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Part I.

Organic Agriculture and Sustainability

Chapter 2.

Organic Agriculture and the Environment
Case Studies

CONSIDERATIONS OF THE ENVIRONMENTAL AND ANIMAL WELFARE BENEFITS OF ORGANIC AGRICULTURE IN THE NETHERLANDS

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Abstract

Policy support for organic agriculture in the Netherlands is based on the assumption that organic agriculture to a large extent fulfils the public's expectations in respect of advantages to the environment and to animal welfare, as compared to non-organic, conventional agriculture. This paper looks at the major issues in which organic agriculture differs from non-organic agriculture and identifies those issues where this difference may be considered significant. Such analysis of the performance of both systems can be done using different measuring rods. Based primarily on field research in the Netherlands, conclusions are drawn and organised in accordance with the OECD environmental indicators for agriculture. Taking those indicators that are relevant for the Netherlands, organic agriculture shows a different overall performance than does non-organic agriculture. However, quantification of their relative position is difficult and conclusions often depend on the measuring rod chosen. Moreover, environmentally and animal welfare benign non-organic production systems are approaching, or even surpass the performance of organic agriculture, by market demand or by legislative force.

Introduction

The existence of a national policy plan[2] on organic farming in the Netherlands can be explained by the following excerpt from the introductory chapter of the plan:

> *The organic sector has an excellent record of socially responsible business practice: in all links of the chain, organic production meets our social requirements in terms of environment, animal welfare and biodiversity, and plays a pioneering role for the entire agrifood complex.* (Ministerie van Landbouw, Natuurbeheer en Visserij, 2000).

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[1] National Reference Centre of the Ministry of Agriculture, Nature Management and Fisheries, the Netherlands. The National Reference Centre is an internal policy advisory body of the Ministry of Agriculture, Nature Management and Fisheries. The information offered and the opinions expressed in this paper do not necessarily suggest, or lead to, present or future policy choices by the Dutch government.

[2] The present policy plan of the Netherlands "An organic market to conquer" is the third policy plan to stimulate organic agriculture. It outlines Dutch policy intentions during the period 2001-2004, stressing market demand as a tool for growth and main incentive to farmers' conversion to organic production methods. For more details see paper by Gabrielle Nuytens-Vaarkamp in Part III, Chapter 9.

During the elaboration of the policy plan, the point was often raised as to how substantial is the evidence that supports organic agriculture's position in the political limelight. There are many claims in the literature of how advantageous organic farming is. Often these claims fail to clearly limit organic farming to a certain well-defined standard of production principles, but instead look at the many examples of production units that support the claims made.

The reference point for the relative position of organic agriculture would of course be "conventional agriculture" with its many faces. Measuring one ill-defined concept against another would give both defenders and proponents of organic agriculture any argument needed to back up their claims.

Over the last few years, discussion on the relative merits of organic agriculture has grown in intensity in the Netherlands and elsewhere. This has prompted the Ministry of Agriculture, Nature Management and Fisheries to commission a desk study on the available information from farms and research institutions in the Netherlands that can shed light on this topic. The two broad topics being reviewed are environmental benefits and animal welfare, in all areas of plant and animal production, as they compare and contrast with "non-organic agriculture", that is, a modern and developing agricultural production system that increasingly is becoming bound to strict environmental and animal welfare rules.

This paper draws heavily on preliminary findings of this study, complemented by a wider look at the literature. Conclusions are grouped according the OECD agri-environmental indicators, aggregating and integrating the detailed findings of the various studies, bringing them to a level that allows input in policy development decisions. Not covered by the OECD agri-environmental indicators are aspects of animal welfare. Objective criteria with which to quantify animal welfare are still very much in development. For the scope of this paper, however, conclusions in this realm are based on broadly accepted criteria of species-specific natural behaviour and animal health.

References for comparison

Reference for "organic agriculture"

Within the European Union (EU), organic production methods, including rules on certification and control, follow what is laid out in Regulation 2092/91 of 1991, as amended (EU, 1993). This regulation sets out rules for organic plant production, animal production, and trade in and processing of organic products. Regulation 2092/91 prescribes "how" organic products should be produced. It does not define the qualities of the product, and only implicitly refers to any environmental criteria for production. Regulation 2092/91 does not mention nature, biodiversity, energy use, transportation costs ("food miles"), or many other aspects of "environment". As regards animal welfare, Regulation 2092/91 sets out many detailed requirements for raising animals, all directed towards "humane" treatment of the animals, allowing a maximum of natural behaviour.

The whole set of rules in Regulation 2092/91, but not more than this, will be used as a reference point in this paper. Outside the comparison, therefore, are all the different ways in which organic farms present themselves. But this limitation is not exclusive to organic farming. Indeed, conventional farms in the Netherlands, through legal requirement or other motives, show an increasing diversity in their care of nature, the environment and animal welfare.

The relative merits of organic agriculture for the environment and for animal welfare are, to an overwhelming extent, limited to the primary production phase. Not only does Regulation 2092/91 not put any particular “environmental” demands on processing and trade of organic products, brief analysis suggests that in practice there is no relevant difference between organic and conventional production systems (Aalders *et al.*, 2000).

Reference for “conventional agriculture”

There is no such practice as conventional agriculture. The differences in crops, soils, livestock, growing and rearing methods, market approaches, legal requirements and localisation, management styles, etc., make it virtually impossible to define one common denominator, except that the approach to production can be classified as “non-organic”. This would make it difficult to define a reference conventional production system with which organic agriculture can be contrasted. However, on the level of single issues, such a comparison is possible, if sufficient room is allowed for qualitative in addition to quantitative descriptions.

Non-organic, conventional agriculture, too, is ruled by market forces and consumer expectations, and bound by laws and regulations. It increasingly uses the “people-planet-profit” approach as a marketing tool, as is shown in many initiatives of “integrated” production, often with their own brands and logos to facilitate consumer recognition and acceptance. These environmentally and animal welfare-benign systems come about out of commercial interest but are increasingly the result of restrictive legislation.

Issues under review

The environmental issues

Based upon the description of the organic farming system as defined by the European rules, the effects on the environment will be determined by the most concrete requirements spelled out, explicitly or implicitly, in Regulation 2092/91. Prohibition of the use of certain pesticides and fertiliser are the most conspicuous. Other effects are leaching of nitrates, emissions of carbon dioxide, ammonia and other greenhouse gases, and energy use. Aggregate effects are taken into consideration if directly attributable to these “single” effects. A case in point can be the natural diversity on the farm. This means that organic farming-related practices that are not exclusively limited to organic farming should not be taken under consideration. These include local marketing of produce (with a subsequent low energy use in distribution) and a certain care for indigenous flora and fauna. The OECD environmental indicators for agriculture (OECD, 2000) will be applied when relevant to the comparison between organic and conventional agriculture, and when relevant to the Netherlands’ geographic situation.

The animal welfare issues

Farm animals are entitled to the right to express their natural behaviour. This is one of the basic rules for organic production. This principle can come into conflict with the need for an economically profitable production process and even with certain demands on other aspects of animal welfare. Other contradictions can exist with requirements for human food safety and environmental protection. Compromises have to be found in organic agriculture too and, to a certain extent, Regulation 2092/91 on organic agriculture can be seen as a good expression of that need.

Measuring rods to use

A serious look into environmental effects and animal welfare in organic agriculture and conventional agriculture must consist of both an absolute and a relative component. The absolute component would consist of objective data. The relative component puts these objective data into a wider perspective and adds relevant qualitative descriptions.

Effects can be expressed in various ways, *i.e.* per hectare or per kilogram of product. Depending on the issue under review, both expressions are relevant. The yield per hectare of an organic production system is lower than that of a conventional production system. If there is a need for total output to be the same for both systems, an organic production system requires a greater production area. Then the effects should perhaps be expressed per unit product.

A yardstick to measure the animal welfare performance of any animal production system must be based on accepted ethical criteria like the right of animals to engage in natural behaviour, and the right to health, food, drink, rest and shelter.

The situation in the Netherlands

Pesticide use

In organic agriculture, very few plant protection agents are used. Those that are used are of “natural” origin, being derived from plants or mineral deposits. This does not infer non-toxicity. Dutch organic farmers use even less plant protection agents than Regulation 2092/91 permits because some of the substances are not registered for use in the Netherlands, *i.e.* rotenone, quassia, ryania and copper salts. The most widely used pesticides in Dutch organic farming are sulphur-based compounds, pyrethrum-derivatives and natural diseases and predators of pests, such as viruses and bacteria. Of these, pyrethrum-based compounds are of high toxicity to invertebrates but of very limited persistence in the environment.

Using its “environmental yardstick”, the Dutch organisation CLM concluded in 1997 that organic agriculture uses some pesticides that can have a negative impact on the environment. However, overall only the most “environmentally benign” forms of conventional production could come close to the positive position organic agriculture holds in this respect (Centrum voor Landbouw en Milieu, 1997).

Monitoring a number of arable farms in the Netherlands between 1997 and 2000, organic farms on average used 0.6 kg/ha active ingredient pesticide, as opposed to 9.7 kg/ha for non-organic farms (Peppelman *et al.*, 2002).

In organic pip fruit growing however, the use of pesticides is intensive, as expressed per hectare, and even more so when expressed per unit product. This use is significantly higher than in non-organic systems. However, most use in organic systems refers to sulphur for the control of apple scab. Even with the high quantities used, the environmental effects are far lower than those of many of the pesticides used in non-organic systems (Peppelman *et al.*, 2002). Still, the latter have shown significant improvement of their environmental performance over the last few years, mainly due to the withdrawal from registration of many synthetic pesticides.

