Evaluating basis for a targeted environmental policy: Do the opportunity costs of enhancing biodiversity differ between organic and conventional farms?

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Abstract

For policy making, it is important to identify the types of farms that are most efficient in enhancement of environmental quality, e.g., conservation of biodiversity. Attractiveness of conservation of biodiversity depends crucially on the opportunity costs of conservation. We use a crop diversity index as an indicator of environmental output to compare efficiency of conventional and organic crop farms. Non-parametric technical efficiency scores are estimated applying data envelopment analysis on a sample of Finnish crop farms for 1994 – 2002. We also estimate opportunity costs, or shadow values, of producing crop diversity. According to our results, there is variation in shadow values of crop diversity between the farms and technology adopted. This information provides basis for design of tailored, cost effective policy instruments such as auctions for conservation payments.

JEL Classification:

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1. Introduction

Taxpayers are showing an increasing interest in the costs of agricultural policies in developed countries. Agri-environmental policies in particular have become to a focus of the general public: support system should reflect the demand for a better environment. (Feng 2007) Yet, agri-environmental policies are largely seen as subsidy programs that compensate the costs of conservation measures to the farmers rather than as payments for documented environmental benefits. One of the challenges is to measure the benefits of environmental improvements. Asymmetric information and adverse selection adds another difficulty to the optimal design of environmental regulation (Sheriff 2009).

Biodiversity conservation on agricultural land has been addressed in various attempts to design environmental targets and policies for agriculture (see Wossink and van Wenum, 2003; van Wenum et al., 2004). As agriculture has shaped the landscapes for centuries, much of the apparently "natural" biodiversity in Europe is in fact a result of active farming practices. Evidently, agricultural production plays an important role in conserving biodiversity. Accordingly, promotion of environmental sustainable farming practices can be considered as a generally accepted goal in agriculture even though there are differences in farming practices and technologies adopted to reach the goal. However, it seems that enhancement of environmental quality, such as biodiversity, is not necessarily recognized as a targeted outcome, or a positive output when production efficiency is measured in practice. This is a consequence of difficulties in measuring environmental benefits.

Our contribution is to analyze efficiency in production within the frame of economic theory by taking into account biodiversity as a good output produced on farms. The motivation is that if the environmental goals are truly part of agricultural policies, the performance of policies implemented should be possible to evaluate. In particular, it is necessary to have indicators for following up how the policies implemented have become manifested in technology choices and corresponding (environmental) benefits accrued. As the scarcity of resources is a point of departure for an economic analysis the trade-offs in production of market and non-market outputs should be made explicit. The trade-offs ultimately determine the costs of agri-environmental policies implemented.

The purpose of this paper is to estimate the performance of conventional and organic crop farms – which represent two alternative technologies - and to evaluate the effect of the inclusion of biodiversity on performance measures. Our measure of biodiversity, or more specifically, crop diversity is a farm level Shannon diversity index, which captures both richness and evenness of cultivated crops on the farms. Thus, we rely in our analysis on a landscape diversity indicator and do not consider for example genetic diversity. We evaluate how efficient alternative farming practices are in using scarce resources in production of both crop yield and crop diversity.

We compare efficiency in organic and conventional agricultural production when only market output (crop yield) and when also non-market environmental by-product (crop diversity) is taken into account. Moreover, we consider efficiency scores when one of the outputs is held as a minimum constraint. Non-parametric technical efficiency scores are estimated applying data envelopment analysis (DEA). The empirical analysis is based on annual cross sections of Finnish crop farms participating in the bookkeeping system for 1994 – 2002. Organic production can be seen as a more restricted production technology[1]. As the number of organic farms is small, we apply so called window analysis (Charnes et al. 1985) for the sample of organic farms when estimating efficiency scores for organic and conventional technologies separately. In this case we assume progressive technical change in four year periods. We also estimate the shadow prices for crop diversity. The shadow prices capture the opportunity costs of crop diversity as measured by crop output forgone. This information is important for policy design since it reveals whether there is heterogeneity in the costs between farms and room for improving cost-efficiency of policy instruments targeting conservation of biodiversity in agriculture.

The paper is organized as follows. In section 2 we introduce the crop diversity index applied in the study and in section 3 we elaborate the production economic grounds of the study. Section 4 presents the empirical method and the next section the Finnish data. Section 6 includes empirical results and the last section concludes.

2. Biodiversity - Crop diversity

Biodiversity (biological diversity) is defined as the variety of all forms of life and can be subdivided into genetic diversity, species diversity, and ecological or ecosystem diversity (Biodiversity, 2005). The concept is widely used, and a distinction can be made between functional – emphasizing the perspective of ecosystem and evolutionary processes - and compositional – emphasizing in turn the

[1] Organic farming as a method of production puts high emphasis on environmental protection. It avoids, or largely reduces, the use of synthetic chemical inputs like fertilizers, pesticides or additives. In the field of crop production fertilization with manure, growing legumes to bind nitrogen from the air, compost of vegetables of low soluble fertilizers, and preventive measures to control pests and diseases, are used. Also crop rotations, mechanical weed control and protection of beneficial organisms are important (Organic Farming in the EU: Facts and Figures, 2004). These restrictions most likely affect the performance of organic farms.

perspective of populations, species and other categories (Callicott et al., 1999). Biodiversity is also often connected to the conservation of biological variation, the extent and future value of which are largely unknown.

Two different schools of considering diversity have evolved in the literature, where different species are given different weights. The ecological school weighs different species according their relative abundance, whereas the economical school emphasizes that different species should be given different weights in the diversity measure due to the attributes they possess (Baumgärtner, 2004). The attributes are what the society actually values and consumes. Here we choose to incorporate an ecological measure of diversity into an economical production theory framework. This approach is based on the idea that the ecological diversity is a good that the society values.

In agricultural systems, biodiversity may be produced as a positive by-product in addition to marketable output such as cereals. Management practices may have various impacts on biodiversity due to crop rotation, application of chemical inputs etc. The problem is that biodiversity is a complex concept with several dimensions. Therefore, it is a challenge to choose proper measures or indicators for biodiversity. The availability of data is a major limitation for the empirical analysis. Here, we rely on a relatively simple measure of biodiversity, so called crop diversity index which can be described as a landscape diversity measure. According to a classification of Callicott et al. (1999) crop diversity index belongs to compositional measures of species diversity.

The species level of biodiversity is quantified in the number of species in a given area (richness) and how evenly balanced the abundances of each species are (evenness) (Armsworth et al., 2004). Note that the species level biodiversity is only one of the levels that can be used in analyzing the biodiversity issue. For example, community level biodiversity describes the species interactions in their natural habitats. The spatial scale is also important since richness increases with area. Usually the choice is either an economically or an ecologically meaningful scale. We choose to study the diversity of agricultural land use at the farm level, within an economical production theory framework. At the farm level, we know the number of crops cultivated and the area under these specific crops. These data are easily available also for government authorities for implementing policy based on crop diversity indices.

