Testing Crop Rotations for Organic Farming*. DARCOF Report No. 1, 1999, 79-89.

Eltun, R. Korsæth, A. and Nordheim, O. (2002). A comparison of environmental, soil fertility, yield, and economic effects in six cropping systems based on an 8-years experiment in Norway. *Agriculture, Ecosystems and Environment* 90: 155-168.

Gasson, R., Crow, G., Errington, A., Huston, J., Marsden, T. and Winter, D. M. (1988). The farm as a family business: a review. *Journal of Agricultural Economics* 39: 1-41.

Haraldsen, T. K., Asdal, A., Grasdalen, C., Nesheim, L. and Ugland, T. N. (2000). Nutrient balances and yields during conversion from conventional to organic cropping systems on silt loam and clay soils in Norway. *Biological Agriculture & Horticulture* 17: 229-246.

Hardaker J. B., Huirne R. B. M., Anderson J. R. and Lien G. (2004a). *Coping with Risk in Agriculture, 2nd edn*. Wallingford: CABI Publishing.

Hardaker, J. B., Richardson, J. W., Lien, G. and Schumann, K. D. (2004b). Stochastic efficiency analysis with risk aversion bounds: a simplified approach. *Australian Journal of Agricultural Economics* 48: 253-270.

Hole, D. G., Perkins, A. J., Wilson, J. D., Alexander, I. H., Grice, P. V. and Evans, A. D. (2005). Does organic farming benefit biodiversity? *Biological Conservation* 122: 113-130.

King, R. P. and Robison, L. J. (1984). Risk efficiency models. In: P.J. Barry (ed), *Risk Management in Agriculture*. Ames, IA: Iowa State University Press, 68-81.

Korsaeth, A. and Eltun, R. (2000). Nitrogen mass balances in conventional, integrated and ecological cropping systems and the relationship between balance calculations and nitrogen runoff in an 8-year field experiment in Norway. *Agriculture, Ecosystems and Environment* 79: 199-214.

Koesling, M., Ebbesvik, M., Lien, G., Flaten, O., Valle, P. S. and Arntzen, H. (2004). Risk and risk management in organic and conventional cash crop farming in Norway. *Acta Agriculturæ Scandinavica C - Food Economics*, forthcoming December 2004.

LP (2000). Landbrukets Priser: Jordbruk, hagebruk, driftsmidler. Oslo: Landbrukets Priscentral (The Agricultural Price Reporting Office) [Annual publication, In Norwegian].

Mäder, P., Fliessbach, A., Dubois, D., Gunst, L., Fried, P. and Niggli, U. (2002). Soil feritlity and biodiversity in organic farming. *Science* 296: 1694-1697.

Mahoney, P. R., Olson, K. D., Porter, P. M., Huggins, D. R., Perrilo, C. A. and Crookston, R. K. (2004). Profitability of organic cropping systems in southwestern Minnesota. *Renewable Agriculture and Food Systems* 19: 35-46.

Meyer, J. (1977). Choice among distributions. *Journal of Economic Theory* 14: 326-336.

Morris, C. and Winter, M. (1999). Integrated farming systems: the third way for European agriculture? *Land Use Policy* 16: 193-205.

NILF (2004a). *Handbok for driftsplanlegging* (*Handbook in Farm Planning*) *2004/2005*. Oslo: Norwegian Agricultural Economics Research Institute.

NILF (2004b). *Driftsgranskinger i i jord- og skogbruk* (*Account Results in Agriculture and Forestry) 2003*. Oslo: Norwegian Agricultural Economics Research Institute.

Offermann, F. and Nieberg, H. (2000). *Economic Performance of Organic Farms in Europe*. Organic farming in Europe: Economics and Policy, Volume 5. Stuttgart: University of Hohenheim.

Pratt, J. W. (1964). Risk aversion in the small and in the large. *Econometrica* 32: 122-136.

Reutlinger, S. (1970). Techniques for project appraisal under uncertainty. World Bank Occasional Paper No. 10. Baltimore: John Hopkins Press.

Ribera, L. A., Hons, F. M. and Richardson, J. W. (2004). An economic comparison between conventional and no-tillage farming systems in Burleson county, Texas. *Agronomy Journal* 96: 415-424.

Richardson, J. W. (2004). Simulation for Applied Risk Management. College Station, TX: Departement of Agricultural Economics, Texas A&M University.

Richardson, J. W., Klose, S. L. and Gray, A. W. (2000). An applied procedure for estimating and simulating multivariate empirical (MVE) probability distributions in farm-level risk assessment and policy analysis. *Journal of Agricultural and Applied Economics* 32: 299-315.

Roberts, W. S. and Swinton, S. M. (1996). Economic methods for comparing alternative crop production systems: A review of the literature. *American Journal of Alternative Agriculture* 11: 10-17.

Schlaifer, R. (1959). *Probability and Statistics for Business Decisions.* New York: McGraw-Hill.

Schlaifer, R. (1969). *Analysis of Decisions under Uncertainty*. New York: McGraw-Hill.

Silverman, B. W. (1986). *Density Estimation and Data Analysis*. New York: Chapman and Hall.

Smith, E. G., Clapperton, M. J. and Blackshaw, R. E. (2004). Profitability and risk of organic production systems in the northern Great Plains. *Renewable Agriculture and Food Systems* 19: 152-158.

Stanhill, G. (1990). The comparative productivity of organic agriculture. *Agriculture, Ecosystems and Environment* 30: 1-26.

Yunlong, C. and Smit, B. (1994). Sustainability in agriculture: a general review. *Agriculture, Ecosystems and Environment* 49: 299-307.