In conventional glasshouse crops, a covenant between government and farmers' organisations has established annual ceilings for the use of pesticides. This brings their performance in this respect closer to that of organic farms.

Nutrient leaching

Some studies suggest that organic agriculture, using more composted organic matter (manure), *i.e.* more input, and achieving lower yields per hectare, *i.e.* less output, than conventional agriculture, has bigger problems in staying below the permitted ceilings for nitrate leaching (Centrum voor Landbouw en Milieu, 1997). However, nitrogen surpluses do not always result in more leaching, as two years of studies on clay soils on 14 farms have shown (Dekking, 2001). A difference between the large (calculated) nitrate surplus and the measured levels of nitrates was explained by high levels of nitrogen fixation in soil organic matter and soil flora and fauna, and for up to 50% by denitrification.

Another way to look at nutrient use is through Regulation 2092/91's limitation on organic farms to apply no more manure than the equivalent of 170 kg/ha of nitrogen, and to limit livestock densities for the different farm animals accordingly. This measure effectively limits leaching of nitrogen. In conventional agriculture, under Dutch national legislation, the maximum nitrogen equivalent on grass pasture is 190 to 220 kg/ha in 2002, depending on soil type.

When, in the case of pigs, outdoor range is offered to the animals, manure and urine can present a serious pressure on the immediate environment. Considering area available per animal, duration of outdoor access, nitrogen-uptake, and nitrogen-production in urine and faeces, on 13 observed production units, about half had over 170 kg/ha N-deposits and the other half had less. Often there is no grass left that could absorb part of the nitrogen, and much of the nitrogen disappears towards the surface water, either through percolation or run-off (Peppelman *et al.,* 2002).

However, the overall picture on nitrate leaching seems to be that either organic farms compare favourably to non-organic farms, or results of research are not conclusive. On phosphate surpluses, no significant difference between the two production systems has been found (Peppelman *et al.,* 2002).

Ammonia emissions

In conventional poultry production, as of the year 2008 or 2010, the date depending on the production purpose of the poultry, ammonia emissions are limited to values ranging from 6-45 grams per bird per year. Modern non-organic production systems do not reach that standard yet and produce from 80 grams (broilers) to 35-110 grams (laying hens) per bird per year. In contrast, current organic production methods show figures over 315 grams per bird per year, not yet considering free range, which would make this figure even higher. Organic production units are exempt from the legal maximum ammonia emissions mentioned earlier (Peppelman *et al.,* 2002).

In dairy production, comparisons between organic and non-organic production systems indicate little difference in ammonia emissions. The few studies available in the Netherlands name positive (*i.e.* "loose barn" stable system) as well as negative (*i.e.* outdoor composting of manure) aspects of organic dairy production (Peppelman *et al.,* 2002).

The relative position of organic pig production systems is not positive. It is expected that in the absence of additional emission reduction measures, organic pig production could emit two to three times the amount of ammonia per animal as compared to non-organic systems (Peppelman *et al.*, 2002). It should be noted that an earlier publication suggested the contrary and attributed a very favourable performance to organic pig production (de Kuijer and Wielenga, 1999).

Energy use

Energy use in agriculture is not regulated or limited. It is not covered by the legislation on organic agriculture. Only in greenhouse vegetable production, targets for the reduction of energy use have been agreed between the Dutch government and producers. Energy use in agricultural production directly relates to agriculture's contribution to the emission into the atmosphere of greenhouse gases that contribute to global warming. Thus, it becomes interesting to look at possible differences in this respect between non-organic and organic agriculture.

Still, the relative performance of one production system compared to the other has to be interpreted with care. Energy use per kilogram of agricultural product, in any production system, not only takes place in the primary production phase. Life cycle analysis incorporating energy use for handling, storage, processing, transport, distribution and, ultimately, handling in the household (refrigerator use, cooking, waste production), as well as losses along all of these steps, could well indicate a low significance of the differences between the two production systems.

In arable production systems, organic farms in one study (Peppelman *et al.*, 2002) consume about 50% more energy per hectare than do non-organic farms. Other studies show smaller differences and the opposite has been seen as well. Although organic farms use less and different fertiliser and other inputs this does not always offset the high consumption per hectare of fossil fuels. If calculated per unit of product, this difference would be remarkably higher.

Energy use in glasshouse horticulture depends largely on the heating regime. Some organic farms do not use heating. In situations where heating is used there is little difference in energy consumption per hectare between organic and non-organic farms. However, the difference in energy use per kilogram of product can be high. In one study on cucumber production, a kilogram of organic cucumber needed 80 to 250% more energy than its non-organic counterpart (Peppelman *et al.*, 2002) because of a lower production volume per hectare.

In fruit growing, a large percentage of total energy needs goes to post-harvest storage. It is likely that organically produced apples, having higher storage losses than non-organic apples, in the end need more energy per unit product.

In poultry production, differences exist in food conversion rates between the organic and conventional systems. Organic chickens consume more "energy" to gain a kilogram. In practise, there are also differences in the origin of the feed; the organic feed is more likely to come from nearby sources in Europe. This is probably true for other farm animals as well. Some preliminary data suggest that organic broilers use 10% less and organic laying hens about 13% less energy than conventionally held chickens (Peppelman *et al.*, 2002).

In pig production, direct energy costs per organic animal are less than they are per conventional animal. However, piglet mortality is higher and the imbalance between the two systems evens out.

In bovine production systems, organic producers do have some higher direct energy use per head of cattle. However, including indirect energy use (in fertiliser and concentrate production) organic production probably shows lower total use (Peppelman *et al.,* 2002).

Animal welfare

Although the welfare of cattle is difficult to quantify, three aspects that constitute major differences between organic and non-organic production systems have been looked into. Regulation 2092/91 prescribes a minimum area per head of cattle in the barn (6m^2). On conventional farms, this is lower. The "loose barn" stable offers more choice to individual cows on where and how to lie down. This system is more widespread on organic farms. The practice of dehorning is less prevalent on organic farms. Outdoor range is always offered to organic cows. On conventional farms only about half of the cattle can roam and graze outside without much restriction (Peppelman *et al.*, 2002).

On health aspects, there are indications of better health of animals on organic farms, partly due to lower production levels with subsequent lower physical stress (Peppelman *et al.*, 2002). Another study suggests higher disease incidence due to lower preventative medicine use (Hovi and Kossaibati, 2002).

The differences between organic egg production and conventional, highly intensive cage egg production are great. However, the differences with more benign conventional production systems, like free-range systems, are very much smaller, to the point of becoming marginal. As an example, organic chickens would have 18cm of perch, whereas alternative, non-organic systems prescribe 15cm. In respect to collective nesting area per bird, the two systems prescribe 120cm^3 and 83.3cm^3, respectively. In many cases, the animal welfare of organic chickens for egg production is offset by problems of cannibalism. In broiler production, however, this relation seems to be reversed (Peppelman *et al.,* 2002). Free-range chickens, whether organic or not, are thought to show a higher incidence of Salmonella and Coccidiosis infections. These generally do not affect the bird directly, but are of concern to human health.

Conventionally held pigs generally have no outdoor range, whereas organic pigs often do, besides having more area at their disposal per individual. Regulation 2092/91 does not require free outdoor range, but in practice many producers do provide outdoor range. Comparisons made by Dutch veterinarians, applying "expert judgement" suggest that organic pigs have a higher degree of welfare than their conventional counterparts do. Mortality before weaning, however, is higher for organic pigs. (Peppelman *et al.*, 2002). Observations are relatively few in number, however, and it is difficult to conclusively demonstrate differences between the two production systems.

Conclusions

Based on the experiences in the Netherlands the following can be said about the relative position of organic farming in respect of environmental performance and animal welfare position. Once again, these conclusions are based on the application of the strict and minimal rules of the EC Regulation for organic production. The OECD agri-environmental indicators (OECD, 2000) provide a useful basic structure for some conclusions on the performance of organic agriculture in the Dutch situation. In these conclusions, the OECD indicators within the categories of "Agriculture in the broader economic, social and environmental context" and "Farm management and the environment" are not specifically addressed, but they are discussed under the similar indicators within other categories.

Nutrient use

The indicators of nutrient efficiency and nutrient balance provide information on the nitrogen input/output ratio and on the potential loss of nitrogen to soil, air and water. Organic arable farming basically compares favourably with conventional agriculture in the Netherlands on the point of nitrate leaching into the soil. However, since the implementation of strict legislation on the use of fertilisers and manure [EU Nitrate Directive and relevant Dutch legislation (MINAS)], some of the large differences between the two production systems are now diminishing. In organic animal production, ammonia emissions are high to very high as compared to non-organic systems. As organic production units are exempt of a part of this legislation there are few incentives for organic farmers to limit nutrient losses, especially atmospheric emissions of ammonia. This holds true especially in production units of pigs and chickens.

Pesticide use and risks

The indicator of pesticide use (kilograms of active ingredient per hectare) is in fact secondary to the more integrated indicator of pesticide risk in which factors like exposure and risk mitigating techniques are incorporated. Organic agriculture uses little pesticides as compared to conventional agriculture. In the Netherlands this is true especially for herbicides (no use in organic agriculture) and insecticides. In some production sectors, *i.e.* organic pip fruit, sulphur fungicides are used in considerable quantities. For pesticides, it can be said that overall risk in organic agriculture is far smaller than in conventional agriculture. Pesticides used in organic agriculture are plant-derived and, even if highly toxic, are often of very short persistence. Copper salts, allowed under Regulation 2092/91, are not registered in the Netherlands. Organic animal production deriving its fodder and concentrate from organic feed crops claims a significant proportion of total organic production area, and in this way can be seen as having a low pesticide use as well.