In this study, richness is measured by the number of cultivated crops like barley, grass silage, potato, or fallow. Evenness refers to how uniformly the arable land area of the farm is distributed to these different crops. Evenness and richness, describing diversity, can be quantified by Shannon diversity index (SHDI) (Armsworth et al., 2004). It has its origin in the information theory (Shannon 1948) and it has been applied in a number of environmental economic studies (e.g., Pacini et al., 2003; Hietala-Koivu et al., 2004; Latacz-Lohman, 2004; Miettinen et al., 2004; Di Falco and Perrings, 2005).

SHDI is calculated applying the following formula:

$$SHDI = -\sum_{i=1}^{J} (P_i \times \ln P_i) \tag{1}$$

where J is the number of cultivated crops, P_i denotes the proportion of the area covered by a specific crop and ln the natural logarithm[2]. The diversity index in equation (1) equals zero when there is only one crop, indicating no diversity. The value increases with the number of cultivated crops and when the cultivated areas under various crops become more even. The index reaches its maximum when the crops are cultivated in equal shares, i.e., when $P_i = 1/J$ (McGarical and Marks 1995).

In this paper, the index is used to approximate the diversity produced by farms, and is therefore modeled as a good output within the frames of production theory. Crop diversity has usually been applied as a landscape indicator at the regional level. However, the use of crop diversity as a proxy for biodiversity at the farm level can be motivated by the fact that the number of different habitats is likely to increase with crop diversity. In conventional farming, a monoculture may be successful whereas organic production technology sets higher requirements for crop rotation ruling out the possibility of monoculture. Thus, organic farming technology is likely to produce higher crop diversity. Numerous studies have also shown that crop rotations conserve soil fertility (Riedell et al., 1998; Watson et al., 2002), improve nutrient and water use efficiency (Karlen et al., 1994) and increase yield sustainability (Struik and Bonciarelli, 1997; see also Herzog et al., 2006).

[2] Shannon diversity index appears in the literature by names Shannon-Wiener (-Weiner or –Weaver) index. According to Keylock (2005) it belongs to the Hill family of indices (like Simpson diversity index) and is based on Bolzmann-

3. Production Theory

3.1 Technology

To describe production technology formally, let $y = (y_1,..., y_m) \in \Re_+^M$ and $x = (x_1,..., x_n) \in \Re_+^N$ be vectors of outputs and inputs, respectively. Production technology can then be represented by the output possibilities set

$$P(x) = \{y \mid (x, y) \in T\} \qquad (2)$$

which describes all feasible output and input combinations of the producer. The technology is denoted by T , and the condition $(x, y) \in T$ is interpreted as x can produce y . We assume that $P(x)$ is convex, closed, and bounded, i.e., compact, and that $P(0) = \{0\}$. The latter equality ensures that inactivity is possible but there is no free lunch. Finally, outputs and inputs are assumed to be freely disposable.

Input and output distance functions can be used to describe the technology when only input and output quantities are known (Shephard, 1953; 1970). In contrast to the traditional scalar-valued production function, distance functions allow multiple outputs (and multiple inputs). For any (x,y) $\in R_+^{M+N}$ the output distance function $D_o(x,y)$ is such that

$$D_o(x,y) = \min \{\lambda > 0: y/\lambda \in P(x)\}. \qquad (3)$$

The output distance function calculates the largest expansion of y along the ray through y as far from 0 as possible while staying in P(x), which means that y belongs to the producible output set if and only if $D_o(x,y) \leq 1$. It is also obvious that the distance function takes the value one only if the output vector belongs to the frontier of the corresponding input vector. Therefore, the output distance function completely characterizes the technology, because it inherits its properties from P(x).

The Farrell (1957) measure of output oriented technical efficiency is the reciprocal of the output distance function, i.e. $F_o(x,y) = (D_o(x,y))^{-1}$. Thus

$$F_o(x,y) = \max \{\mu: \mu y \in P(x)\}. \qquad (4)$$

Gibbs-Shannon entropic form. Sometimes the index is presented in the form of exp(SHDI). At the maximum the latter form provides the number of species for the uniform distribution (maximum entropy).

Probably the most often used models of technical efficiency are variants of the Farrell type model[3]. By duality output and input orientations have a convenient interpretation as an increase in revenue and a reduction in costs, respectively. One desirable property of the Farrell type measure is that it is invariant with respect to the units of measurement in inputs and outputs.

3.2 Modeling biodiversity as a good output

In addition to crops that can be sold on the market, agricultural production provides also other, non-market outputs. This is illustrated in Figure 1 where we have two outputs: crop output and non-market crop diversity.

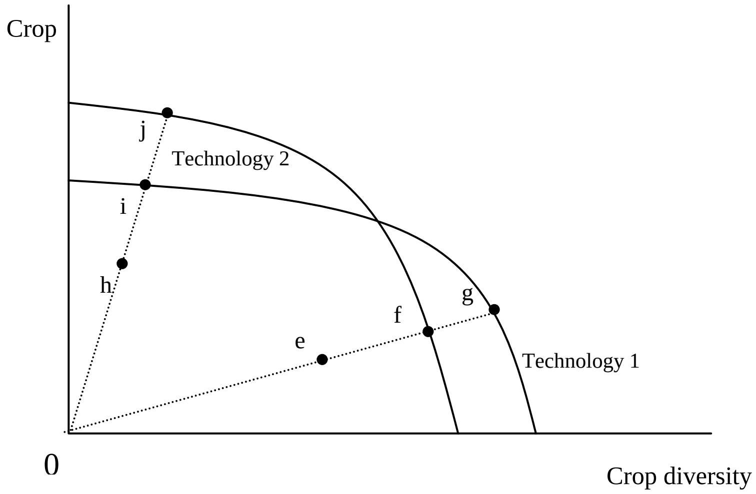

Figure 1. An illustration of technical output efficiency in case of two outputs (crop and crop diversity).

The transformation curves show how much of the crop output has to be sacrificed to increase crop diversity, given inputs. Technologies 1 and 2 (organic vs. conventional) which allow for different production possibilities at a given input level are illustrated by two separate transformation curves (or outer boundaries of producible output sets). Technical efficiencies are derived from the radial distances from the frontier. For example, a technical efficiency score for point e with respect to technology 1 (0e/0g) is different compared to technical efficiency with respect to technology 2 (0f/0g). In our illustration in Figure 1, producible output sets of the two technologies cross[4]. Figure

[3] Chambers et al. (1998) have shown that the proportional distance function (the reciprocal of Farrell technical efficiency) is a special case of directional distance functions.

