COMPARISON OF RISK IN ORGANIC, INTEGRATED AND CONVENTIONAL CROPPING SYSTEMS IN EASTERN NORWAY

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ABSTRACT

Risk is important for farmers' choice of cropping system. The aim of this study was to compare risk of organic, integrated and conventional cropping systems. 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 statistical procedure to smooth the sparse experimental data. Stochastic efficiency with respect to a function was used to rank the cropping systems for farmers with various degrees of risk aversion. The results show that the organic system was riskiest, but the existing payment system and organic price premiums makes it the most economically viable alternative today.

Key words: Risk analysis, crop farming, stochastic simulation, risk aversion, stochastic efficiency with respect to a function

INTRODUCTION

It is a 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. Important attributes in sustainable agriculture are ecological, social and economic perspectives (Yunlong and Smit, 1994). The effects of different cropping systems on environment, agronomy and economic aspects are important in that connection.

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 different cropping systems was initiated in 1989 at Apelsvoll Research Centre in the eastern part of Norway. Eltun et al. (2002) compared environmental, soil fertility, yield and economic effects between the cropping systems. The economic analysis was however simple, ignoring the effects of risk.

There are reasons to believe that different cropping systems behave differently given the same weather situations and thus have different impacts on whole-farm risk. For example restrictions on pesticide and fertiliser use may give different production risk in organic farming than in conventional farming. 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

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(mean) of the profitability between cropping systems will often be too simple.

Most economic studies comparing cropping systems look exclusively at profitability by analyzing average net farm income (Roberts and Swinton, 1996). However, profitability is an insufficient criterion as it ignores that the risk profile for net income can be quite different between cropping systems.

One method for incorporating effects of profit (in)stability is stochastic simulation. 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 USA. In general, optimal crop rotation choices depended both on price premiums and farmer's degree of risk aversion.

We expand on the procedure used by Ribera et al. (2004). Our goal is to compare the risk between conventional, integrated and organic cropping systems in eastern Norway, and to quantify the importance of specific organic area payments and price premiums on economic viability. The Apelsvoll experimental cropping data are supplemented with budgeted data.

Materials

It is hard to find relevant and reliable data to compare differences in risk between cropping systems. One option could be to use non-experimental farm-level panel data, i.e., repeated observations over time on the same farms. There are two main problem with non-experimental farm-level panel data for comparing risk between cropping systems: 1) they are very hard (if not impossible) to find; 2) they would normally include noise, such as different climate, soil and growing conditions, disease and weed stress, topology conditions, farm management practice etc., that have little to do with differences in risk between the cropping systems.

An alternative to the non-experimental farm-level panel data is to use experimental panel data, as used in our study. Then you avoid most of the problems mentioned in point 2 above. The problems with this type of data are: 1) usually few observations; 2) farm practices and results from experimental conditions differ from what is obtained in the real life; and 3) data are often only from one site.

This last point reduces the generality of the results. However, some generality can be drawn, since the focus in the study is differences in risk between cropping systems, and the differences would often not be very different from other sites with quite similar weather and growing conditions. Regarding point 2 above, the yield effects should not influence comparisons of the systems, since all yield data were experimental. Further, the experimental practice and yield data used in this study were close to what is the typical for crop farms in eastern Norway. Our approach to reduce the effects of sparse data problems is discussed in the "Method" section.

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, while the data used in this study is based on the results for 1991-1999. The period 1991-1999 was fairly representative of the normal annual variation in growing conditions. Following three cropping systems are included in our dataset: CON – conventional crop production without manure; INT – integrated crop production without manure; and ORG – organic crop production with manure. Each cropping system in the experiment is represented on two model farms of 0.18 ha. Each model farm has eight rotation plots and an eight-year crop rotation. All of the crops in each rotation are present each year. Table 1 summarizes the main characteristics of the cropping systems. More detailed description of the experiment design, management of individual cropping systems and soil conditions on the model farms are described in Eltun et al. (2002).