Soil quality

The soil quality indicators refer mainly to risks of wind and water erosion. Both risks are not very relevant in the Netherlands. In general, soils on conventional farms may have a slightly lower organic matter content than those on organic farms, but there is no indication that this has an impact on either type of erosion.

Water quality

Water quality is of paramount importance in the Netherlands. This applies to both ground water and surface water. The OECD indicators emphasise nitrate and phosphorus. Nitrate load is sometimes lower and sometimes higher in organically managed soils. Phosphate pollution in, and eutrophication of surface water will occur less in organic production systems. Additionally, the pesticide load in ground and surface water evidently is lower in organic production systems than in conventional systems.

Land conservation

Land conservation in general deals with water retention capacity and with off-farm sediment flow. Both indicators have little relevance in the Netherlands, with its lack of steep slopes and slow-moving rivers. Management of both surface water and sub-soil water levels is extensive in the Netherlands and affects organic and conventional agriculture alike.

Greenhouse gases

The emission of green house gases (GHGs), carbon dioxide CO_2, methane CH_4, and nitrous oxide N_2O, from agricultural sources was 12.2% of total emissions in the Netherlands in 1995-1997 (OECD, 2000). As livestock farming and the use of inorganic fertilisers are an important source of methane and nitrous oxides, it is probable that conventional agriculture produces more of these GHGs per animal than does organic agriculture. Organic agriculture is significantly less intensive, and an increase in organic animal production would signify a lower total number of animals in the country and subsequently lower total production of GHGs.

Use per hectare of on-farm of fossil fuels and carbon dioxide production seems to be higher on organic farms than on non-organic farms. When using kilograms of produce as a measuring rod, energy use will certainly be higher. Especially prominent is organic glasshouse cultivation, with high energy use per unit of product.

Biodiversity and wildlife habitats

Biodiversity indicators are genetic, species and ecosystem diversity indicators. Wildlife habitat indicators are six in total, expressing state and trends in wildlife habitats on land farmed with different intensities.

Genetic diversity refers to the richness in genetic make-up of plant cultivars and animal breeds used in agriculture. In the Netherlands, organic agriculture exploits the same cultivars and breeds as does conventional agriculture. There is a need for cultivars and breeds that are better suited for organic production, but there seem to be no technical impediments to develop them. Rather, there are constraints of an economic order. A more varied crop rotation is usually practised on organic farms than on conventional farms. In addition, on some organic farms "old" crop species and cultivars are sometimes produced to supply specific niche markets. As much of the genetic variety of crops and breeds is available in germplasm collections and *in vivo*, it is difficult to say that organic agriculture significantly contributes to maintenance of this richness.

Where species diversity is concerned, many studies have shown a more diverse and rich arthropod and bird life on organic farms than on other farms, resulting from the explicit prohibition of the use of certain agro-chemicals and a more diverse crop rotation schedule (van Bruggen, 2002). Also present on many organic farms is a bigger range of "landscape elements" like ponds, hedgerows, trees to provide shade for livestock, etc. Although not required by the Regulation, organic farmers' convictions of the benefits of this diversity make their holdings markedly different from non-organic farms.

This is one side of the coin. On the other, someone could say that in an intensive production system less surface area would be needed to produce the same quantity of agricultural output. Theoretically, the remaining area could then be dedicated to nature preservation, in which case there is not necessarily any less biodiversity and wildlife habitat. This would be difficult, if not impossible, to quantify as all depends on the yield differences between the organic system and the conventional system, their environmental performance, the crops used, and the land use of the "surplus" area.

Ecosystem diversity and wildlife habitat indicators all indicate a favourable position for organic agriculture. The need for non-chemical plant protection, more extensive grazing regimes for farm animals, longer crop rotation cycles, management practices to shelter and stimulate wildlife diversity to contribute to natural weed and insect control, and others, all stimulate the presence of wildlife.

Landscape

Landscape indicators address landscape functions, structures and values. In legislation on organic farming nothing is said about the need to preserve or enrich the landscape. In practice, however, the management needs of organic agriculture often signify more attention to landscape units like hedgerows, shade trees for cattle, etc. Creation and maintenance of a diverse landscape is the result of certain management needs like crop protection and animal welfare. Though this would not be limited to organic farms, conventional farmers often do not have the economic or ideological motivation or management needs to engage in them.

Animal welfare

The main difference between organic and non-organic dairy cattle management systems refers to management practices such as the provision and duration of outdoor range, dehorning and disease treatments. Although organically managed herds have more access to pasture, and suffer less high production-related stress factors, they also seem to have more health problems because less preventative medicine is used.

The main difference between organic and non-organic poultry production systems refers to the average area allotted to each individual, removal or not of part of the beak, and the presence of outdoor runs, often including access to pasture. In organic egg production, a larger percentage of hens die because of cannibalism-related problems than in other production systems. It is therefore difficult to provide definite answers on the relative merits of organic production.

The main difference between organic and non-organic pig production systems refers to the average area allotted to each individual, castration of males, removal or not of part of the tail and fangs, and the presence of outdoor range. In general, organic production systems seem to provide more welfare to the animals than conventional systems.

Overall conclusions

Depending on the yardstick and on the environmental or animal welfare criterion under review, the relative position of organic *versus* non-organic agriculture is not clear. There are many indications that the organic production method is an interesting model for innovations in other production systems, giving useful suggestions for lowering the environmental impact. On the other hand, the low yields of many organic crops translate into a relatively high environmental impact per unit of produce. This is true for most sectors and in particular for glasshouse horticulture and poultry. In policies directed towards sustainability and lowering of the impact of agricultural production, support for organic agriculture could be one of the policy instruments. Additional instruments, such as environmental legislation, are necessary to counter the undesired effects of all production systems.

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SOIL QUALITY OF ORGANICALLY MANAGED CITRUS ORCHARDS IN THE MEDITERRANEAN AREA

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Abstract

Soil quality can be defined as the capacity of a soil to function, whilst maintaining the environmental quality and promoting plant and animal health. It also refers to the capability of soil to function at present and in the future for an indefinite period of time. Soil quality is a basic concept in the sustainable management of any agricultural system aimed at producing, avoiding or reducing negative effects on the environment, preserving resources and saving energy on a medium- or long-term basis and its assessment might be considered a means for the evaluation of the environmental sustainability of agricultural systems. A study was conducted with the aim of evaluating the contribution of the introduction of organic farming system to the environmental sustainability of organic farming in Southern Italy, with the assessment of soil quality of conventionally and organically managed citrus orchards. The study was carried out by a field survey, based on a comparative approach at a regional basis and by a farm-level experimental trial. The results obtained indicate an increase of the soil quality on organically managed citrus orchards, thus indicating that the introduction of an organic farming management system may contribute to the increase of the environmental sustainability of citrus production in Southern Italy.

Introduction

Soil quality is the final product of preservation and degradation processes and, according to Doran and Parkin (1994), it can be defined as "the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health". In a more simplistic way, the definition cited above refers to the capability of the soil to function at present and in the future for an indefinite period of time.

According to the above-cited definition, soil quality is a basic concept in a sustainable management of any agricultural system aimed at production, avoiding or reducing negative impacts on the environment, preserving resources and saving energy on a medium- or long-term basis (Colombo, 2000). Consequently, the soil quality assessment could be considered an efficient instrument that contributes to the evaluation of the environmental sustainability of agricultural systems (Tittarelli and Canali, 2002). However, it is important to note that the evaluation of environmental sustainability is

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just one side of this issue, since agricultural sustainability is a wider concept, including also economic sustainability and social viability (OECD, 1992).

During the past 10 years, many papers dealing with soil quality, assessing biological, physical and chemical properties in organically managed systems, have been published and an updated review was produced by Stockdale *et al*. (2001). Most of the studies have been conducted at field and/or farm scale; only a few of them refer to regional scales and there are no references whatsoever for the soil quality assessment in organically managed soils in the Mediterranean area.

The case study

In 2000, the Italian organic area and land area in conversion was 1 million hectares, corresponding to about 5% of the total national agricultural surface and 25% of the European organic managed cultivated area (Italian Ministry of Agricultural Policies' website, 2001). The distribution of the Italian organic surface was not homogeneous, since 70% of organic farms are localised in Southern Italy, where there is a Mediterranean climate type.

Organic citrus, cultivated on 20 000 ha, are widespread in Calabria, Arco Ionico Metapontino and Sicily, and can be considered one of the most important organically managed crops in Southern Italy, (Lunati, 2001).

The study was carried out with the aim of evaluating the contribution of introducing organic farming systems to the environmental sustainability of agriculture in Southern Italy, assessing soil quality of the most widespread organically managed crop of the area. In particular, the study focused on the Navelina and Tarocco orange orchards localised in Eastern Sicily, carrying out a field survey based on a comparative approach (Larson and Pierce, 1994) of soil quality indicators (Canali *et al.*, 2001). Soil characteristics were analysed in 54 farms under both organic and conventional management. Farms were selected to obtain similar pairs (27) under the same environmental conditions and homogeneous data regarding cultivations and rootstock to reduce effects not linked to the soil management. At the beginning of the study, the requested three-year conversion period foreseen by the law in force (EEC Regulation 91/2092) was completed for all the organic citrus orchards included in the survey.

The soil survey was carried out evaluating both inherent and dynamic soil characteristics (Karlen *et al*., 2001). Inherent characteristics of a soil mainly depend on parental material and on the pedogenetic conditions in which it originates and they are slightly influenced by human activities. Consequently, these properties have been considered in order to exclude differences between organic and conventional soils which do not depend on the management system.