[4] It is of course possible that one of the technologies dominates at all output combinations.

1 shows that the assumption of whether all farms have access to the same technology, or of whether organic and conventional farms do not have access to the same technology, may be crucial in the measurement of efficiency.

In Figure 1 we have assessed technical output efficiency by an index which is calculated by increasing the outputs equi-proportionally until the frontier is reached. This direction is chosen without taking into account the preferences of the society related to these different outputs. It is thus a technical efficiency measure. In principle, the optimal product mix according to Pareto optimality principle is when the marginal rate of transformation (MRT, the slope of the transformation curve) equals to the marginal rate of substitution (MRS, the slope of the (utility) indifference curve) for the society (e.g., Just et al. 2004). Figure 2 illustrates the tangent points of technology frontiers and indifference curves (MRT=MRS) at different technologies. The slopes of tangents may differ by technology (for example conventional and organic).

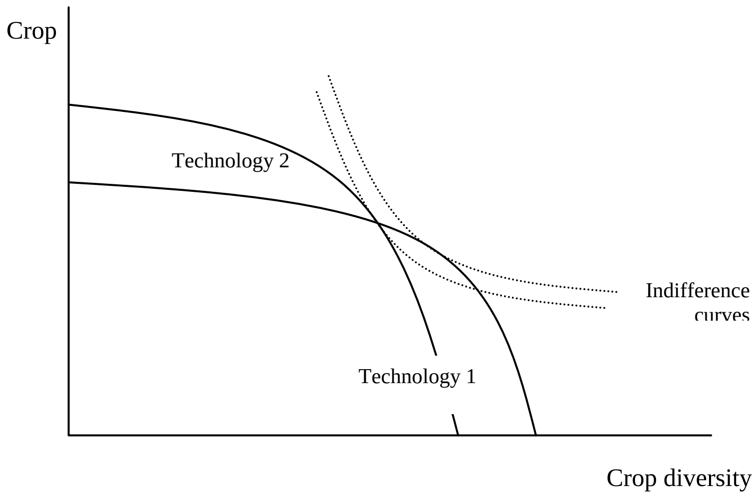

Figure 2. Technology frontiers and indifference curves.

In practice, we do not know the preferences of the society. However, it is possible to derive a shadow value for crop diversity by applying the shadow prices of outputs, the known price of crop output and the current output mix between market and non-market outputs.

4. Empirical Method

4.1 Data envelopment models

The firm is said to be technically efficient if it lies on the boundary of the output possibility set, $P(x)$. There are several possibilities to define the boundary, often referred as the frontier. Data envelopment analysis (DEA) is a non-parametric method that provides a piecewise linear, either convex or non-convex envelopment for the observations. It has been developed for evaluating the performance of multi-input multi-output production (see Debreu, 1951; Farrell, 1957 and Koopmans, 1951; Charnes et al., 1978).

The DEA models applied in this study are output oriented assuming that *P(x)* satisfies convexity. If technical efficiency obtains its maximal value (one), the production is efficient, and it is not possible to increase output (given inputs) in comparison to the reference units. If production is technically output inefficient, output can be increased using given inputs.

DEA models are fairly simple linear programming (LP) models which have to be solved for each decision making unit (farm) separately. In the case of variable returns to scale, we define the model with outputs, y_m, and inputs, x_n, when *k* decision making units form the reference set and each of them, *k'*, is in turn compared to the reference set. In our notation below, $F_o(VRS,S)$ or ϕ denotes technical output efficiency under variable returns to scale (V) and strong disposability (S) assumptions. The efficiency measure is the reciprocal of output distance function, $(D_o(x,y))^{-1}$ (Färe et al., 1994). The superscript *t* in Equation (5) refers to the annual solution of the LP problem.

$$
\begin{aligned}
& F_o(VRS,S) = (D_o^t(x,y))^{-1} = \max \phi \\
& s.t.\ \ \phi y_{k'm}^t \le \sum_{k=1}^{K} z_k y_{km}^t, m = 1,...,M, \\
& \sum_{k=1}^{K} z_k x_{kn}^t \le x_{k'n}^t, n = 1,...N, \\
& \sum_{k=1}^{K} z_k = 1, \\
& z_k \ge 0, k = 1,...,K.
\end{aligned} \tag{5}
$$

The DEA model of variable returns to scale is obtained by a constraint for intensity variables $\sum z_k = 1$, which restricts the scaling of units in the search for an optimal solution such that the sum of weights of the observations has to equal one. When the intensity variables z are not constrained, the scaling of reference units up and down is unlimited, which coincide with constant returns to scale (CRS). The CRS assumption implies that the efficiency ranking of units is independent of the choice of orientation, be it input or output. In agriculture, larger farms tend to be more technically efficient than smaller ones when assessed by the CRS DEA model (e.g., Sipiläinen, 2003). The possible heterogeneity in size, or indication on the economies of scale is partially removed when VRS models are applied. This also supports the VRS type model for our application as the average sizes of farms in alternative production technologies differ.

If we are only interested in technical efficiency of crop production, disregarding crop diversity, we may apply the model with only one traditional crop output. We may, however, easily extend the analysis taking into account other outputs. If we assume that crop diversity is a desirable output that farms also produce we may solve the LP problem with two outputs. The very nature of the DEA models is that after adding other outputs the number of efficient decision making units increases.[5] This property coincides with the problem of omitted outputs since in that case we may underestimate the true technical efficiency of a decision making unit.

The traditional two output DEA model assumes that the efficiency score is calculated as a possibility for an equi-proportional increase in outputs, given inputs and reference units. Thus, we in principle assume that socially optimal proportions of these outputs are already produced but our target is to produce more both of them. This is a critical assumption when we take into account non-market outputs which do not have a market price. We may also think that the target of the society would be to increase either crop diversity given inputs and traditional output or to increase traditional output given inputs and crop diversity. This would be interpreted as if a socially optimal level of one of the outputs was already produced but the purpose was to evaluate the possibilities to increase the other output. To assess these options, we introduce in the LP model a slightly different set of constraints. In particular, we assume that only the traditional output is adjusted but the crop diversity is treated as an ordinary constraint indicating that crop diversity of the feasible solution should be at least as large as in our decision making unit. Technical efficiency is thus only measured in relation to traditional output. This is similar to technical sub-vector efficiency introduced by Färe et al. (1994), and applied to variable inputs by Oude Lansink et al. (2002).

