Modelling conventional and organic farming: a literature review

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Abstract

Literature shows a significant development of organic farming in Europe but with considerable differences between countries. These depend on general agricultural policy (the set of regulations and laws), specific policy incentives, and also on differences in consumer behaviour. This paper reviews scientific literature on the evaluation of the technical, economic and environmental aspects of conversion from conventional towards organic production. The methods and results of empirical and normative modelling studies at the farm level, with special regard to farm management and policy, are analysed. Empirical modelling studies show the importance of incentives and agricultural policy, and the usefulness of integrated modelling for determining the effects of different policies on farm management. Normative modelling shows the effects of new policy instruments and technology, and allows the high level of detail needed for what-if analysis. Normative models of conversion to organic farming confirm the importance of incentives and the agricultural policy context.

Additional keywords: farm modelling, conversion, empirical modelling, normative modelling, policy, environment, transition

Introduction

Organic farming claims to have the potential to provide benefits in terms of environmental protection, conservation of non-renewable resources, improved food quality, reduction in output of surplus products and the reorientation of agriculture towards areas of market demand (Lampkin, 1990). Some European governments have recognized these potential benefits and responded to them by encouraging farmers to adopt organic farming practices, either directly through financial incentives or indirectly through support of research, extension and marketing initiatives. However, farmers' decisions on whether or not to make the switch from conventional to organic farming have not been studied extensively thus far.

The study reported in this paper is part of a larger project that focuses on developing a farm-level model that can be used to support farmers and government in the transition process from conventional to organic farming systems in economic and environmental terms. The model will be used to determine the effects of different policies on the conversion to organic farming systems.

The objective of this paper is to present a review of scientific literature on the evaluation of technical, economic and environmental implications of conversion from conventional towards more sustainable production, i.e., organic farming. Methods and results of different studies will be compared and the advantages and disadvantages of different approaches will be analysed.

The paper starts with definitions of organic farming and the way these definitions are operationalized into policy. Next, some data and background information concerning the history of organic farming in the EU and in the Netherlands are given. After that, empirical and normative modelling research is analysed to determine their suitability for modelling conversion from conventional to organic farming. This analysis is based on articles in peer-reviewed scientific journals. Finally, conclusions will be drawn concerning modelling of conversion from conventional towards organic farming.

Defining organic farming and conversion to organic farming

Aims and definitions of organic farming

There are many definitions of organic farming. Mannion (1995) refers to it as a holistic view of agriculture that aims to reflect the profound interrelationship between farm biota, agricultural production and the overall environment. Scofield (1986) stresses that organic farming does not simply refer to the use of living materials, but emphasizes the concept of 'wholeness', implying the "systematic connection or co-ordination of parts in one whole." As Scofield points out, the concerns that motivated the early adopters of organic farming include issues of soil health and structure, the exhaustible nature of artificial fertilizers, and human health.

According to the Codex Alimentarius (Le Guillou & Scharpé, 2001), organic farming involves holistic production management systems (for crops and livestock) emphasizing the use of management practices in preference to the use of on-farm inputs. This is accomplished by using, if and when possible, cultural, biological and mechanical methods in preference to synthetic materials.

One of the most significant expositions of the aims and principles of organic farming is presented in the International Federation of Organic Agriculture Movements' (IFOAM) basic standards for production and processing (Anon., 2002). In the words of the principle aims of IFOAM, organic farming even involves a clear vision of a major change in society in order to make organic farming possible:

> "(...) to interact in a constructive and life-enhancing way with natural systems and cycles; (...) to consider the wider social and ecological impact of the organic production and processing system; (...) to progress toward an entire production, processing and distribution chain which is both socially and ecologically responsible."

Lampkin & Padel (1994) provide a more operational definition of organic farming. They state that the aim of organic farming is:

> "to create integrated, humane, environmentally and economically sustainable agricultural production systems, which maximize reliance on farm-derived renewable resources and the management of ecological and biological processes and interactions, so as to provide acceptable levels of crop, livestock and human nutrition, protection from pests and diseases, and an appropriate return to the human and other resources employed".

In some respects, this definition stands as the complete opposite to conventional productivist agriculture, which implies extensive use of artificial inputs such as fertilizers and pesticides designed to increase productivity in food production.

Practical aspects of organic farming

Some practical consequences of organic farming concerning crop and livestock production can be described by the following.

In crop production, soil fertility and biological activity should be maintained by use of green manure, leguminous plants and an ample crop rotation scheme. Fertilizing takes place with manure of organic origin – no synthetic fertilizer is allowed. For crop protection against pests and diseases, besides ample crop rotation schemes, natural enemies are used. Weed control is based on the selection of varieties and mechanical methods.