According to the aim of the study, a data set of soil descriptors of dynamic properties (Karlen *et al.*, 2001) related to soil quality has been chosen, in conformity with the criteria proposed by Doran and Zeiss (2000). Since the main differences between the two soil management systems are supposed to be the input/output budget of nutritive elements (Intrigliolo *et al.*, 2000) and the improvement of soil organic fertility and of environmentally linked attributes, the soil quality indicators chosen were related to soil carbon and nitrogen cycles (pools and processes) and to the availability of nutrients for the crop.

Inherent soil properties

Soil samples were collected in January and February both in organic and conventional orange orchards, according to official guidelines (Intrigliolo *et al.,* 1999). The sampling time was defined in order to maximise the interval since the last fertilisation. At least four soil specimens were collected in all the selected orchards and then mixed together to form the single sample to be used for the analyses.

Soil inherent characteristics were determined according to the Italian official guidelines for soil analyses (MiPAF, 1999) and are reported in Table 1. No significant differences between organically and conventionally managed soils were observed for these parameters.

Table 1. Inherent soil parameters (mean values)

Parameter	Organic	Conventional
Clay (%)	33.9	31.7
Silt (%)	21.6	20.7
Sand (%)	44.5	47.6
pH	8.0	7.9
$EC_{1:2}$ (mS cm^{-1})	0.34	0.39
Active lime (g kg^{-1})	57	46

Source: Intrigliolo *et al.*, 2000.

Soil organic carbon and humified organic matter

Increases in organic carbon in soils under organic management have been widely reported (Fließbach and Mader, 1997; Stockdale *et al.,* 2001) and this change has lead to a great number of the modifications to the biological and physical properties of the soil. Among the different organic carbon pools of soil, the humified stable portion of the non-living fraction is considered to be more strictly linked to soil quality, which is responsible for positive impacts for the benefit of various soil functions on a medium or long-term basis (Herrick and Wander, 1997).

The soil samples collected were analysed to determine the total organic carbon (TOC) contents and, in order to evaluate the stability level reached by the soil organic matter, humic fraction extracted was analysed through the isoelectric focusing technique (IEF). Humic acids were extracted by a 1:20 soil-$NaOH/Na_4P_2O_7$ (0.1M) solution at 65°C for 48 hours, and 25mL of this solution was precipitated by acidification with HCl 1 M until reaching pH<2.0. After the centrifugation, the precipitate was re-solubilised with NaOH 0.1 M. Ten millilitres of this solution was dialysed in 6.000-8.000 Dalton membranes and then lyophilised to obtain a purified soil humic matter (Ciavatta *et al.*, 1990). This fraction, obtained from each soil, was analysed through the isoelectric focusing technique (IEF) in a pH range of 3.5-8.0, on a polyacrylamide slab gel (Ciavatta and Govi, 1993), using a defined mixture of carrier ampholytes (Pharmacia Biotech): 25 units of Ampholine pH 3.5-5.0; 10 units of Ampholine pH 5.0-7.0; 5 units of Ampholine pH 6.0-8.0. A pre-run (2h; 1200V; 1°C) was performed and the pH gradient formed in the slab was checked by a specific surface electrode. The electrophoretic run (2h 30'; 1200V; 1°C) was carried out loading the water-re-solubilised extracts (5 mg C × 100 μL^{-1} × $sample^{-1}$). The electrophoretic bands were stained with an aqueous solution of Basic Blue 3 (30%) and then scanned by an Ultrascan-XL Densitometer, obtaining a typical IEF profile for each investigated soil. Peaks were numbered and the peaks' area was determined for each soil IEF profile, assuming that the area of all IEF profiles be 100%. The sum of the peaks' areas focused at pH>4.5 (corresponding to more humified organic matter) was calculated and named A_s%.

The results showed higher TOC values in organic managed soils (13 322 mg×kg^{-1}) as compared to conventional ones (10 776 mg×kg^{-1}), even if the differences showed no statistical significance ($p = 0.15$) (Table 2).

Table 2. Dynamic soil parameters (mean values, *p*-level and significance)

Parameter	Conventional	Organic	*p*-level
TOC (mg×kg$^{-1}_{soil}$)	10 776	13 322	0.15
A_s (%)	54.70	59.30	0.27
C_1 (mg×kg$^{-1}_{soil}$)	102	120	0.30
C_7 (mg×kg$^{-1}_{soil}$)	347	514	0.01
C_{21} (mg×kg$^{-1}_{soil}$)	552	827	0.03
C_0 (mg×kg$^{-1}_{soil}$)	575	894	0.01
C_1/TOC (%)	1.01	0.89	0.28
C_{21}/TOC (%)	6.69	6.14	0.24
N_{tot} (mg×kg$^{-1}_{soil}$)	1 083	1 289	0.20
NPM (mg×kg$^{-1}_{soil}$)	34.10	39.0	0.76

Isoelectric focusing (IEF) is an electrophoretic technique, commonly used to investigate humic matter extracted from soils (Ciavatta and Govi, 1993) and fertilisers (Govi *et al.*, 1991; Canali *et al.*, 1998). It is based on the separation of different humic substances on the basis of their isoelectric point and their molecular weight. It is well known that the more the organic matter is humified, the higher will its isoelectric point be, which means that the organic molecules focus at higher pH values (Govi *et al.*, 1994).

When comparing the IEF patterns of four pairs of organic and conventional soil, differences in the less acidic part of the profiles, corresponding to the pH values higher than 4.5, were noticed. In order to quantitatively evaluate these differences, we calculated the sum of the area of the peaks focused at pH>4.5 (A_s%).

The A_s parameter was higher in organic soils as compared to conventional ones (Table 2) and, even if this difference was not statistically significant, it was observed in 75% of all cases. Since more humified organic compounds focus at higher pH values, this finding indicates that organic matter extracted from organic soils is characterised by a higher level of humification.

Carbon mineralisation

Biological properties have been often utilised to evaluate soil quality in studies having different purposes and that are performed in different environmental conditions. Activity, dimension and diversity of bacteria, fungi, micro- and meso- fauna population have been widely used to assess soil quality in organically managed soils as well (Stockdale *et al.*, 2001).

Carbon mineralisation has been considered a reliable characteristic for the evaluation of the microbial soil activity (Anderson and Domsch, 1985), since it can supply information on the soil metabolic status and the turnover of organic matter (Trinchera *et al.*, 2001). It represents a key soil process and even if it is considered to be characterised by a low sensitivity to changes in soil management (Brookes, 1994), when evaluated in combination with TOC, it may supply useful information on carbon utilisation and energy requirements in the system.

Collected soil samples were analysed for C mineralisation by measuring $C\text{-}CO_2$ production $[mg(C\text{-}CO_2)\times kg^{-1}{}_{soil} \times d^{-1}]$ in the soil in potential conditions (Isermeyer, 1952), after the 1st, 2nd, 4th, 7th, 10th, 14th, 17th and 21st days. Cumulative $C\text{-}CO_2$ mineralised after 1 (C_1), after 7 (C_7) and 21 (C_{21}) days were calculated for each soil sample. The kinetic study of organic carbon dynamism was performed by fitting the cumulated data into experimental curves by first order exponential equations $C_t = C_0(1\text{-}e^{-kt})$. This elaboration allowed to calculate the potentially mineralisable carbon C_0 $[mg(C)\times kg^{-1}{}_{soil}]$ and the kinetic constant k ($days^{-1}$) for each investigated soil. Mineralisation coefficients (C_1/TOC% and C_{21}/TOC%) were determined to obtain information on the mineralisation activity related to the various types of farming management.

Some examples of the resulting cumulative curves for the C mineralisation, related to organically and conventionally managed citrus orchard soils, are reported in Figure 2. For all investigated soils, the first order exponential equation was able to fit experimental data and basal respiration was reached after 21 days of incubation. Mean values of mineralised C after 1, 7, 21 days of incubation, C_0, k, and the mineralisation coefficients (C_1/TOC, C_{21}/TOC) are presented in Table 2. C_1, C_7, C_{21} and C_0 were higher in organic than in conventional soils, being highly significant from a statistical point of view in the case of C_7, C_{21} and C_0 ($p = 0.01$, 0.03 and 0.01, respectively). As far as the mineralisation coefficients are concerned, they were lower in organic soils, suggesting a decreased energy requirement and a reduction of organic matter consumption in these soil systems as compared to the conventional ones (Flieβbach and Mäder, 1997).