Traditional technical efficiency and sub-vector efficiencies are illustrated in Figure 3. The output set includes both crop output and crop diversity. Traditional Farrell type technical output efficiency is measured as a proportional expansion of outputs along the solid line from point A to the frontier. The crop sub-vector efficiency specified in Equation (6) below is described as an increase of crop output along the vertical broken line from point A to the frontier, and crop diversity sub-vector

[5] Coelli et al., (1998) writes: ”The addition of an extra input or output in a DEA model cannot result in a reduction in the technical efficiency scores” (p. 181).

efficiency is defined as an expansion of crop diversity output along the horizontal dotted line from point A to the frontier.

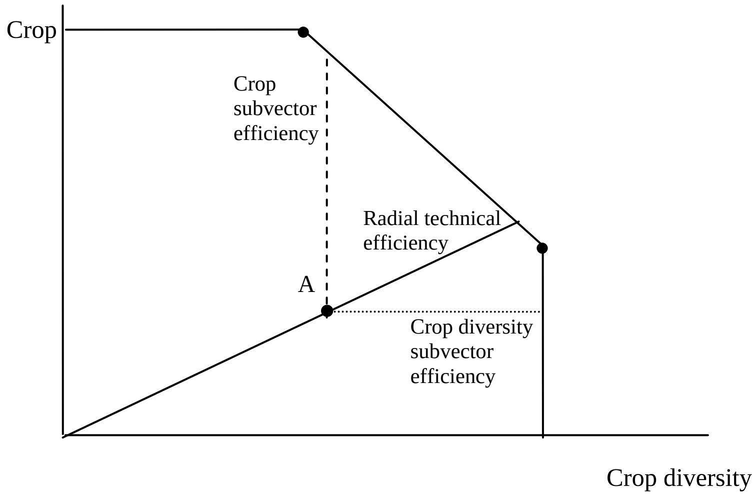

Figure 3. An illustration of traditional and sub-vector technical efficiencies.

A formal presentation of the crop sub-vector efficiency when m=1 denotes crop output and m=2 crop diversity is the following[6]:

$$
\begin{aligned}
& F_o(VRS, S, sub) = (D_o^t(x, y))^{-1} = \max \phi \\
& s.t.\ \ \phi y_{1k'}^t \le \sum_{k=1}^{K} z_k y_{1k}^t \\
& y_{2k'}^t \le \sum_{k=1}^{K} z_k y_{2k}^t \\
& \sum_{k=1}^{K} z_k x_{kn}^t \le x_{k'n}^t, n = 1, \ldots N, \\
& \sum_{k=1}^{K} z_k = 1, \\
& z_k \ge 0, k = 1, \ldots, K.
\end{aligned}
\tag{6}
$$

For the efficiency analysis, we have to choose the reference sets for technology, organic or conventional. The small number of observations for organic farms poses a challenge for analyzing the organic technology separately. Therefore, we apply window analysis suggested by Charnes et al. (1985): observations from several years (in our case four years) are assumed as different units. In traditional window analysis the earliest period is dropped out when a new period is introduced. We apply a four years' window, or a rotating unbalanced panel. In principle, we take a technical change into account as the reference set for the last period in the window includes observations of this

[6] Also in this case the VRS model is obtained by adding a constraint for weights z that should sum up to one.

specific year and three earlier years. However, we cannot totally avoid the problem of a small number of observations in these comparisons as the averages of technical efficiencies tend to diminish when the number of observations increases. When the number of observations in the sample increases, the convergence to the minimum is relatively slow.

4.2. Derivation of shadow prices in the context of DEA

Relative shadow prices (relative weights) for inputs and outputs can be obtained from the dual (primal in Charnes et al. 1978) solutions of the above mentioned linear equation system (Equation 3). The dual form looks as follows (VRS) for a regular model:

$$\begin{aligned} &F_O(V,S) = \min \sum \mu_n x_{k'n} + \omega \\ &s.t. \ \sum \nu_m y_{k'm} = 1 \\ &\sum \nu_m y_{km} - \sum \mu_n x_{kn} + \omega \le 0 \ \ \forall k \\ &\nu, \mu \ge 0 \ \ \forall m, n; \omega \quad \text{is} \quad \text{free.} \end{aligned} \tag{7}$$

Multiplier weights μ_n and ν_m can be interpreted as relative shadow prices and ω as fixed costs. If we drop ω we obtain a constant returns to scale model instead of a variable returns to scale model.

We apply relative shadow prices estimated from the above dual formulation of DEA when determining the value of crop diversity. The marginal rate of transformation between two outputs can be derived as a ratio of their marginal products (the first order derivatives), and this ratio should at the optimum equal to their prices:

$$MRT_{y_{m1}y_{m2}} = \frac{\partial y_{m1}/\partial x}{\partial y_{m2}/\partial x} = \frac{\frac{\partial F(\bullet)}{\partial x} \Big/ \frac{\partial F(\bullet)}{\partial y_{m1}}}{\frac{\partial F(\bullet)}{\partial x} \Big/ \frac{\partial F(\bullet)}{\partial y_{m2}}} = \frac{\partial F(\bullet)}{\partial y_{m2}} \Big/ \frac{\partial F(\bullet)}{\partial y_{m1}} = \nu_{m2} / \nu_{m1} \tag{8}$$

When we get estimates for relative shadow prices (the slope) and know the true price of one of the outputs (crop output) we may solve the absolute shadow value of crop diversity.

5. Data

We use a Finnish bookkeeping farm data set which covers the period from 1994 to 2002. The original farm data formed a complete panel, but because of a small number of organic farms the panel was complemented with organic farms which participated in the bookkeeping system at least for two years. This increased the number of observations towards the end of the study period, in addition to the switches from other production lines (e.g., milk production) to crop production. The farms were classified as crop farms if their animal density was less than 0.1 animal units per hectare and the share of grains in total sales return at least 20 %. The first criterion was the same as in a previous study of Oude Lansink et al. (2002). The second one drops specialized sugar beet and potato farms out of the sample. The total number of observations was 78 in 1994 and it increased up to 103 by 2002. The data set consists of 831 observations in total.

Table 1. Descriptive statistics of conventional and organic farms.