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

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

[a] Early potatoes in the period 1991-1994.
[b] With undersown crop (timothy, red clover and alsike clover).
[c] For CON and INT spring wheat in the period 1998-1999. For ORG spring wheat in 1994-1995 and 1998-1999.
[d] With undersown crop (annual ryegrass and white clover).
[e] Less use of mineral fertilizers compared to the CON system.
[f] Autumn ploughing in the period 1991-1994.
[g] 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. The consolidation resulted in six crops in the CON and INT systems and seven crops in the ORG 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 (kg ha^{-1})	Barley II (kg ha^{-1})	Oats (kg ha^{-1})	Potato (kg ha^{-1})	Spring wheat (kg ha^{-1})	Winter wheat (kg ha^{-1})	Clover grass (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.
[b] o = observed value from the experiment, s = subjective extreme values given by an expert group.

Compared to the CON system, the average yields were lower for all individual crops in the INT system, and lowest in the ORG system. 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.

In Norway, target prices and support payments are determined in annual negotiations between the two farmers' unions and the government. The potato price has been quite unpredictable, and was specified as stochastic. Deflated (to 2004-money value) historical potato prices in NOK (Norwegian kroner) 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.

Grain prices have been non-stochastic. 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 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 8.15) 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.

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.

Deterministic product prices (reduced for the yield dependent hauling cost and ensilage cost for clover grass), input prices and prevailing area payment schemes (2004/2005) were taken from NILF (2004a). These variables together with variable costs are shown in Table 4.

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

[a] Stochastic variables are specified in Table 3.
[b] Included the specific organic area payments of NOK 2500 ha^{-1} for grains and potatoes and NOK 550 ha^{-1} for grasslands.
[c] The expected value of the stochastic specified irrigation cost is included here, in addition to miscellaneous cost in potato production.
[d] Product price for clover grass is in NOK $(kg\ DM)^{-1}$.

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.

Scenario analysis

The model was used to analyse three scenarios. First, given prevailing payment system and organic price premiums comparison of the three cropping systems CON, INT, and ORG 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). The organic price premiums are to a larger extent determined by supply and demand forces in the market. The price premium may decrease, as more converters will increase the supply.

In scenario two the area payment for organic farming are removed. The ORG producers are then assumed to receive the same area payments as CON and INT producers.

In scenario three, in addition to the organic payments were also the organic price premiums removed. This scenario illustrates the ORG system's economic viability without any price premiums or organic support payments. For this last scenario, input prices on organic seeds were almost down to prices on conventional seeds.

METHOD

We used a stochastic simulation model that estimated the empirical probability distribution for annual net farm income ($\tilde{I}$), given three alternative cropping systems. For each cropping system the simulation model was represented by:

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

where:

A_j is the area in hectare of crop j in the cropping system, is then 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 experimental sample data consisted of nine annual observations, and maybe some adjustment of irregularities should be done. In simulation, sample data can either be fit to a parametric distribution (such as the normal) or one let the "data speak" using the empirical distribution. Standardised probability distributions are often inadequate because they are not flexible enough to fit the sparse data. On the other hand, letting the sparse sample data speak through empirical distributions may give biased and irregular distributions. In cases with sparse data it usually makes sense to smooth out any irregularities in the sample data or empirical distributions. Irregularities in an empirical distribution are usually a result of sampling from the true distribution and reflect sampling error. It is almost always reasonable to assume that the population follows a smooth distribution, implying that the irregularities should be eliminated in fitting a distribution (Anderson, 1974). Figure 1 illustrates the empirical and a smoothed CDF (cumulative density function) of organic barley yields in the Apelsvoll experiment.

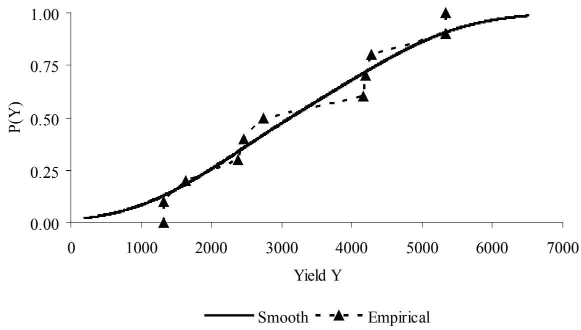

Figure 1. Empirical and smoothed CDF (cumulative density function) for organic barley yield per ha.

Supplementary information that can make the sparse data more reliable should be considered. For example, it seems reasonable that the upper and lower bounds of a true underlying continuous distribution would be more extreme than those observed from a sparse data set, see the smoothed CDF in Figure 1. Expert-judgments can be used to achieve qualified estimates on such bounds.