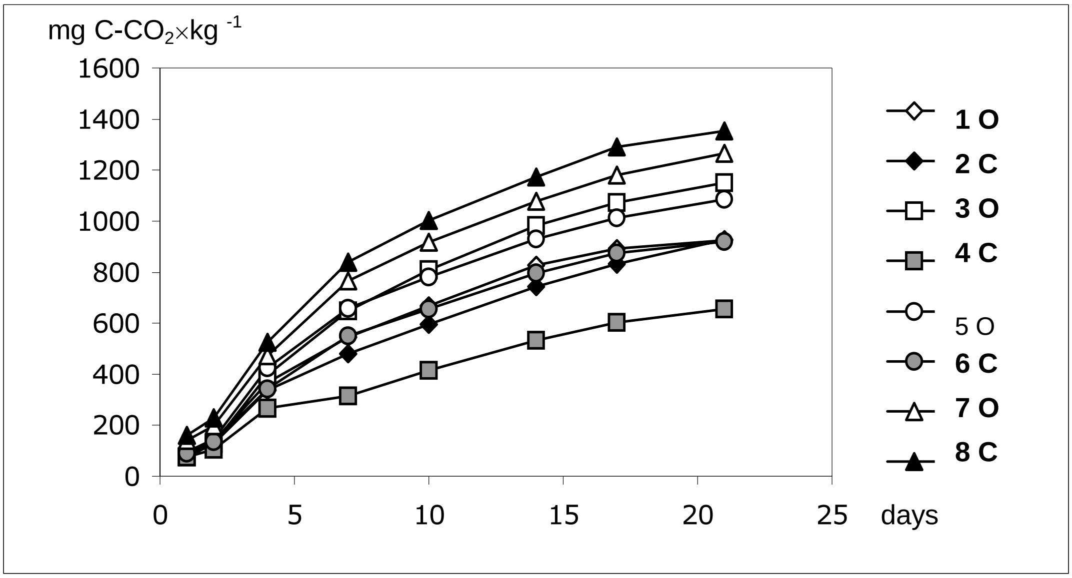
Nitrogen contents and mineralisation

Nitrogen is a key element for crop production and a total N content in the soil has always been considered as a long-term quality and fertility parameter. For this reason, its measurement (Kjeldahl's procedure, N_{tot}., $mg\times kg^{-1}$) was included in the data set performed in the survey.

Nevertheless, the total nitrogen value is a meaningless indicator of the N turnover in the soil, incapable of supplying information about the availability of the element for crops in the short-term period and to evaluate potential pollution risks inherent to losses of mineral N to the waters and to the atmosphere.

On the other hand, soil N mineralisation can be considered an index of soil quality, due to the relation between this process and the capacity of the soil of supplying N for crop growth and also due to the pollution risk of waters and the atmosphere. According to this affirmation, the N mineralisation is often included in minimum data sets set up to evaluate soil quality (Canali and Benedetti, 2002).

Figure 1. Some cumulative curves of C-mineralisation for organic (O) and conventional (C) soils



In this study, N mineralisation was estimated from the NH_4-N (mg×kg^{-1}) accumulated after 7 days of anaerobic incubation at 40°C, according to Sahrawat and Ponnamperuma (1978), slightly modified by Canali *et al.* (2000). This procedure is highly recommended when there is a need for a quick, work-saving, inexpensive procedure (*i.e.* field survey approach on a large-regional scale) (Canali and Benedetti, 2002).

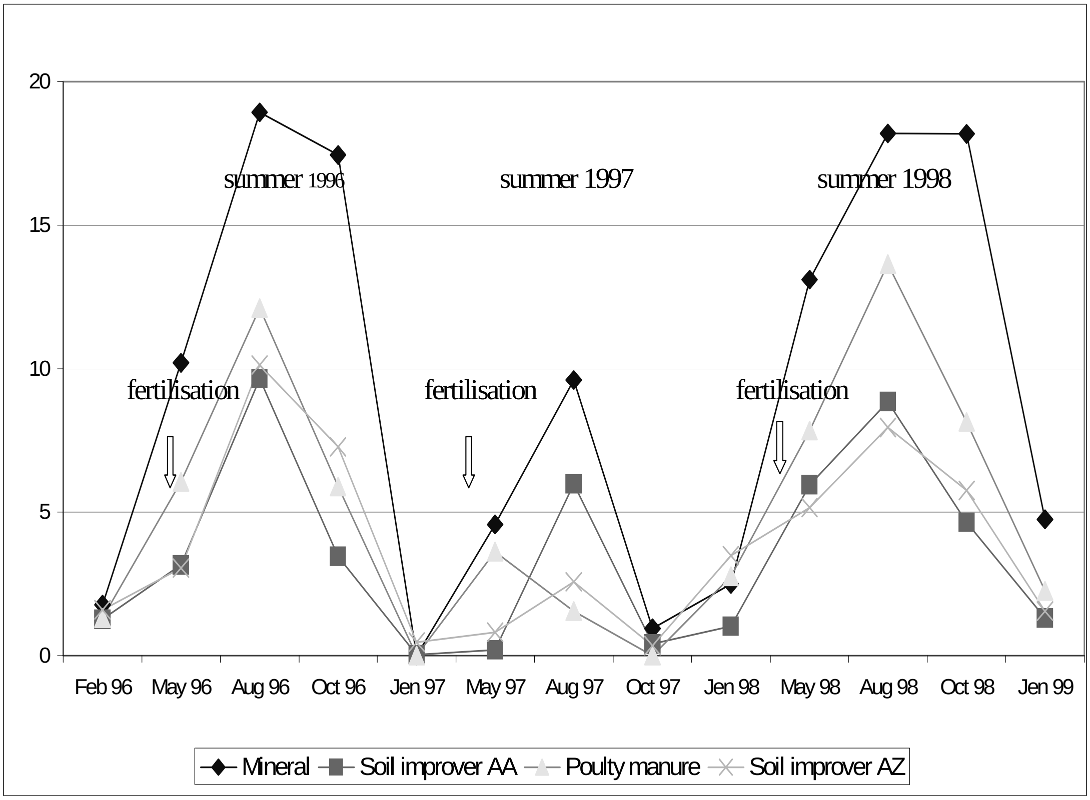
Soil samples (16g) were air dried and ground to pass through a 2mm sieve. The samples were placed in 50ml test tubes containing 40ml distilled water, covered and incubated at 40°C for 8 days. The test tubes were shaken for a few seconds each day, in order to mix the water and soil suspension. After the incubation, the soil was extracted with KCl 2N and 40ml KCl 4N was added to the suspension in order to preserve the soil solution ratio at 1:5. The samples were shaken for 1 hour and then filtered through paper filters. Determinations were performed in triplicate and the difference between the NH_4^+-N amount released by the sample after incubation and the amount released by the non-incubated sample was taken as mineralised nitrogen (NPM). Anaerobiosis was controlled by determining nitric (NO_3^--N) and nitrous (NO_2^--N) nitrogen concentrations at the end of incubation. Only negligible traces of oxidised forms of N were observed.

Results obtained for total N content, mineral N and NPM are reported in Table 2. N_{tot} was higher in organic managed soils (1 289 mg×kg^{-1}) as compared to conventional ones (1 083 mg×kg^{-1}), even if the differences showed no statistical significance. In any case, in this parameter, there is a strong tendency towards an increase of the N content in organic soils, revealed by the low p values (0.20), a fact which may be of interest. This finding seemed to indicate an increase of the long-term storage of this nutritive element in organically managed systems. No significant differences were detected in the N mineralisation process.

NO_3^--N content of soil

A three-year study (1996-98) to assess soil nitrates dynamic was conducted in an organically managed orange orchard (Valencia late grafted on sour orange rootstock) located in Lentini (SR), Sicily (Southern Italy). Four treatments distributing the same dose of nitrogen using four different types of fertilisers and soil improvers were carried out (mineral N fertiliser — conventional; dried poultry manure; compost from distillery by-products; compost from olive oil production by-products and manure) adopting a randomised block experimental design with three replicates.

Figure 2. Soil N-NO_3^- (mg kg^1)



During the three-year period, the nitrogen nutrition status (assessed by leaf analysis) and the yield of the orange orchard were monitored and no significant differences among the treatments were observed. Concentrations of nitrates (NO_3^--N) in the soil layer between 0-30cm depth were determined every three months throughout the study period. NO_3^--N in 1:10 soil-KCl (2M) extracts were determined by continuous flow colorimetry (Autoanalyzer Technicon II), as suggested by Kampshake *et al.* (1967).

Figure 2 shows the concentration of soil nitrate values observed in the trial period. For all the treatments, the tendency is characterised by high values in the summer due to the combined effect of fertilisation and native soil N mineralisation, since, in this season, soil conditions are not limiting for biochemical activities (optimal soil water contents maintained by micro irrigation and high soil temperature). On the other hand, low values measured in the winter could be ascribed to the rainfall that may leach nitrates from the superficial soil layer.

Nitrate concentration in the soil strongly depends on the treatments and it is linked to the typology of the fertiliser applied. The treatments managed and fertilised according to organic farming methods always show lower soil nitrate contents as compared to conventional ones. The results above-reported have allowed us to affirm that the potential risk of nitrate losses is lower in the organic plots, where organic fertilisers and soil improvers were applied, than in the conventional ones (Canali *et al.*, 2000).

Conclusions

The chemical and biochemical parameters considered in this study, have supplied valuable information on differences in the soil quality and fertility between organic and conventional managed citrus orchards located in Eastern Sicily, where there is a Mediterranean climate.

Organic soils were characterised by a higher C-mineralisation (higher C_7, C_{21}, C_0), a higher humification level (higher values of A_s), an increase in the soil nutrient (N) and energy (C) pools (higher TOC and N), plus a better efficiency in the organic matter turnover (lower C-mineralisation coefficients). These findings suggest that organic managed soils could be considered as more sustainable systems. Generally speaking, as has been theorised in Odum's hypothesis (Odum, 1969), natural ecosystems show a balance in the energy and nutrients economy, characterised by an equilibrium between the organic matter input and the residual organic matter amount (Pinzari *et al.*, 1999).

Furthermore, the amount of potentially leaching nitrates was shown to be lower in organically managed soils than in conventional ones. Consequently, the introduction and the spread of the organic farming system in the citrus cropping area should reduce the risk of polluting the waters.

All results obtained, deriving from the comparatively large-scale soil survey and from the farm-level experimental design, have given proof of an improvement in the soil quality in organically managed citrus orchards. Consequently, the introduction of organic farming management systems can contribute to increasing the environmental sustainability of citrus production in Southern Italy.