	Conventional		Organic	
N	689		142	
	Mean	St.dev.	Mean	St.dev.
Output (€)	32918	25036	14952	20523
SHDI	1.30	0.18	1.41	0.33
Labor (h)	1831	1010	1533	1104
Land (ha)	64	36	49	43
Energy (€)	5445	3435	4454	5433
Other variable (€)	20058	13939	12247	17945
Capital (€)	63346	44078	51049	57493

The number of organic crop farms was 11 in 1994, and in 2002 it was 20. We use crop returns as a proxy of the quantity of aggregate marketable output. Crop output is measured at constant prices of the year 2000. Both for organic and conventional farms output at constant prices is obtained by dividing crop returns by the respective price indices of conventional outputs published by Statistics Finland[7]. The main reason for using only price indices for conventionally produced goods is that we do not have a reliable price index for organic products. In addition, we do not know the exact magnitude of a price premium for organic production. This means that we have to assume equal prices and price changes for organic and conventional products, and a possible price premium for organic products will increase our proxy of the output quantity. In spite of this, the average traditional crop output is considerably lower on organic than on conventional farms (see Table 1). All subsidies (direct payments) paid on the basis of the arable land areas of the farms are excluded. As a measure of another positive output, or desirable environmental by-product, we use an indicator of crop diversity, or a Shannon crop diversity index (SHDI). The average crop diversity index is on

[7] The division of monetary input or crop output values by respective indices is not necessary if we only analyze the farms in cross-sections of specific years. However, when we employ for example a window analysis over time for organic farms the use of constant monetary values is necessary.

average larger on organic farms.[8] The distribution of SHDI in the samples of organic and conventional farms is illustrated in Figure 4.

6. Results

6.1 Efficiency scores for conventional and organic farms

We apply DEA on separate data sets of conventional and organic farms. For organic farms, we use so called window analysis assuming progressive technical change. This means that, for example, the efficiency scores for 1997 are calculated using the observations from 1994 to 1997 as the reference set but the mean is calculated on the basis technical efficiencies of the farms observed in 1997[9]. Using several years' observations as the reference set of organic farms increases the dimensions in the DEA almost to the same level as in the annual analysis of conventional farms (without a window).

The results for separate data sets for conventional and organic farms (window analysis for organic) are presented in Tables 2 and 3. First, we estimate the Farrell type technical output efficiencies applying a model of one output (crop output) and five inputs and variable returns to scale (Equation 5). The results can be read in the column indicated by 1O5I. Second, we take into account biodiversity effects of the production by including crop diversity as an output in addition to the traditional crop output. The traditional one is sold on the market and the latter is assigned to the landscape effects. For the two-output case, efficiency scores are reported in column 2O5I. Finally, a sub-vector efficiency model for two outputs and five inputs is applied; the results are found in the column 2O5sub.

The means of the technical efficiency scores for the two farming technologies seem to be very close to each other but the pattern of changes varies; in the group of conventional farms the average technical efficiencies are at their lowest level in 1998 and 1999, and at their highest in 2000. In the group of organic farms, efficiency decreases constantly since 1999. It seems that the variation in these two technologies is somewhat different but this may be explained by the different ways of constructing the reference sets.

[9] When we apply a four year window and assume technical progress we cannot calculate mean efficiencies in 1994-1996.

Table 2. Technical efficiencies for conventional farms (annual reference sets).

	1O5I		2O5I		2O5Isub	
	Mean	St. dev	Mean	St. dev	Mean	St. dev
1997	0.771	0.177	0.911	0.095	0.832	0.177
1998	0.671	0.203	0.834	0.132	0.717	0.215
1999	0.663	0.241	0.872	0.129	0.735	0.246
2000	0.835	0.154	0.903	0.113	0.867	0.150
2001	0.728	0.189	0.878	0.115	0.789	0.190
2002	0.723	0.196	0.897	0.099	0.793	0.183
Mean	0.734		0.883		0.791	

1O5I – one output, five input Farrell type model; 2O5I – two output, five input Farrell type model; 2O5ICsub - two output, five input crop sub-vector efficiency model.

Table 3. Technical efficiencies for organic farms (reference sets of four year windows).

	1O5I		2O5I		2O5Isub	
	Mean	St. dev	Mean	St. dev	Mean	St. dev
1997	0.787	0.209	0.905	0.115	0.804	0.209
1998	0.749	0.282	0.933	0.086	0.812	0.269
1999	0.756	0.236	0.950	0.061	0.818	0.211
2000	0.710	0.236	0.898	0.114	0.805	0.222
2001	0.734	0.240	0.882	0.133	0.780	0.230
2002	0.719	0.253	0.886	0.123	0.746	0.258
Mean	0.740		0.906		0.791	

1O5I – one output, five input Farrell type model; 2O5I – two output, five input Farrell type model; 2O5ICsub - two output, five input crop sub-vector efficiency model.

We should notice that the number of observations on which the annual average technical efficiencies of organic farms are calculated, is only 14-20[10]. However, the results suggest that the average efficiencies in the two technologies do not differ considerably when the reference group applies the same technology, i.e., organic reference technology for organic farms and conventional for conventional farms. The result is independent of the model the analysis is based upon.

6.2 Shadow values or opportunity costs of crop diversity

We apply the dual formulation of DEA to calculate shadow values for the crop diversity using Equations 7 and 8. When calculating the shadow value for the crop diversity we assume that the actual price of one unit of crop output is EUR 1 at the constant price of the year 2000.

Table 4 presents the shadow values based on the separate efficiency estimations of organic and conventional technologies. We only compare the results of non-zero shadow values from 1997 to

[10] The number of annual observation in the last year of the window.

2002, since we apply window analysis in the group of organic farms. In addition, the distribution of shadow values of crop diversity is truncated at EUR 10000 in order to exclude some extreme values (4 observations for organic and 10 for conventional farms).

Table 4. Shadow values of crop diversity (SHDI) per hectare by technology in euros.

	Conventional		Organic	
	Mean	St. dev	Mean	St. dev
1997	977	1135	1006	1308
1998	1133	1254	1076	1936
1999	2276	2101	1315	1453
2000	860	1191	1697	1929
2001	871	1035	1912	1579
2002	1531	1569	1265	780

The differences in shadow values between technologies are statistically significant for years 1999, 2000 and 2001. However, variation in shadow value is large in both samples, and the mean values do not follow any specific pattern over the time period considered.

For policy design, the shadow values provide important information. The shadow values reflect the opportunity costs of farms to increase crop diversity. Therefore, the least cost observations of organic and conventional farms have been ordered by the estimated shadow values or opportunity costs (per hectare) of increasing the crop diversity (SHDI) by one unit.