Livestock production focuses on animal welfare, animal health care and organic feeding. Farm animals must be kept in a natural way with sufficient run-out, space, light and litter in the stable. For each animal minimum indoor and outdoor room should be available. Nutrition, care and housing should offer the animals an optimum natural resistance against diseases. Natural and homeopathic medicines have preference. The foodstuffs should be organically produced and only a restricted number of additives is allowed (Anon., 2004).

Conversion aspects of organic farming

The agri-environmental measures introduced by EU Council Regulation 2078/92 (Anon., 1992) encourage conversion to and maintenance of organic farming by providing financial compensation to farmers for any losses incurred during conversion. In the European Union, organic production of agricultural products is regulated by Council Regulation 2092/91 (Anon., 1991). This regulation sets out strict requirements that must be met before agricultural products, whether produced in the EU or imported from third countries, can be marketed as organic. In particular, it severely restricts the range of products that can be used for fertilizing and for plant pest and disease control, and requires each member state to set up a certification body and an inspection system to certify compliance with these principles. The principles must normally have been followed for at least two years before sowing or, in the case of perennial crops, at least three years before harvesting, before the products can be sold as organic. During this period the farm is said to be 'in conversion' (Hau & Joaris, 1999).

Two types of conversion can be distinguished (Lampkin & Padel, 1994):

1. Staged (step-by-step) conversion. Every year a certain area of the farm is converted to organic farming. Some certification bodies do not accept this type of conversion;
2. Single-step conversion. The whole farm converts to organic farming at the same moment. This enables the farm to gain access to premium prices sooner, but means that all the risks, learning costs and financial impacts of conversion are concentrated into a short period of time, while for arable farming rotation disadvantages can arise because not all of the farm can be planted to fertility-improving crops at the same time.

In the case of livestock production, the animals also have to be converted from conventional to organic production. The conversion period depends on the animal type and varies from 6 weeks for layers to 12 months for beef cattle (Anon., 2004).

Lampkin & Padel (1994) drew some general conclusions about conversion based on their EU-wide study. During the conversion (transition) period a farmer should aim to:

1. Improve soil fertility by establishing a rotation with legumes, so that crops can be produced without inorganic nitrogen fertilizer or large amounts of purchased manure;
2. Adjust the stocking rate to the natural carrying capacity of the farm, so that livestock can be kept without large amounts of purchased concentrates and/or forage;
3. Change the management system to maintain animal and plant health with the limited inputs available according to organic production standards.

Necessary changes depend on the intensity and the condition of the farm before conversion. Usually some investment in machinery and/or buildings is required in order to meet organic standards. After the conversion period the farmer can apply for full organic certification and will usually be allowed to use a symbol and gain access to premium prices when available.

In the early 1990s, an analysis of the experiences of farmers who had converted their farms to organic systems indicated that the main problems encountered during the conversion process were (Lampkin, 1990):

1. Shortage of forage on livestock farms (due to a reduction in yields and increased reliance on home-grown forage);
2. Excess protein in rations of livestock herds, leading in some instances to health problems;
3. Problems with weed control (notably docks, couch and thistles);
4. High workloads in peak periods;
5. Financial difficulties due to lack of access to price premiums until conversion is complete, conversion-related investments and 'disinvestments' and information-gathering costs for production and marketing (Lampkin & Padel, 1994).

Growth of the organic farming sector

During the 1980s, organic farming received political attention in many European countries through political recognition of the production system (i.e., standards, certification systems and labels) (Lampkin *et al.*, 1999a). Public financial support for organic farmers was introduced for the first time in Europe (in Denmark) in 1987 to cover economic losses during the two-year conversion period (Michelsen, 2001). During the 1990s, political interest in organic farming moved to the level of the EU, which introduced a common set of production standards for organic plant production in 1991 (EU Regulation 2092/91) (Anon., 1991). In 1999 this was supplemented by common standards for organic livestock production (EU Regulation 1804/99) (Anon., 1999) and by an option for financial support of organic farmers. The latter followed from the measures accompanying the reform of the Common Agricultural Policy in 1992 (EU Regulation 2078/92) (Anon., 1992). In the following years, member states implemented various organic farming policies according to this legislative framework (Lampkin *et al.*, 1999a). Since 1999, organic farmers in all EU countries have been receiving support under the agri-environmental programmes that are granted under the rural development regulation of Agenda 2000 (Häring & Dabbert, 2004).