The entire information obtained suggest that the assessment of alternative (organic *versus* conventional) management systems ought to continue, according to a long-term dynamic approach and using a wider range of parameters and soil system descriptors that may be useful for a better understanding of the soil functions.

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ENERGY BALANCE COMPARISON OF ORGANIC AND CONVENTIONAL FARMING

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Abstract

This paper presents five examples with energy balance comparisons of organic and conventional farming systems in Denmark and Germany. In general, the examples show that conversion to organic farming leads to a lower total fossil energy use and, consequently, to lower greenhouse gas emissions. However, the exemplified organic farming practices also resulted in a lower amount of production per area of agricultural land, a different product quality, and eventually another product price than per unit of similar conventional products. Therefore, direct comparisons of the two systems are difficult. It is recommended that policy makers include fossil energy issues in the evaluation of impacts from organic compared to integrated or conventional farming systems. The examples from intensive farming systems in Denmark and Germany show promising results, where conversion to organic farming might serve as a measure to conserve fossil energy resources for the use of future generations and for the development of less industrialised areas of the world. The challenge is to find the optimal type and extent of conversion, matched with other environmental and socio-economic consequences.

What is special about the energetics of organic farming?

Organic farming differs from integrated or conventional systems by means of a defined set of production standards (IFOAM, 2002). These standards, which in most countries are implemented in the form of nationally adapted, organic farming regulations (*e.g.* The Danish Plant Directorate, 2002), affect the potential energy flows in and out of agricultural systems.

This paper presents five examples where energy inputs and outputs are compared for organic and conventional farming systems. In these examples, it is quantified how conversion to organic farming might affect both the direct and indirect fossil energy embedded in the inputs to agriculture, and how the organic farming regulation on input factors affects the output produced, and thereby the energy balance given as the fossil energy use per unit of product produced in organic and conventional farming, respectively. The examples focus on factors particularly affecting the energy balance when

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converting to different organic farming systems, compared to more or less “integrated” conventional farming systems.

The examples are divided into farm product and national level energy balances. At the farm product level, the energy effect of using synthetic nitrogen fertilisers in conventional spring barley production is compared to the exclusive use of animal and green manures under an organic system. The second example compares organic and conventional fodder production systems under different management scenarios. Subsequently, an example of the energy use in organic and conventional production of milk is presented, with a focus on the energy effect of imported compared to locally produced fodder. At the national level, the energy use per hectare in the organic and conventional dairy farm sectors of Denmark is compared, and the possibilities of Life Cycle Assessment (LCA) are discussed. Finally, a national level energy balance for Danish agriculture is presented and is used as a base to compare three scenarios for conversion to 100% organic farming. In this context, the eventual energy savings from conversion to organic farming are compared to the decline in production capacity, and the different potentials in production of bioenergy from conventional and organic farming are discussed. Moreover, the effects on national greenhouse gas emissions from conversion to organic farming are calculated.

Agricultural energy use

Agricultural energy use is, in accordance with the United Nations’ Food and Agriculture Organization’s (FAO) definition of basic energy concepts (Hulscher, 1991), defined as the net fossil energy measured in joules (J) used for production of agricultural products until they leave the farm. This energy use is divided into direct and indirect energy. Direct energy is energy input used in the production, when such input can be directly converted into energy units (*e.g.* diesel fuel, lubricants, and electricity for lubrication and drying). Indirect energy is energy used in the production when such input cannot be converted directly into energy inputs (*e.g.* machinery, fertilisers and pesticides would come into the latter category). Energy use is simulated with the model described in Dalgaard *et al.* (2001) with some modifications in the German example. All energy use is posited to come from fossil energy carriers in the form of coal, diesel oil, or natural gas, each leading to a fixed amount of carbon dioxide released per J energy used, or eventually from carbon dioxide neutral biofuels (Dalgaard *et al.*, 2002b).

Energy use at the farm level

Example 1: Barley grain production

The first example calculates the energy balance for conventionally and organically grown spring barley on an irrigated (30 mm), sandy soil in Denmark. The type and number of field operations are similar in the two fields, except for the fact that the organic system uses mechanical weed control, no pesticides, and spreads slurry instead of using synthetic fertilisers, according to Danish regulations for organic farming (The Danish Plant Directorate, 2002). The resulting yields are predicted by Halberg and Kristensen’s (1997) model. The unit for the outputs are Scandinavian Feed Units (SFUs).[2]

Table 1 shows a lower energy use per kg of spring barley production for the organic system compared to the conventional system. However, the direct fuel energy use is higher for the organic

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[2] 1 SFU corresponds to 12 MJ metabolisable energy.

system because of higher fuel consumption for mechanical weed control and spreading animal manures compared to a lower fuel consumption for application of pesticides and synthetic fertilisers in the conventional example. In total, the direct energy use per ha is 28% higher in the organic compared to the conventional example, even though the energy use for drying the organic grains is lower per ha because of a lower grain yield. The indirect energy use is substantially higher in the conventional than in the organic example. This is mainly because of the assumed use of energy expensive synthetic nitrogen (N) fertilisers in the conventional example.[3] In contrast, the use of pesticides requires a comparatively low amount of energy (250 MJ/ha) and is a good idea from an energy viewpoint. For example, fungicide treatment of spring barley can, alone, yield around 5 kg/ha extra grain (Pedersen *et al.*, 2001), with an energy content of 6 000 MJ metabolisable energy gained if used for fodder, or 7 500 MJ heat energy gained if combusted in a stoker. In conclusion, the total direct plus indirect energy use is 35% lower per ha organic compared to conventional spring barley. However, the yield is also 28% lower, and therefore the energy use per produced SFU of barley is only marginally lower for the organic compared to the conventional example.

Table 1. Energy accounts (MJ/ha) for spring barley grown on irrigated sandy soil in Denmark

	Conventional	Organic
Direct energy		
Fuel	3 400	5 000
Lubricants	300	440
Field irrigation	1 500	1 500
Drying	500	360
Sub-total	5 700	7 300
Indirect energy		
Machinery	1 100	1 600
Fertilisers and lime	6 700	50
Pesticides	250	0
Sub-total	8 050	1 650
Total energy use	13 750	8 950
Yield (SFU/ha)	5 000	3 600
Energy Efficiency (MJ/SFU)	2.8	2.5

Source: Dalgaard *et al.* (2002c).

Example 2: Forage production

The second example calculates energy balances for forage production. The calculations are based on five years' (1997-2002) field trials from Karkendamm Experimental Station in Northern Germany (Taube and Wachendorf, 2000; Trott *et al.*, 2002; Volkers *et al.*, 2002; Wachendorf *et al.*, 2002). Based on these results, parameters of energy utilisation are calculated and compared for permanent grass/clover under different management systems (grazing, one silage cut + aftermath, two silage cuts + aftermath, four silage cuts + no aftermath), and for maize silage. In this example, energy

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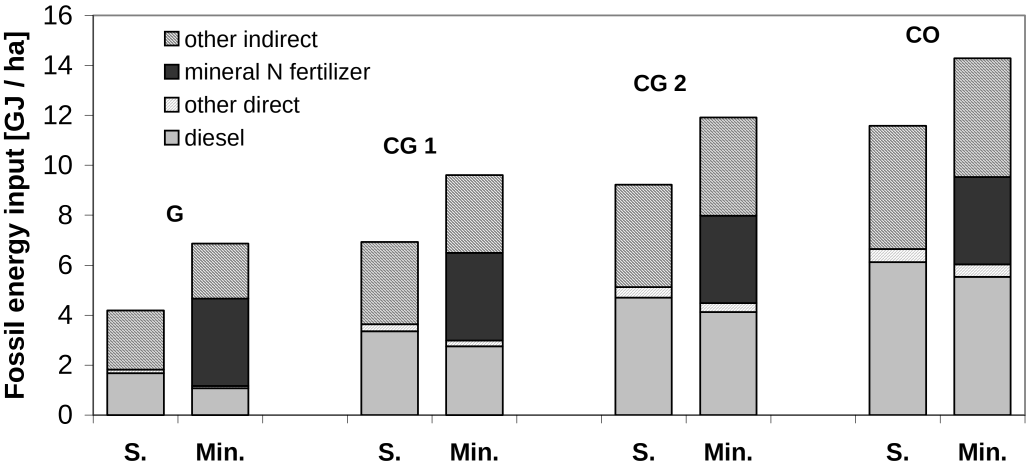
[3] 120 kg N/ha is applied with 6 000 MJ/ha energy embedded. Moreover, an additional 700 MJ/ha is embedded in the phosphorus and potassium fertilisers and lime applied. If the energy cost of N fertilisers were reduced by 20%, from 50 MJ/kg N to 40 MJ/kg N, the energy efficiency would be equal in the conventional and organic system.

yields are expressed in NEL,[4] and energy consumption is compared to the NEL yield resulting from different combinations of N fertilisation with slurry and mineral N fertiliser.

The main difference between the energy balances in organic and conventional forage production is due to application of mineral N fertiliser. Figure 1 shows that the total fossil energy input both for grazed grass/clover and different types of cut grass/clover can be reduced by about 2 GJ per ha by replacing mineral N with cattle slurry. For organic grassland farming, diesel use may be assumed similar to that of conventional grassland farming. This is because fertiliser or pesticide applications make up only a small proportion of total diesel use for field operations compared to the required field operations for silage making. As grazing land usually requires only low amounts of pesticides (*e.g.* one herbicide application every 3-5 years), there might be no significant effect of pesticide utilisation on indirect energy input between conventional and organic grassland farming. Figure 1 also shows that cutting requires significantly more energy input than grazing due to increased diesel use for mowing, chopping, and silage transport.