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). Our procedure uses a kernel density estimation (KDE) function (Silverman, 1986) to smooth out irregularities in the sparse sample data for yields and prices.

Risk analysis requires both probabilities and preferences for outcomes held by the farmer. The subjective expected utility hypothesis (SEU) states that a person will seek to make risky choices consistently with what they believe, as measured by their subjective probabilities, and with what they prefer, as evaluated via their utility functions for consequences (Hardaker et al., 2004a). The shape of the utility function reflects a person's attitude towards risk. Several attempts have been made to elicit such utility functions from relevant farmers in order to put the SEU hypothesis to work in the analysis of risky alternatives in agriculture. Usually the results have been rather unconvincing. Partly to avoid the need to elicit a specific single-valued utility function, methods under the heading of stochastic efficiency criteria have been developed.

In this study we apply a method called stochastic efficiency with respect to a function (SERF) (Hardaker et al., 2004b) as efficiency criteria. The SERF method partitions a set of risky alternatives in terms of certainty equivalents (CEs) as the selected measure of risk aversion is varied over a defined range. A CE is defined as the sure sum with the same utility as the expected utility of a risky alternative (Hardaker et al., 2004a). The general rule for SERF analysis is that the efficient set contains only those alternatives (in our case crop systems) that have the highest (or equal highest) CE for some value of risk aversion in the relevant range.

To compute the CEs we start by picking a particular form for the utility function (in this study the negative exponential function). For a chosen utility function the utility of permanent income (expressed as CE) can be calculated depending on the farmer's degree of risk aversion and the distribution of the permanent income (which is the output from the simulation procedure).

The range of risk aversion to be used in the SERF analysis is crucial. The farmer's relative risk aversion with respect to wealth is the appropriate one for prescriptive analysis. Hardaker et al. (2004a) show how to get consistency between relative risk aversion with respect to wealth and absolute risk aversion (for the negative exponential utility function used in this study) with respect to permanent income (as is the payoff measure in our study).

The model used in our study was programmed in Excel and simulated using the Excel Add-In, Simetar (Richardson, 2004).

Results and discussion

Existing Norwegian price and public payment system

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

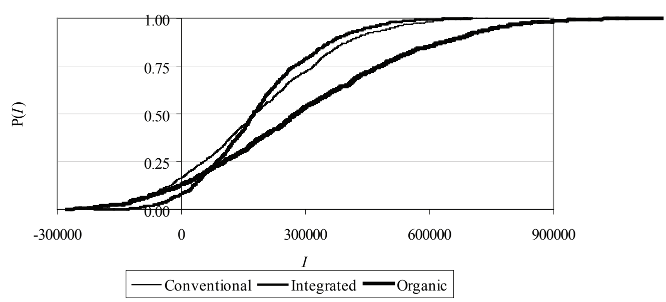

Figure 2. CDFs of annual total net farm income (I) in NOK under CON, INT and ORG cropping systems. Farm size 40 ha.

Three observations can be drawn from Figure 2. First, the ORG system had in general a higher net farm income than the CON and INT systems. Second, the net income from the ORG system was, informally described, the most risky one, since the CDFs for ORG was less steep than for CON and INT. The relative variability in yields was in general highest for the ORG system (Table 2). In addition, the high yield variability combined with the organic price premium gives a multiplier effect on the net farm income's variability in ORG farming. Third, under existing payment schemes, all of the crop systems had a small probability of generating negative net farm income.

The expected mean annual net farm income for ORG was NOK 300 000, for INT NOK 188 000, and for CON NOK 187 000. In other words, the CON and INT systems had almost the same expected income. Crop yields were higher under the high input CON strategy, but were offset by cost savings in the INT system because of less tillage, less fertilizer, and less pesticide. Comparison of CDFs for the CON and INT crop systems shows that they have a slightly different risk profile, where the INT system was least risky. Which of these two alternatives a farmer would prefer, depends on his/her degree of risk aversion. To rank the risky alternatives, the SERF approach resulted in a CE-graph shown in Figure 3.

A risk-neutral farmer ranks the CON and INT crop systems almost equally (as also indicated by expected mean incomes). The INT cropping system is slightly more preferred than the CON system for farmers at any degree of risk aversion, since of these two systems INT has higher CEs for all values of degree of risk aversion.