In the Netherlands, among different subsidy regulations of the Ministry of Agriculture, Nature and Food Quality relevant to organic farming, there is a regulation supporting the conversion to organic production (*Regeling Stimulering Biologische Productiemethode*, RSBP). The RSBP is implemented by the *Dienst Landelijke Service* (LASER). This regulation provides financial support during the conversion period in order to compensate the loss in income, according to the Conversion Scheme (Lampkin *et al.*, 1999a). However, there is an additional condition: one must produce organically for at least five years. The subsidy is given per five years per hectare. For the future development of organic farming in the Netherlands, as in some other European countries, an action plan was developed to promote organic agriculture. As part of this action plan, marketing of organic products, advisory services and consumer information are supported (Yussefi & Willer, 2002). The action plan developed by the Dutch government (*Plan van Aanpak Biologische Landbouw 2001–2004*) in 2000 includes an important target. Five per cent of the total agricultural area should be organically managed by the year 2005 and 10% by the year 2010 (Yussefi & Willer, 2002).

In 1985 the area of organic production amounted to 100,000 ha in the whole of the EU. The number of organic farms was 6,300 or less than 0.1% of the total number of farms. Organic production areas and number of organic farms of five EU-countries with substantial organic production and of the Netherlands are shown in Figure 1 and Figure 2, respectively. Differences in the size of organic farming between countries can be explained partly by the differences in specific policy incentives (Lampkin *et al.*, 1999b) and partly by the differences in consumers' behaviour (Anon., 2003). More than half of all the organic farms were located in France and Germany. Since then organic farming in the EU has experienced a dynamic development, especially in the 1990s. From 1993 to 1998 the organic farming area nearly tripled (Foster & Lampkin, 2000). By the end of 1999, the number of farms in the EU had increased to more than 127,000 holdings with 3.3 million hectares, or nearly 1.5% of all holdings and