Figure 1. Energy input of forage production systems



Notes:

1. Four different grass/clover management systems are compared (G = grazing, CG 1= one silage cut + aftermath, CG 2 = two silage cuts + aftermath, CO = cutting only, with four cuts per year).
2. Energy input is shown for each system using either slurry (S = 20 m³ ha^{-1} slurry, no mineral N fertiliser) or mineral N application (Min = 70 kg ha^{-1} mineral N fertiliser, no slurry).

Forage crops differ significantly in their energy efficiency[5] (Figure 2). Except for the low N intensity, rotational grazing system, forage maize has the highest energy efficiency over the entire N fertilisation range. This is due to: (1) lower direct energy input (diesel) in maize production when compared to cutting-only treatments on grassland; and (2) higher energy yields of forage maize. However, the results are from conventional maize production and cannot be directly transferred to organic farming. The highest energy efficiency was obtained when grassland was grazed over the entire season and not given any mineral N fertiliser. But this system cannot be directly compared to grass or maize silage production, as grazing alone does not fulfil the feeding requirements of highly

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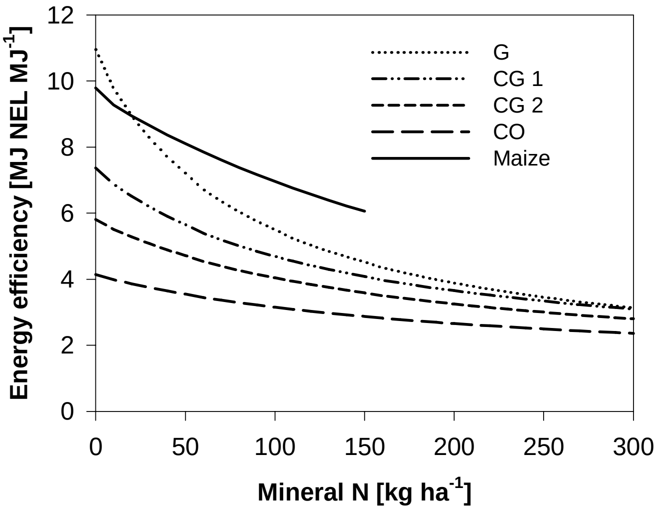
[4] Net Energy Lactation (NEL) is the energy value in forage or concentrate feedstuff directly available for milk production in dairy cows.

[5] The energy efficiency in forage production is expressed as the energy output per energy input of direct and indirect fossil energy.

productive dairy cows. The results also show that in organic farming with low fertilisation densities and no adding of mineral fertilisers, the energy efficiency of grazed grass is significantly higher than that of mowed grass, while the difference between the two practices is insignificant in conventional systems with high N fertilisation per ha. Therefore, the energy balance of organic farming would especially gain from grazing.

From example 2 it is concluded that the lowest input of fossil energy and highest energy efficiency in both conventional and organic forage production is obtained with grazing systems. Concerning silage making, forage maize requires less energy input and obtains a higher energy efficiency compared to cutting of grassland. The most significant contribution of organic farming to reducing energy use is the non-use of mineral N fertilisers.

Figure 2. Energy efficiency of forage production systems



Note:
Energy efficiencies of forage maize and four different grass/clover management systems (G = grazing, CG 1 = one silage cut + aftermath, CG 2 = two silage cuts + aftermath, CO = cutting only, with four cuts per year) as affected by mineral N application. Slurry application: 20 m³/ha in all treatments.

Example 3: Milk production

The third example calculates energy balances for milk production. The calculations are based on organic and conventional plans for one year's foddering of a Holstein Friesian milking cow held in cubical houses (Dalgaard *et al.*, 1998). The organic system includes more roughage and grain than the conventional fodder ration, and the energy use for these two fodder types are accounted as produced on the farm. In contrast, the conventional plan includes more imported concentrates. The yearly milk yield predicted by Sørensen *et al.'s* (1992) model and added meat converted to milk on energy basis 1:10 are equal for the two plans.

Table 2 compares energy use per milk yield in organic and conventional dairy farming. The total energy use per kg milk produced is lower in organic than in conventional dairy farming because of the energy-inexpensive grassland grazing (example 2) and a lower import of energy-expensive concentrates. The following section discusses whether this result can be generalised to the national level.

Table 2. Energy use (GJ) for milk production in Denmark

1 milking cow in 1 year	Conventional	Organic
Fodder		
Grazing	3.6	2.3
Grass silage	2.4	1.5
Whole crop silage	1.0	0.8
Straw	0.0	0.0
Grain cereals	2.7	3.3
Imported concentrates	7.4	6.7
Straw bedding	0.4	0.4
Housing	8.0	8.0
Farm buildings	2.5	2.5
Total	28.0	25.6
1 000 kg milk*	9.0	9.0
MJ/kg milk	3.1	2.8

* Meat converted to milk on energy basis 1:10.
Source: Dalgaard *et al.* (2002c)

National energy balances

Example 4: Dairy farming in Denmark

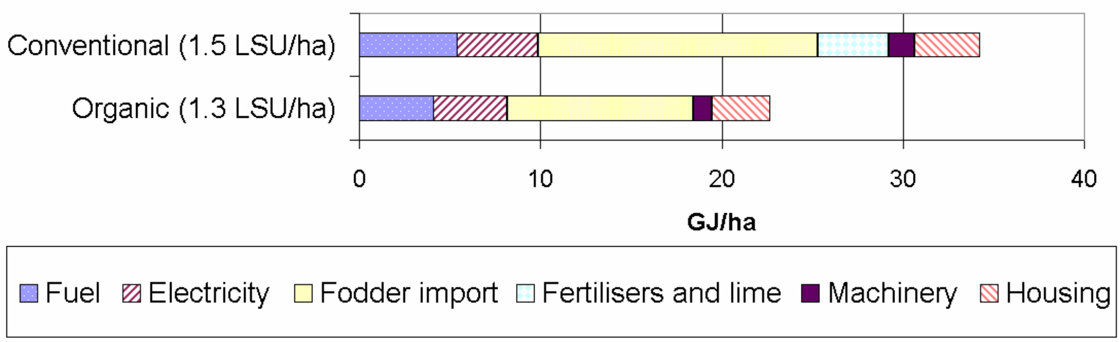
The fourth example demonstrates a method to calculate and compare the national average energy use per hectare in the organic dairy farm sector with that of the conventional dairy farm sector. The calculations are based on farm statistics from the year of 1999. The data set includes more than 1 500 variables concerning land use, crop yields, livestock production, financial account variables etc. (Olsen, 2001), from which the energy use is calculated for a number of farm types. Some of these data are collected for the EUROSTAT farm accountancy data network, FADN (McClintock, 1989). Therefore, similar calculations may in the future be extended to other EU countries. In the present data, organic farming is only represented with one farm type, organic dairy farming, whereas conventional farming is divided into a number of farm typologies. As an example, the energy use in the organic dairy farm type is compared to that of the average conventional dairy farm.

Figure 3 shows the energy use in MJ/ha for the organic and conventional dairy sector in Denmark. For both sectors, the direct energy use (fuel, electricity, machinery and housing) is lower than the indirect energy use (fodder import and fertilisers and lime). Comparison of the conventional and organic sector shows that the direct energy use is almost identical for the two sectors, but the conventional sector uses much more energy for fertiliser production and fodder production than the organic sector does. Therefore, the total energy use per hectare is higher in the conventional than in the organic sector. However, it is very important to notice that the average organic farm produces less milk per hectare than conventional farms do (*i.e.* the number of LSU/ha in Figure 3 differs between the two farm types), and it is still unknown whether the conventional sector uses more or less energy per litre milk produced, on the average, than does the organic sector.

To calculate the total energy use per litre milk can be difficult because Danish dairy farms — besides milk and meat production — also produce, for instance, cash crops, sugarbeet and rapeseed.

This means that the direct and the indirect energy use in the milk sector is not only connected to the production of milk but also to other products. Fortunately, it is possible to address the problem by using Life Cycle Assessment, which is a method used to estimate the resource use and environmental impact of a product (Dansk Standard, 2001). This method has lately been used to estimate the energy use of the Danish conventional pig sector (Dalgaard *et al*., 2002a) but, as already mentioned, has not been applied to the dairy sector yet.

Figure 3. Average energy use per hectare in the organic and conventional dairy farm sector of Denmark, 1999



Example 5: National energy use, bioenergy production and emissions of greenhouse gases

In the final example, the total national energy balance for Danish agriculture in 1996 is calculated and compared to the following three scenarios for conversion to 100% organic farming:

A. Full national self-sufficiency with fodder (*i.e.* no import). This particularly limits pig production because it was assumed that the total Danish EU milk quota would still be produced after conversion.

B. 15% import of fodder for ruminants and 25% import for non-ruminants. Again, pig production is limited, but less than in scenario A.

C. The same level of animal production after conversion as in 1996 (unlimited import of fodder).

In each of the scenarios, crop production on the 2.7 x 10^6 ha agricultural area of Denmark is estimated for the present practice on organic Danish farms (Halberg and Kristensen, 1997) and for an expected improved future practice. Moreover, livestock production in LSUs[6] is determined by the above scenario conditions, and the subsequent need for fodder imports is calculated (Table 3). On the basis of these data, the energy use and the emissions of greenhouse gases are calculated according to Dalgaard *et al*. (2002b) and IPCC (1997).