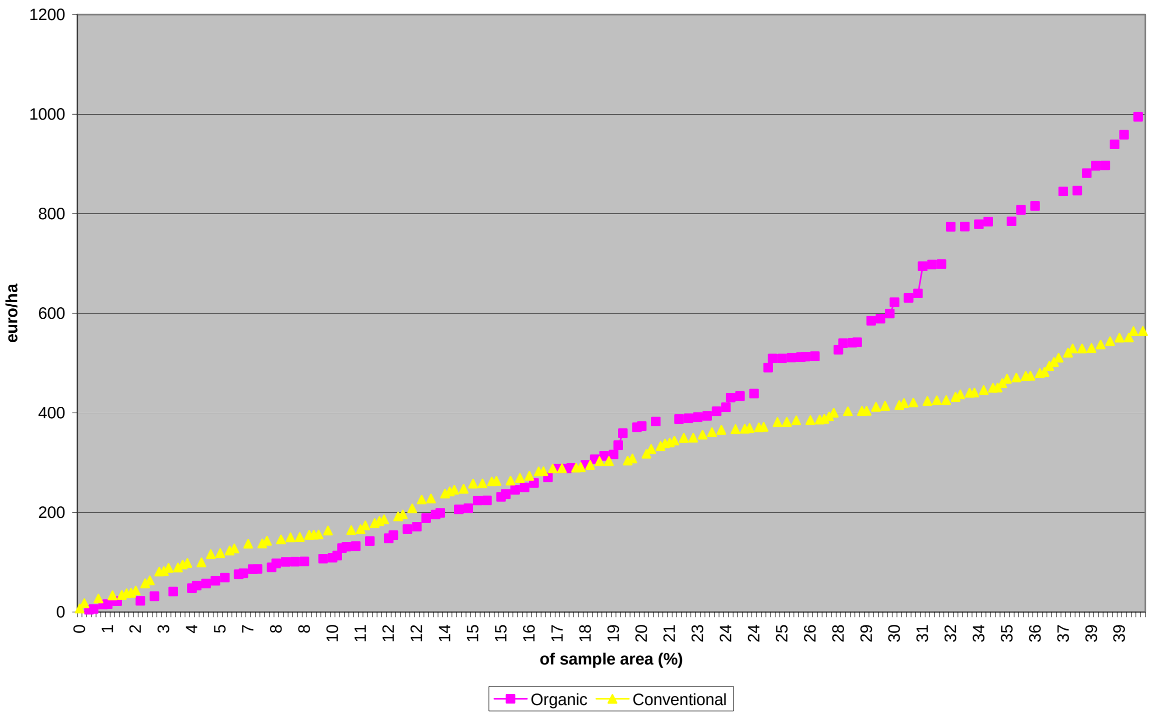

Figure 5. Shadow values of crop diversity for organic and conventional farms.

In Figure 5, the shadow values for 40 % of total land area in both samples are illustrated; the highest values reach EUR 1000 per hectare in the organic and almost EUR 600 per hectare in the conventional sample. The least opportunity costs illustrated in Figure 5 can be interpreted as supply curves for crop diversity. The curves cross at about EUR 300 per hectare of a unit of SHDI. The opportunity costs of organic farms are systematically smaller for a land area of less than 20 % or up to the crossing point. For these least cost farms, the opportunity cost of crop diversity is on average EUR 165 per hectare for conventional farms which is roughly 25 % higher than for organic farms, i.e., EUR 130 per hectare. The least cost farms are the most potential candidates for receiving conservation payments if auctions are expected to increase cost-efficiency in conservation of crop diversity on farm land. In the remaining 80 % of the farm land, the opportunity costs of crop diversity are higher and increase more rapidly on the organic than on the conventional farms.

It is particularly interesting to examine whether differences in the opportunity costs depend on the current level of crop diversity on the farm. This is illustrated in scatter plots in Figures 6 a and b.

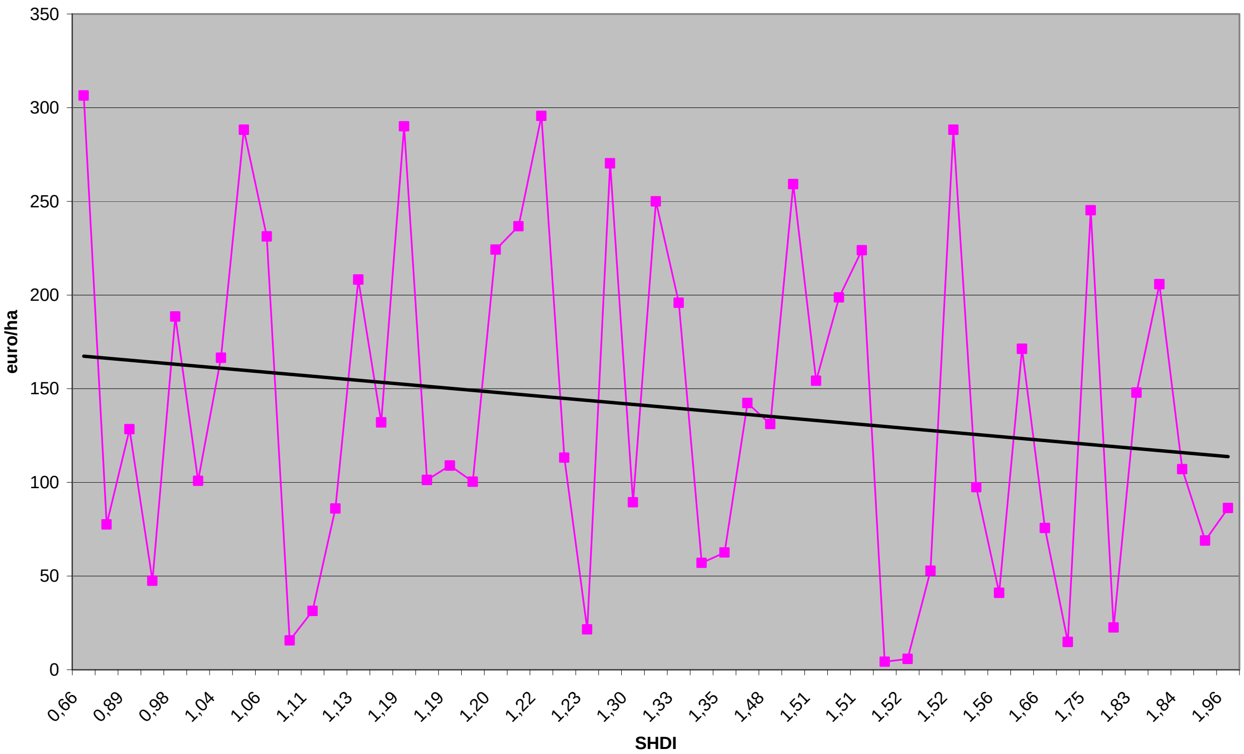

Figure 6a. Shadow values of crop diversity for organic farms by crop diversity (SHDI).