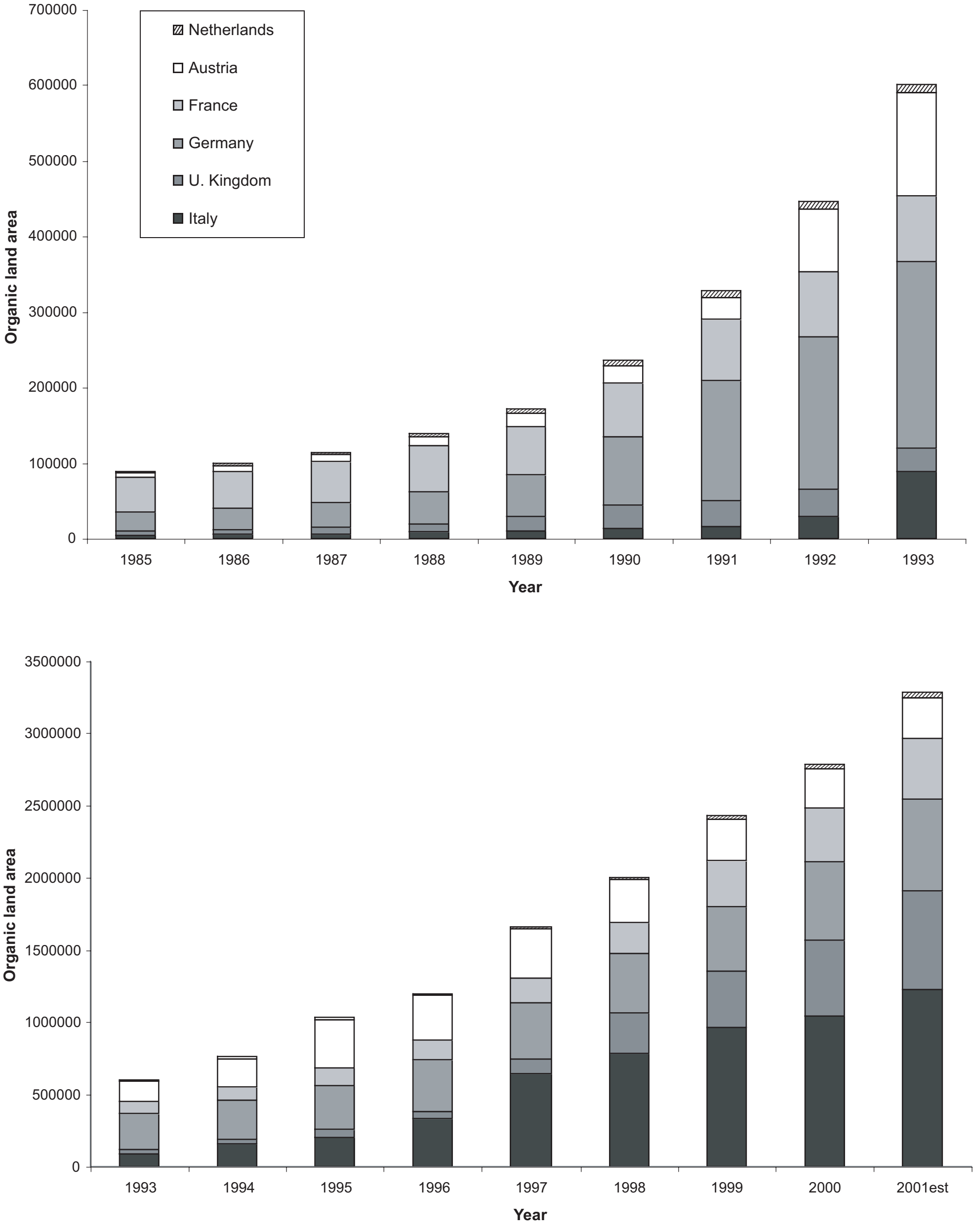

Figure 1. Organic land area (ha) in six EU-countries over the period 1985–2001.

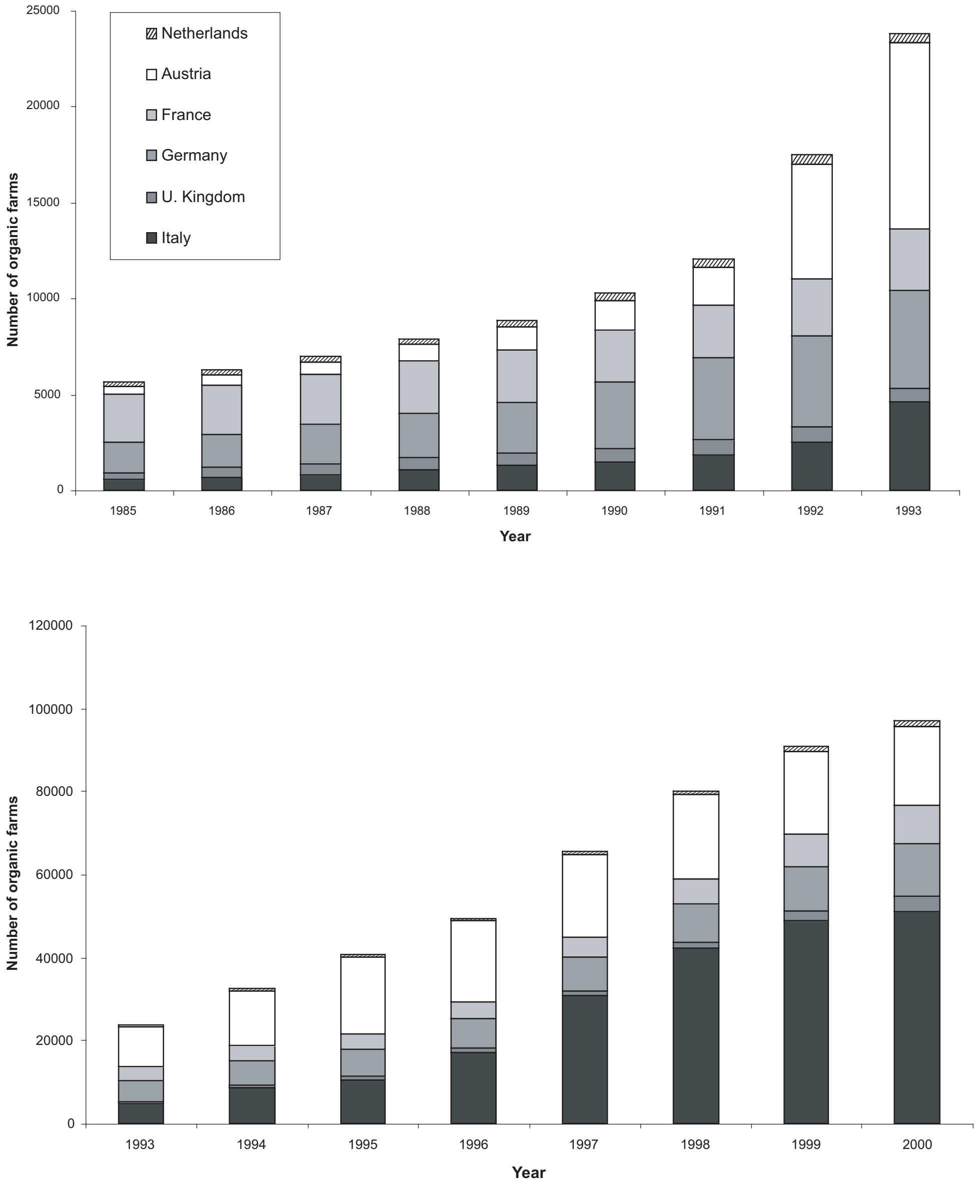

Figure 2. Number of organic farms in six EU-countries over the period 1985–2000.