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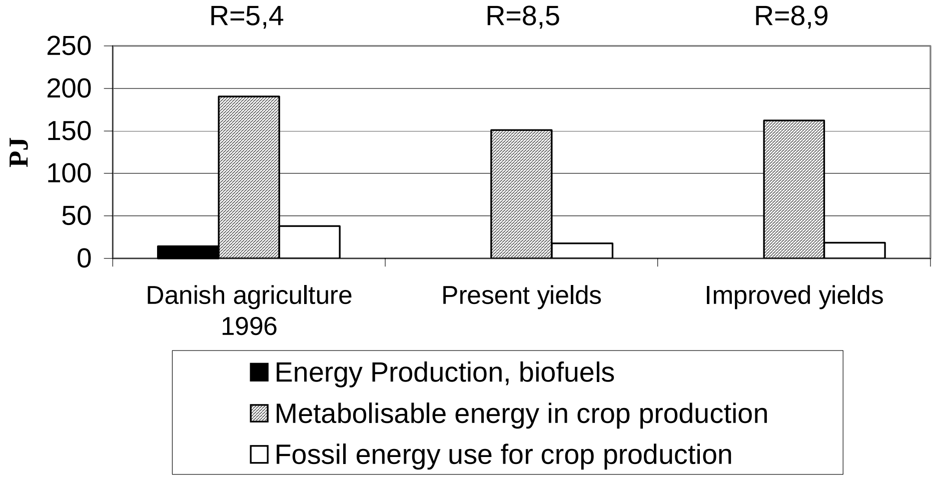
[6] 1 Livestock unit (LSU) corresponds to 1 Holstein Friesian dairy cow held in 1 year, or 30 slaughter pigs produced.

Table 3. Total Danish crop production, fodder import and animal production in 1996 and in the three scenarios for conversion to organic farming (calculated from Alrøe *et al.*, 1998)

		Conventional Agriculture	Organic Scenarios *Present (improved) crop yields*		
			A	B	C
Crop production	10^9 SFUs	15	12 (13)	12 (13)	12 (13)
Fodder import	10^9 SFUs	4	0 (0)	2 (3)	4 (3)
Livestock units	10^6 LSUs	2.3	1.7 (1.7)	2.1 (2.3)	2.4 (2.4)

An important difference between present conventional production and the scenarios for conversion to organic farming is the lower crop yields in organic farming. In the organic scenarios, the average yield in MJ metabolisable energy declines by between 15% (if an expected improvement of the yields in organic farming occurs) and 21% (if the present yields in organic farming are sustained). In comparison, the fossil energy use declines by 52% and 53%, respectively, and the ratio (R) between energy production and net energy use is higher for organic than for conventional crop production.

Figure 4. Energy production in the form of biofuels (straw and biogas), metabolisable energy in crops and fossil energy use for crop production[1]



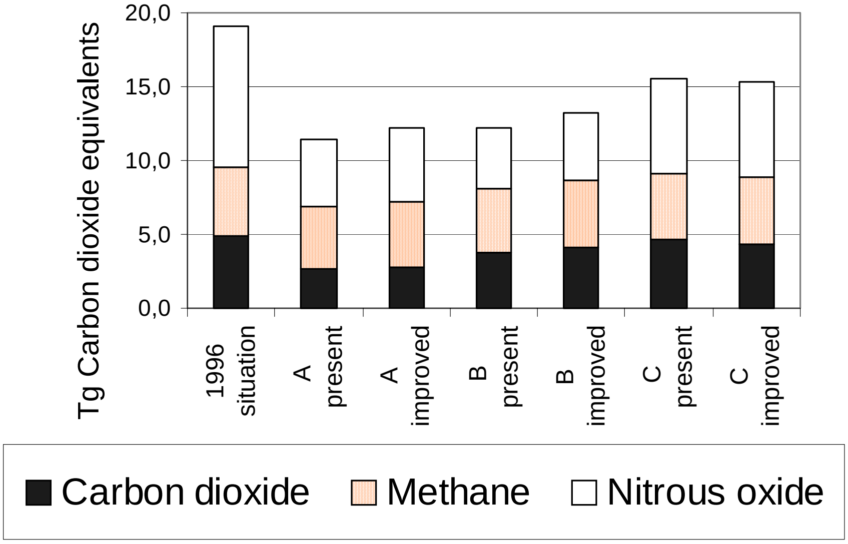
Notes:
1. 1 PJ = 10^{15}J.
2. Results are shown for the present situation in Denmark 1996, and for the organic scenario, calculated for the present yields in organic farming and for expected, improved future crop yields.
3. R is the ratio between energy production and net energy use calculated as the fossil energy use minus the bioenergy production.
Source: Dalgaard *et al.,* 2002b.

In the present situation, significant bioenergy production, primarily from combustion of straw and from biogas extracted from slurry, takes place in Denmark (Figure 4). This should be deducted from the energy used for crop production. However, the potential for further bioenergy production from straw and biogas is twice this present production of around 14 x 10^{15} J bioenergy. Moreover, 2 x 10^9 kg grain was exported from Denmark in 1996, compared to no export in the organic scenario (C), with a national animal production comparable to the present situation (Table 3). If these cereals were burned in power plants for heat and electricity, a gross energy production of about 30 x 10^{15} J might be achieved. In this situation, conventional farming has a more positive energy balance than any of the scenarios for conversion to organic farming (Dalgaard *et al.*, 2002b). However, there are many unanswered questions concerning possibilities for combined food energy systems (Kuemmel *et al.*, 1998), which may be introduced in organic as well as conventional farming and change the conclusion from this example. Further investigations within this area are therefore recommended.

Table 4. Total Danish agricultural energy balance (10^{15} J) for the 1996 situation and for three organic scenarios with present and improved yields

	Danish Agriculture	**Organic Scenarios** *Present (improved) crop yields*		
	1996	A	B	C
Crop production	38	18 (18)	18 (18)	18 (18)
Livestock production	39	13 (14)	28 (31)	40 (34)
Total	77	31 (32)	45 (50)	57 (53)
Energy production	14	0 (0)	0 (0)	0 (0)
Net energy use	63	31 (32)	45 (50)	57 (53)

Figure 5. Total national agricultural emissions of greenhouse gases



Note: 1Tg = 10^9kg.
Source: Dalgaard *et al.*, 2002b.

In the three scenarios for conversion to 100% organic farming, the net fossil energy use of Danish agriculture, calculated to 66 x 10^{15} J, was reduced by between 10% and 51% (Table 4). The highest reduction was found in the scenario with national self-sufficiency in fodders (A), while the lowest reduction was found in the scenario where the present level of animal production was sustained after conversion to organic farming (C).

The net energy use reduction, resulting from conversion to organic farming, leads to lower emissions of the greenhouse gas carbon dioxide. In Figure 5 the reductions in each scenario are accounted and compared to related emissions of the two other important greenhouse gases, methane and nitrous oxide. Not surprisingly, the total greenhouse gas emissions are lowest in the scenario with the highest fodder self-sufficiency and the lowest animal production (A), while the highest emissions found are where the animal production and the fodder import are high (C). In scenarios A and B, the greenhouse gas emissions are increased when the crop yields are improved, while the opposite is the case in scenario C. The cause for this is that animal production in scenarios A and B is limited by the total crop yield. Therefore, higher yields lead to higher animal production and higher greenhouse gas emissions. In scenario C, on the contrary, animal production is not limited by the crop yield because imports of fodder sustain animal production equal to the one in 1996. Consequently, higher yields lead to lower fodder imports, which lowers the total greenhouse gas emissions.

Conclusions and policy recommendations

Based on the presented examples from Denmark and Germany it is concluded that:

- Typically, conversion to organic farming leads to a lower total fossil energy use. However, organic farming practices also result in a lower amount of production per area of agricultural land, a different product quality, and eventually another product price than per unit of similar conventional products.

- In the examples presented, the reductions in the energy inputs were higher than the reductions in outputs from the production. Consequently, the energy efficiencies, defined as output per energy input, were higher in the organic than in the conventional farming examples.

- A higher use of locally produced forage crops in organic dairy production may reduce the energy use via reductions in the energy-costly import of concentrates.

- The fossil energy use reductions lead to similar reductions in emissions of carbon dioxide. This gas contributes with between one-quarter and one-third of the total greenhouse gas contribution from agriculture.

- The potential for bioenergy production is higher in conventional than in organic farming. Fully utilising this potential, conventional farming apparently has a more favourable energy balance and a lower net greenhouse gas emission than organic farming. However, there are still many unanswered questions concerning possibilities for combined food energy systems, which may change this conclusion.

The recommendation for policy makers is to include fossil energy use issues in the evaluation of impacts from organic compared to integrated or conventional farming systems. Within the next generation, the world is predicted to encounter shortage of fossil oil energy and, combined with the concern for energy use-induced climate changes, organic farming should be considered a measure to reduce fossil energy use. However, the type and extent of conversion should be carefully evaluated and matched with other environmental and socio-economic consequences of conversion. The examples presented show promising experiences from Denmark and Germany, countries with highly intensified conventional agriculture. In other regions of the world the conclusion might differ, but nevertheless the industrialised countries have an obligation to save fossil energy resources for the use of future generations and for the development of less industrialised areas of the world.

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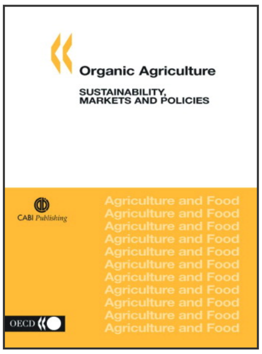

Organic Agriculture

Sustainability, Markets and Policies

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