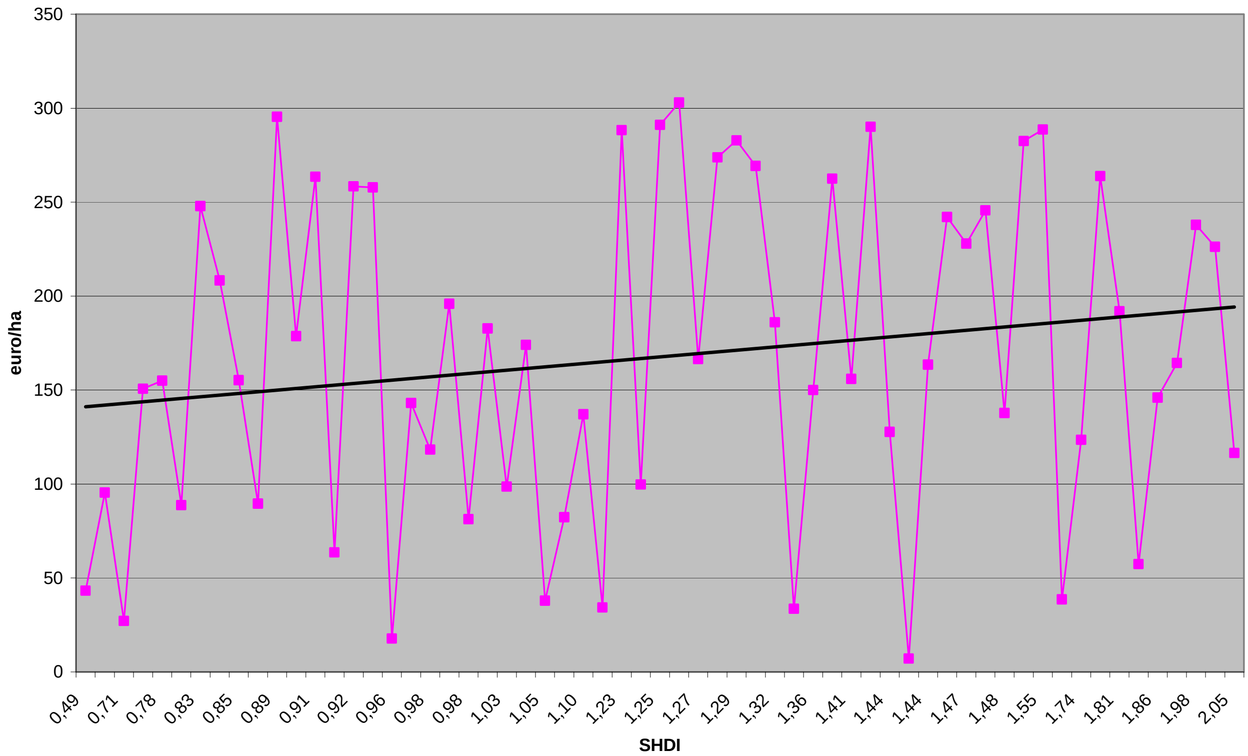

Figure 6b. Shadow values of crop diversity for conventional farms by crop diversity (SHDI).

The opportunity costs per hectare for the least cost organic and conventional farms seem to differ. This is confirmed by the trend lines plotted in Figures 6 a and b. These findings have clear policy implications. On average, there are not necessarily differences in costs between organic and conventional farms in enhancing biodiversity as measured per unit of crop diversity index. However, there is room for tailored policy instruments targeting certain types of farms if high crop diversity is a goal. The opportunity cost of crop diversity decreases with SHDI in organic farming. A similar cost advantage does not seem to apply to conventional farms that have high crop diversity. Of course, how the environmental target has been defined matters for the cost of policy: should the environmental policies aim at increasing crop diversity on farms that currently have low crop diversity? Given the findings from our data set, those organic farms that have least opportunity costs seem to have higher crop diversity measured by SHDI. In contrast, the costs of conventional farms are expected to be lower when addressing a change starting from low values of SHDI, i.e., starting from 0.5 rather than from 1.5. Since the conventional farms form the majority of farms (over 95%), their costs are directly reflected in overall costs of enhancing crop diversity in agriculture. Therefore, it is interesting that the conventional farms seem to have increasing cost with an increase in crop diversity.

7. Conclusions

Consideration of actual environmental benefits to be achieved is important for design of agri-environmental policies. The Shannon crop diversity index used in comparison of conventional and organic practices in this study has been an attempt to introduce another desirable output into the production process to take into account environmental benefits.

In our sample, organic farms had on average slightly higher crop diversity than conventional farms measured by Shannon crop diversity index. The results of the efficiency analysis based on the sample of organic farms indicates that there is a trade-off between crop yield and crop diversity – the opportunity costs of crop diversity for least cost organic farms tend to get smaller with higher crop diversity. In other words, higher crop diversity does not necessarily lead to larger yields or increases in the value of organic crop output. In contrast, the opportunity costs of crop diversity of least cost conventional farms in our sample increase slightly with the level of current crop diversity. Yet, the positive trend is not very strong. All in all, the opportunity costs of crop diversity are on average higher for conventional than organic farms up to 20 % of least cost farming area. Thereafter, the opportunity costs of crop diversity increase more rapidly on the organic than on the conventional farms in the remaining 80 % of the farm land.

Although crop diversity as a policy goal cannot be justified by an expected increase in the value of crop output in the short run, crop diversity may provide benefits in the long run and other benefits that are not related to agricultural productivity. Even though our approach is only a first step towards analyzing simultaneously economic and environmental impacts of alternative farming technologies, the overall message of our analysis is clear. Normally, there is a trade-off between several outputs. Multiple outputs, including environmental impacts, should be accounted for as the efficiency ranking of alternative technologies is dependent on what is actually considered as outputs. The heterogeneity of farms in terms of producing environmental benefits is important to identify if tailored agri-environmental policies are expected to lead to cost efficiency and savings in the use of taxpayers’ money.

Further research is needed in specifying other possible environmental benefit indices which could be calculated on the basis of farm accountancy data available for regulators. In our analysis, we concentrated on the annual diversity variation at the farm level. Regarding the evaluation of landscape values, the scale of analysis should, however, exceed the borders of farm units. Therefore, the aggregation over farms and time become important issues for policy assessments.

References

Armsworth, P.R., Kendall, B.E. & Davis, F.W. 2004. An introduction to biodiversity concepts for environmental economists. Resource and Energy Economics 26: 115-136.

Baumgärtner, 2005. 'Measuring the diversity of what? And for what purpose? A conceptual comparison of ecological and economic biodiversity indices', Working Paper, University of Heidelberg.

Biodiversity. 2005. Stanford Encyclopedia of Philosophy. http://plato.stanford.edu/entries/biodiversity/, referred 8.12.2005)

Callicott, J.B., Crowder, L.B. & Mumford, M.R. 1999. Current normative concepts in conservation. Conservation Biology 13: 22-35.