2.4% of the total agricultural area. In Austria and Sweden, organic farming reached rather significant shares of 10 to 15% of total agriculture in the late 1990s, either in terms of number of farmers or total agricultural area. An explanation for the growth of organic farming is that during the 1980s and 1990s it received growing public attention throughout Europe as part of the general interest in socially responsible alternatives to the particular type of societal modernization that accelerated after World War II (Michelsen *et al.*, 2001).

In the Netherlands in the 1990s the growth in number of organic farms increased considerably. Between 1993 and 1997 an average of 60 farms per year were converted. In 1998 and 1999 more than 200 farms converted per year, which is equivalent to an annual growth of more than 25%. In 2000 and 2001 the growth rate dropped to 14 and 8%, respectively (Melita, 2001). In July 2001, 1.47% of the total agricultural area of the Netherlands was organically managed.

Modelling conventional and organic farming

When the relationship between agricultural production methods and economic and environmental sustainability at the farm level is examined we can distinguish two main categories of models: empirical and normative models.

Empirical models are understood here as econometric models. Econometric models are statistical representations of farm-level systems, often as aggregate systems of equations for input demand and output supply. Econometric models allow for statistical testing of economic and/or technical relationships (Pindyck & Rubinfeld, 1998; Wallace & Moss, 2002).

Normative models are mechanistic optimization and simulation models. Optimization and simulation models are both systems of equations and/or inequalities designed to replicate farm-level activities related to production, marketing and finance. A distinction often made between optimization and simulation models is that the former involve explicitly the specification of an objective function (e.g. profit maximization), while this is not the case for simulation models (Hazell & Norton, 1986; Weersink *et al.*, 2002).

Farm modelling, both empirical and normative, is an important tool for farm planning and extension, research planning and evaluation, and policy analysis (Klein & Narayanan, 1992). Lee (1983) distinguishes three specific needs of farm modelling: (1) understanding likely responses of farms to specific economic conditions and policy provisions, (2) understanding the likely distributive effects of these conditions and provisions, and (3) providing additional detail and likely behavioural responses not well specified in macromodels. According to these purposes of farm modelling two main types of farm model can be distinguished:

1. Models to support farm management;
2. Models to support policy making.

Models to support farm management concern particular effects of different management practices on the income of the farmer and on the environment. They analyse how different input combinations and constraints influence the output results of the farm.

Models that focus on policy analysis aim to clarify the effect of different policy instruments on management decisions and through it on economics and environment (Baum & Schertz 1983). In such a way different policy alternatives can be compared. Alternatives include, for example, taxes, subsidies, transferable permit schemes, insurance and credit instruments (Falconer, 1998; Oskam *et al.*, 1998).

Empirical modelling

There are many econometric studies dealing with economic and environmental aspects of conversion to more sustainable farming systems such as organic farming. They are summarized in Table 1, and it is clear that the majority of the reviewed econometric studies are oriented towards supporting policy making.

Table 1. Overview of empirical modelling studies.

Study	Country	Orientation	Subject	Method
Cooper (1997)	USA	Policy analysis	Calculate minimum incentive payment to adopt ‘best management practice’	Traditional discrete choice analysis of contingent valuation survey data and market data
Oglethorpe & Sanderson (1999)	UK	Farm management policy analysis	Analysing economic and environmental effect of environmental policy	VEMM[1] SEUM[2]
Lohr & Salomonsson (2000)	Sweden	Policy analysis	Determine factors that influence required conversion subsidy	Utility difference method
Pietola & Oude Lansink (2001)	Finland	Policy analysis	Analyse conversion factors Economic incentives	Bellman equation Probit model Monte Carlo simulation
Wynn *et al.* (2001)	UK	Policy analysis	Analysing factors that influence the entry into Environmentally Sensitive Area	Multinomial logit model Duration analysis

[1] VEMM = Vegetation Environment Management Model.

[2] SEUM = Subjective Expected Utility Maximising Model.

Cooper (1997) made an attempt to estimate the minimum incentive payments a farmer would require in order to adopt more environmentally friendly “best management practices” (BMPs). This was done by using contingent valuation method (CVM) survey data (farmers’ responses concerning the adoption of BMPs given hypothetical incentive payment values per acre) in combination with actual market data (farmers’ actual responses on the amount of incentive payments) from four watershed regions in the United States. Combining actual market data with the CVM data adds information to the analysis, thereby most likely increasing the reliability of the results compared with analysing the CVM data only. Traditional discrete choice analysis was applied to analyse the combined data. Adoption rates (percentage of farmers adopting BMP) predicted with the combined data model are significantly higher than those predicted using the traditional discrete choice analysis based on CVM data only. Hence, the author concluded that using traditional CVM analysis results to determine payments to attain a given level of adoption is likely to result in overpayment.