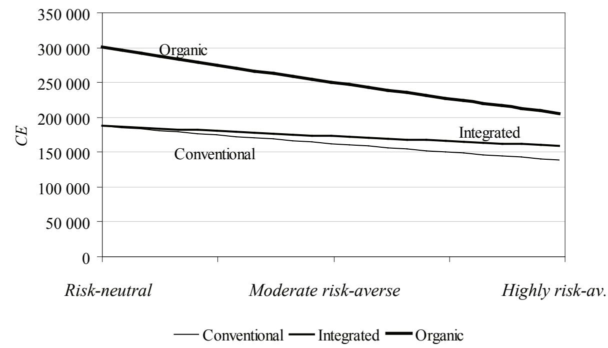

Figure 3. Certainty equivalents (CEs) for annual net farm income in NOK for the CON, INT and ORG crop systems.

Effects of removing organic area payments

The presiding results may be sensitive to changes in the payment system. If the area payments for organic farming are removed and ORG producers receives the same area payments as CON and INT producers the net farm income distribution for ORG is changed (Figure 4).

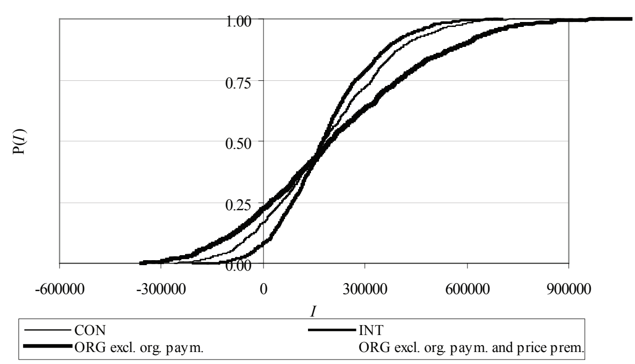

Figure 4. CDFs of annual total net farm income (I) in NOK if organic area payments are removed for the ORG system (bold line) and if organic area payments and price premiums are removed for the ORG system (shaded bold line).

Comparing Figure 4 with Figure 2 shows a negative shift in the ORG system's CDF of annual total net farm income if organic area payments are 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 payments. Figure 5 shows for this scenario the normative rank of cropping systems for different degrees of risk aversion.

Under these circumstances the ORG systems seems to be most preferred for farmers with risk aversion levels less than moderate and the INT system is more efficient for farmers with risk aversion levels greater than moderate.

One can also analyse how large the organic area payment must be, under prevailing market prices, to make the ORG systems from the farmers' point of view economic equivalent with

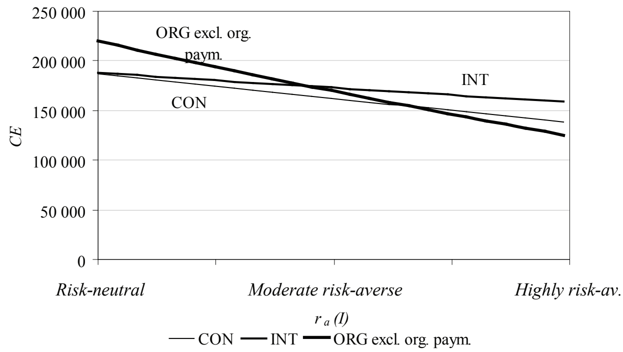

Figure 5. Scenario with no area payments for organic farming. CEs for annual net farm income in NOK for the CON, INT and ORG (without organic area payments) cropping systems.

the CON and INT system. As an example, a highly risk-averse CON farmer that receives an annual additional payment of NOK 13 000 (for example as area payment) would consider the economic viability in ORG production equal to the CON system.

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.

CONCLUSIONS

The results show that the organic cropping system stands out as the most economically viable alternative today, even though it had higher risk. Without area payments for organic farming and price premiums, the other two cropping systems performed best. The farmers' degree of risk aversion was of importance in choice of cropping systems. The experimental data used are from soil and growing conditions with a high crop yield potential. Crop yield losses when converting to organic farming practices may be higher in less fertile areas.

Even the results are site specific for the eastern part of Norway, may the differences in risk between cropping systems would not be very different on other sites with quite similar weather and growing conditions.

A farmers' choice of cropping systems could include other concerns than economics. 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. Eltun et al. (2002) using the experimental data from Apelsvoll 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). 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.

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