Chambers, R.G., Chung, Y. & Färe, R. 1998. Profit, directional distance function, and Nerlovian efficiency. Journal of Optimization Theory and Applications 98(2): 351 - 364.

Charnes, A., Cooper, W.W. & Rhodes, E. 1978. Measuring the inefficiency of decision making units. European Journal of Operational Research 2: 429 – 444.

Charnes, A., Clark, T., Cooper, W.W. & Golany, B. 1985. A developmental study of data envelopment analysis in measuring efficiency of maintenance units in U.S. Air Forces. Annals of Operational Research 2: 95-112.

Coelli, T., Rao, D.S.P. & Battese, G.E. 1998. An introduction to efficiency and productivity analysis. Kluwer Academic Publishers.

Debreu, G. 1951. The coefficient of resource utilization. Econometrica 19(3): 273 – 292.

Di Falco, S. & Perrings, C. 2005. Crop biodiversity, risk management and the implications of agricultural assistance. Ecological Economics 55: 459-466.

Dobbs, T.L. & Pretty, J.N. 2004. Agri-environmental stewardship schemes and 'multifunctionality'. Review of Agricultural Economics 26(2): 220-237.

Farrell, M.J. 1957. The measurement of productive efficiency. Journal of the Royal Statistical Society. Series A, 120: 253 – 281.

Feng, H. 2007. Green payments and dual policy goals. Journal of Environmental Economics and Management 54: 323-335.

Färe, R., Grosskopf, S. & Lovell, C.A.K. 1994. Production frontiers. Cambridge.

Herzog, F., Steiner, B., Bailey, D., Baundry, J., Billeter, R., Bukácek, R., De Blust, G., De Cock, R., Dirksen, J., Dormann, C.F., De Filippi, R., Frossard, E., Liira, J., Schmidt, T., Stöckli, C., Thenail, C., van Wingerden, W. & Bugter, R. 2006. Assessing the intensity of temperate European agriculture at the landscape scale. European Journal of Agronomy 24: 165-181.

Hietala-Koivu, R., Lankoski, J. & Tarmi, S. 2004. Loss of biodiversity and its social cost in an agricultural landscape. Agriculture, Ecosystem and Environment 103: 75-83.

Hole, D.G., Perkins, A.J., Wilson, J.D., Alexander, I.H., Grice, P.V. & Evans A.D. 2005. Does organic farming benefit biodiversity? Biological Conservation 122: 113-130.
Karlen, D.L., Varvel, G.E., Bullock, D.G. & Cruse, R.M. 1994. Crop rotations for the 21st century. Advanced Agronomy 53: 1-44.

Keylock, C.J. 2005. Simpson diversity and the Shannon-Wiener index as special cases of a generalized entropy. Oikos 109(1): 203-207.

Koopmans, T.C. 1951. An analysis of production as an efficient combination of activities. In T.C. Koopmans (ed.) Activity analysis of production and allocation. Cowles Commission for Research in Economics. Monograph 13. New York. John Wiley and sons, Inc.

Latacz-Lohman, U. 2004. Dealing with limited information in designing and evaluating agri-environmental policy. Paper presented in 90th EAAE seminar on 28.-29.10.2004, Rennes, France. 17 p.

McGarical, K. & Marks, B.J. 1995. FRAGSTATS: Spatial pattern analysis program for quantifying landscape structure. USDA Forest Services. PNW-GTR-351. Portland, OR, USA.

Miettinen, A., Lehtonen, H. & Hietala-Koivu, R. 2004. On diversity effects of alternative agricultural policy reforms in Finland: An agricultural sector modelling approach. Agricultural and Food Science 13: 229-246.

Organic Farming in the EU: Facts and Figures, 2004. (http://europa.eu.int/comm/agriculture/qual/organic/facts_en.pdf, referred 23.7.2004)

Oude Lansink, A., Pietola, K. & Bäckman, S. 2002. Efficiency and productivity of conventional and organic farms in Finland 1994-1997. European Review of Agricultural Economics 29(1): 51-65..

Pacini, C., Wossink, A., Giesen, G., Vazzana, C. & Huirne, R. 2003. Evaluation of sustainability of organic, integrated and conventional farming systems: A farm and field-scale analysis. Agriculture, Ecosystems and Environment 95: 273-288.

Ricci Maccarini, E. & Zanoli, A. 2004. Technical efficiency and economic performances of organic and conventional livestock farms in Italy. Paper presented in 91st EAAE seminar on 24.-25.9.2004, Crete, Greece. 28 p.

Riedell, W.E., Schumacher, T.E., Clay, S.A., Ellsbury, M.M., Pravecek,M. & Evenson, P.D. 1998. Corn and soil fertility responses to crop rotation with low, medium, or high inputs. Crop Science 38: 427-433.

Shannon, C.E. 1948. A mathematical theory of communication. Bell System Technical Journal 27:379-423, 623-656.

Sipiläinen, T. 2003. Suurten maito- ja viljatilojen suorituskyky. Helsingin yliopisto. Taloustieteen laitos. Julkaisuja 38.(In Finnish, English summary)

Sipiläinen, T., Oude Lansink, A. & Pietola, K. 2005. Learning in organic farming – An application on Finnish dairy farms. Paper presented at the XIth Congress of EAAE, Copenhagen, Denmark, August 24-27, 2005.
Stoltze, M., Piorr, A. Häring, A. & Dabbert, S. 2000. Environmtental impacts of organic farming in Europe. Organic farming in Europe: Economics and Policy 6: 1-127.

Struik, P.C. & Bonciarelli, F. 1997. Resource use of cropping system level. European Journal of Agronomy 7: 133-143.

Watson, C.A., Atkinson, D., Gosling, P. Jackson, L.R. & Rayns, F.W. 2002. Managing soil fertility in organic farming systems. Soil Use Management 18: 239-247.

van Wenum, J.H., Wossink, G.A.A. & Renkema, J.A. 2004. Location specific modeling for optimizing wildlife management on crop farms. Ecological Economist 48: 395-407.

Wossink, G.A.A. & van Wenum, J.H. 2003. Biodiversity conservation by farmers: analysis of actual and contingent valuation. European Review of Agricultural Economics 30(4): 461-485.

Shephard, R.W. 1953. Cost and production functions. Princeton: Princeton University Press.

Shephard, R.W. 1970. Theory of cost and production functions. Princeton: Princeton University Press.

Sheriff, G. 2009. Implementing second-best environmental policy under adverse selection. Journal of Environmental Economics and Management 57: 253-268.