Oglethorpe & Sanderson (1999) aimed to explain how a utility maximizing economic modelling framework can be linked to an ecological modelling system in order to do *ex ante* assessment of the ecological impact of certain key agricultural management parameters. Two models, the Subjective Expected Utility Maximising Model (SEUM) and the Vegetation Environmental Management Model (VEMM) were initially developed for independent analyses. Data pertaining to a survey of farm sites were used to analyse the types of relationships that emerge between agricultural management parameters and grassland vegetation. A specific case-study site was selected for assessment of ecological and economic performance of potential policy scenarios. The results of the analysis highlight the high relevance of such an integrated modelling system for environmental policy decision support.

Lohr & Salomonsson (2000) focused on analysing the factors that determine whether a subsidy is required to motivate organic conversion by using a utility difference model with Swedish data. Survey data were collected through questionnaires. Several hypotheses were tested related to factors that affect the necessity of subsidy for conversion. Results showed that farmers requiring higher subsidies managed larger, less-diversified farms, and were more concerned with the quality of organic inspection and of technical advice. Access to more market outlets and information sources substituted for subsidy level in the farmers' utility function. From these results Lohr & Salomonsson concluded that services rather than subsidies may be used to encourage conversion to organic agriculture.

Pietola & Oude Lansink (2001) focused on analysing the factors determining the choice between conventional and organic farming technology in Finland and on the probability of choice given these factors. They examined farmers' responses to economic incentives that aim to stimulate a switch to organic farming technology, using data on observed farmer behaviour. A Bellman equation was used to analyse the factors determining the choice between conventional and organic farming technology. The choice probabilities were estimated in a closed form by an endogenous Probit-type switching model using maximum likelihood estimation (MLE). Finally a Monte Carlo simulation was applied to simulate maximized random return streams. The results suggested that decreasing output prices in conventional production and increasing direct subsidies trigger the switch to organic farming. The switch is also more likely on farms having large land areas and low yields. Intensive livestock production and labour-intensive production have a lower probability of switching to organic farming. The results of this study can help in designing policies that target farmers' choice of production technology.

Wynn *et al*. (2001) aimed to model the entry decisions of farmers and the speed of entry to Environmentally Sensitive Areas (ESA) in Scotland. A multinomial logit model was used for modelling entry decisions and a duration analysis was made to quantify the relative speed at which the farmers joined the ESA scheme. Models were based on a survey of 490 farmers sampled from across all ten ESAs in Scotland. The rather straightforward results indicated that non-entrants were less aware of and less informed about the scheme than entrants. Furthermore, the probability of entry was increased when the scheme prescription fitted the farm situation and when the costs of compliance were low. The duration analysis suggested several factors accelerating scheme entry: an interest in conservation, more adequate information and more extensive systems. They concluded that the logit and duration models were reasonably successful in explaining the probability and speed of entry to the scheme, respectively.

Normative modelling

In the reviewed studies concerning normative modelling models supporting farm management and models supporting policy making are found (see Table 2).

In the first management-oriented study De Koeijer *et al.* (1995) examined whether mixed farming systems offer more perspectives for an economically and environmentally sustainable agriculture than specialized farms. They used static linear programming (LP) to analyse the effect of an intensive co-operation between two specialized farms and also multiple goal programming to determine the trade-off between income and environmental pollution in several farming systems. They concluded that intensive co-operation between arable and dairy farms offers important economic advantages.

Berentsen *et al.* (1998) aimed to quantify economic and environmental consequences for intensive and extensive dairy farms typical for the province of Utrecht, the Netherlands, when converting to organic dairy farming. For this analysis a static LP model was used with the objective function of maximizing labour income of the farm. From the results it appeared that the extensive farm benefited from conversion while the intensive farm lost income. The environmental consequences of intensive and extensive dairy farming systems were quite different. The environmental consequences for the organic farms showed a much lower nitrogen surplus (nitrogen fixation was left out) and a phosphate surplus that was at best equal to that of the conventional farm. Especially on the extensive farm, manure from other farms was needed to supply nitrogen. Due to fixed ratios between phosphate and nitrogen in manure this leads to overfertilization with phosphate.

De Buck *et al.* (1999) analysed the role of risk in the adoption by farmers of new systems by means of a model that determines differences in production risks between conventional and sustainable farming systems. The model consists of two main parts: (1) crop husbandry models (HMs) for several husbandry activities at the crop level, and (2) a LP model at the farm level. The HMs generate management tracks by means of decision rules, based on the tactics in crop husbandry and weather uncertainty. Combining outcomes of the HMs, the LP model selects optimal management tracks on an annual basis. In the LP model, tactics are re-assessed by means of the HMs, using information of the LP solution. This iterative procedure enables production risks of conventional and sustainable farming systems to be compared, considering fixed, allocatable resources for the whole farm firm. The model can be used (1) to estimate

Table 2. Overview of normative modelling studies.

Study	Country	Type of farm	Main subject	Method	Dynamic or static	Data source
Farm management oriented						
De Koeijer *et al.* (1995)	Netherlands	Arable/dairy (co-operation)	Trade-off between economics & environment	Linear programming & multiple goal programming	Static	Typical Netherlands
Berentsen *et al.* (1998)	Netherlands	Dairy	Economic and environmental consequences of conversion	Linear programming	Static	Typical Urecht region
De Buck (1999)	Netherlands	Arable	Production risk in conventional and sustainable farming	Crop husbandry models Linear programming	Static Dynamic	Dutch FADN[1]
Policy oriented						
Wossink *et al.* (1992; 1994a; 1994b)	Netherlands	Arable	Policy analysis environmental regulation Policy instruments	Linear programming (MIMOSA system)	Static	Representative Netherlands
Donaldson *et al.* (1995)	UK, France	Arable	Analyse the effect of CAP[2] reform on income & environment	Recursive linear programming	Static	Crop growth model EPIC[3] model
Hasler (1998)	Denmark	Crops & livestock	Cost effectiveness of measures to reduce nitrogen leaching	Linear programming Non-linear programming	Static	Survey Account
Falconer *et al.* (2000)	UK	Arable	Effect of pesticide taxation on management & income	Linear programming	Static	Case study

[1] FADN = Farm Accountancy Data Network.
[2] CAP = Common Agricultural Policy.
[3] EPIC = Erosion Productivity Impact Calculator.

risks of different farming systems, omitting innovations in the sector, using all possible natural conditions as model input, (2) to objectively compare farming systems under similar farm and management situations, and (3) to evaluate new techniques on their suitability for a farming system. This paper shows that these methods are very useful and flexible in linking agro-ecological knowledge with farm management models. The authors concluded that, ideally, an optimizing algorithm for the HM modules, consisting of dynamic networks, would be Dynamic Programming.

The other group of normative models is policy-oriented. In several studies Wossink *et al.* (1992) and Wossink & Renkema (1994a, b) used a static LP model with an environmental component (nutrient loss and pesticide use) to evaluate the effects of alternative environmental policy instruments (such as taxes, subsidies and transferable pollution licenses), and to examine how environmental, price and market policies change arable farming at the farm and regional level. They concluded that LP is a good tool for analysing the interactions between production intensity, environmental aspects and farm income, and for comparing the implications of different policy options at farm level.

Donaldson *et al.* (1995) examined the effects of Common Agricultural Policy (CAP) price changes on income and environment on arable farms in two regions: south-east England and south-west France. For this policy analysis a crop growth model and an economic model were integrated. The crop growth model was used to generate yield and pollution data. These data were incorporated into the economic recursive LP model. The economic model was run from 1990/91 to 1994/95 in recursive fashion. The results indicated that modal farms in both regions did not have lower incomes following implementation of CAP reforms in 1992/93 compared with the previous years. However, in reality, farms in south-east England appear to be penalized by the reforms when compared with the 'no reform' situation. In the French situation, farm income was higher with CAP reform than without. In south-east England the farms appeared to be penalized by the reforms when compared with the 'no reform' situation. Donaldson *et al.* (1995) attributed this to the fact that crop yields in this region were 40% higher than those used to calculate the average regional yields (used in the calculation of area payments). In the French model, farm income was higher with CAP reform than without as a result of the very high area payment on some of the irrigated crops and the much lower discrepancy between actual yields in the region and the yields used to calculate the area payments. With CAP reforms, modelling results of reality indicated an increased area of lower (10–30%) nitrogen-input crop production in both cases. This is associated with lower rates of nitrate loss. The authors concluded that this approach, which combines a crop growth model with an economic LP model, was very suitable for identifying the effect of relative price changes resulting from the CAP reform on farmers' resource allocation.

Hasler (1998) made an analysis of environmental policy measures aimed at reducing nitrogen leaching at the farm level for typical Danish crop farms and livestock holdings. The objective was to estimate the cost-effectiveness of the measures (four different levy rates on commercial nitrogen fertilizer) in reducing nitrogen leaching. Cost-effectiveness was expressed as costs per kg reduction in nitrogen leaching. The reductions in nitrogen leaching levels from the measures were compared with the political target. Hasler used static linear and non-linear programming to model the effects of levies on nitrogen leaching. The results indicated that the imposition of levies on commercial nitrogen fertilizer would provide incentives for reducing fertilization and for substituting commercial nitrogen fertilizer for livestock manure.

Falconer & Hodge (2000) aimed to evaluate the implications of pesticide taxation on the management practices of farmers by using a static LP model for a case-study arable farm. The effects of input taxation on pesticide use and income of the farmers were analysed. The model suggested that pesticide use could be reduced significantly while actually increasing farm income through conversion to low-input farming. They concluded that if producers adhere to current systems, a pesticide tax at politically acceptable levels introduced as a stand-alone measure would perform poorly. Pesticide taxation should be part of a package of measures including, in particular, education and training to encourage and assist farming system change.

Discussion and conclusions

Environmental-economic farm modelling is considered a useful instrument for gaining insights into the interactions of production management, environmental aspects and farm income, and for comparing the implications of different policy instruments. The number of recent scientific publications dealing with this type of modelling, however, is not really high. This type of research is typically carried out in north-western European countries such as the Netherlands and UK. The number of studies dealing with conversion from conventional towards organic farming is even lower. Most of the studies deal with analysing the consequences of farming practices or political measures.

A difficulty that often arose while analysing the studies was the low level of detail of the model descriptions. In some cases this made understanding the studies quite difficult.

There are some major differences between empirical and normative modelling. Empirical or econometric models give an average view based on the data set used (i.e., certain types of farms, sector). Also normative models can be based on an average data set within one region or one sector, but can also use typical or specific farm data (which is not necessarily average for all the farms in that region). The main difference is in the purpose and the use of these models. Empirical models mainly search for the factors influencing a certain dependent variable. Normative models use a given data set to explore the effect of future changes. Using this modelling technique a 'what-if' analysis can be made by including new variables (e.g. new taxes or subsidies) in the model to see how they affect the decision making of farmers.

The empirical studies mainly focus on determining the main factors influencing the conversion to more sustainable farming systems and the effect of different policies on the decision making of farmers. In most cases econometric analysis is well suited to analysing the agricultural policy context. The ability to aggregate from individual units to a larger scale in a statistically consistent manner is a major advantage

(Weersink *et al.*, 2002). However, empirical models have some shortcomings. First, the level of detail is usually rather low. Second, empirical modelling is by definition hindsighted: the models are based on historical data and cannot deal easily with new technologies or new types of policy. In principle the conclusions based on such analyses are valid only for the data (i.e., outputs and inputs) in the period of observation (Falconer & Hodge, 2000).

Normative studies deal with the economic and environmental consequences of different management practices and also with the effects of different policy scenarios on the decision of farmers concerning conversion to more environmentally friendly production methods. Normative modelling makes it possible to analyse the effect of different policy incentives on farm management in a more detailed way. By this type of modelling new technology and new types of policy can be analysed, which makes it suitable for 'what-if' analyses (Van Ittersum *et al.*, 1998). In these studies mathematical programming is used in particular. The main conclusion of these studies is that mathematical programming is a suitable tool for analysing the interactions between management measures and production intensity on the one hand, and environmental aspects and farm income on the other. Moreover, it is a useful tool for determining the implications of different policy options at the farm level, as in the trade-off between economic and environmental aspects.

The majority of the normative studies did not include time in the model. However, for modelling conversion of farms from conventional to organic farming systems the inclusion of time is important. There are two main reasons for including the time aspect. One reason is that there is a possibility for farmers to convert stepwise (in case of arable farming), which gives them more time to learn the new production method. It also ensures income through still allowing production of conventional products next to the in-conversion products (which still sell for conventional prices but must be produced organically) during the conversion period. By modelling over time it is possible to see in which year what area of certain crops would be the best to produce (i.e., from an economic or/and environmental point of view) in an organic way and how it would develop over the years. The other reason is that there is the possibility of analysing the effect of different policy incentives before, during and after the conversion period. In a dynamic model these instruments can be included (e.g. different amounts of taxes or subsidies in a certain year of the conversion). In accordance with Sparkers *et al.* (2003) it can be stated that for this reason dynamic linear programming is very suitable for modelling the conversion period of farms. The requirement of economic and environmental objectives can be covered by the use of multiple objectives in a linear programming model (Zander & Kächele, 1999; Ten Berge *et al.*, 2000; Kropff *et al.*, 2001).

From the analysis it appears that farmers also include considerations other than strictly economic ones in the decision whether or not to convert. Especially, behavioural aspects like the risk attitude and risk perception of farmers are important to mention. These aspects could be included in a linear programming model using quadratic risk programming or dynamic stochastic programming methods (Hardaker *et al.*, 2004).

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