The Environmental Impacts of Organic Farming in Europe

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Executive Summary

Organic farming has become an important aspect of European agri-environmental policy. Since the implementation of EC Reg. 2078/92, the EU promotes organic farming based explicitly on its positive effects to the environment. The objective of this report is to contribute to a better understanding of organic farming's effects on the environment and to help clarify its possible contribution to European agri-environmental policy.

Approach

In this study, environmental and resource use impacts of organic farming are assessed relative to conventional farming systems. The primary source of information for this report is a survey of specialists in 18 European countries (all EU-member states plus Norway, Switzerland and the Czech Republic) using a structured questionnaire. These experts were asked to refer back to their national literature on the subject. The second important source of information used in this report is a literature search in international databases completed by the authors.

For the purpose of this study, the OECD set of environmental indicators for the agricultural sector has been adapted, taking into consideration only those indicators that directly affect the system of organic farming. Following indicator categories will be evaluated: Ecosystem, natural resources, farm input and output, and health and welfare.

As data availability on the subject has not always been satisfying, a qualitative multi-criteria analysis has been chosen as an approach. Due to the subjective elements involved therein, the report tries to achieve maximum transparency by showing step by step how each of the conclusions has been reached.

Standards of organic farming

Organic farming world-wide is defined by standards set by the organic farming associations themselves. In recent years it has also been defined by the EU. An important objective of these standards is the achievement of desired environmental goals. This and the pure existance and control of such standards is the most important aspect differentiating organic farming from conventional farming. In order to achieve desired environmental results two methods are used:

1. the regulation of the use of inputs to achieve an environmentally sensitive system; and
2. the requirement of specific measures to be applied or, in some cases, of the outcome of environmental or resource use.

In general, the first method is more important and the second is more a supplement. There is considerable variety in the standards found which might influence both competitiveness environmental and resource performance.

Impact of organic farming on indicators

The results of environmental indicator assessment are summarised according to the following categories.

Ecosystem: This category comprises the review of research results on floral and faunal biodiversity, habitat diversity and landscape conservation. The main findings are that organic farming clearly performs better than conventional farming in respect to floral and faunal diversity. Due to the ban of synthetic pesticides and N-fertilisers, organic farming systems provide potentials that result in positive effects on wildlife conservation and landscape. Potentially, organic farming leads to a higher diversity of wildlife habitats due to more highly diversified living conditions, which offer a wide range of housing, breeding and nutritional supply. However, direct measures for wildlife and biotope conservation depend on the individual activities of the farmers. Furthermore, research deficiencies were ascertained in connection with the measurement of habitat and landscape diversity. It needs to be stressed, that organic farming, as well as each form of agriculture, cannot contribute directly to many wildlife conservation goals. However, in productive areas, organic farming is currently the least detrimental farming system with respect to wildlife conservation and landscape.

Soil: The impact of organic farming on soil properties has been researched comprehensively. Information is somewhat scarce only in respect to soil erosion. Results show that organic farming tends to conserve soil fertility and system stability better than conventional farming systems. This is due to mostly higher organic matter contents and higher biological activity in organically farmed soils than in conventionally managed. Furthermore, organic farming has a high erosion control potential. In comparison, no differences between the farming systems were identified as far as soil structure is concerned. Soil performance is, however, highly site specific.

Ground and surface water: The research results reviewed show that organic farming results in lower or similar nitrate leaching rates than integrated or conventional agriculture. Farm comparisons show that actual leaching rates per hectare are up to 57% lower on organic than on conventional fields. However, the leaching rates per unit of output were similar or slightly higher. Critical areas for nitrate leaching in organic farming are ploughing legumes at the wrong time and the selection of unfavourable crops planted afterwards and composting farmyard manure on unpaved surfaces. However, consciousness of the problem and its handling has increased recently. Alternative measures have been developed and introduced in organic farming practise as well. Organic farming does not pose any risk of ground and surface water pollution from synthetic pesticides. Although incorrect organic farm management practices could indeed bear some potential risks for polluting ground and surface water, the detrimental environmental effects from organic farming tend to generally be lower than those from conventional farming systems. Thus organic farming is the preferred agricultural system for water reclamation areas.

Climate and air: This section deals with the differences between organic and conventional farming with respect to greenhouse gases, NH_3 emissions and air contamination due to pesticides. Research on CO_2 emissions show varying results: On a per-hectare scale, the CO_2 emissions are 40 - 60% lower in organic farming systems than in conventional ones, whereas on a per-unit output scale, the CO_2 emissions tend to be higher in organic farming systems. Quantitative research results on N_2O emissions in different farming systems are scarce. Based on deduction, experts conclude that N_2O emissions per hectare on organic farms tend to be lower than on conventional farms, while the N_2O emissions per kg of milk are equal or higher, respectively. However, due to the fact that almost no quantitative data is available, no definite differences between organic and conventional farming systems can be identified. Quantitative research results on CH_4 emissions in different farming systems are also scarce. Experts estimate that organic farming has a lower CH_4 emission potential on a per hectare scale, while CH_4 emissions per kg of milk are estimated to be higher in organic dairy farms than in conventional ones. However, due to the insufficient data basis, again, no definite differences between the farming systems can be identified. Calculations of NH_3 emissions in organic and conventional farming systems conclude that organic farming bears a lower NH_3 emission potential than conventional farming systems. Housing systems and manure treatment in organic farming should aim for further reduction, although they provide fewer opportunities for abatement of emissions than slurry based systems. Due to the fact that synthetic pesticides are not permitted in organic farming, significantly lower air contamination is ensured than in conventional farming.

Farm input and output: The studies reviewed about on-farm balances of nutrients, water and energy with respect to organic and conventional farming can be summarised as follows: nutrient balances of organic farms in general are close to zero. In all published calculations, the N, P and K surpluses of organic farms were significantly lower than on conventional farms. Negative balances were found for P and K. Most research studies reviewed indicate that energy consumption on organic farms is lower than on conventional farms. Energy efficiency calculated for annual and permanent crops is found to be higher in organic farming than in conventional farming in most cases. However, no research results on water use in organic and conventional farming systems are available.

Animal health and welfare: Animal welfare and health are the subject of only a few comprehensive scientific studies. Hence, the actual situation provides the following picture: housing conditions and health status depend highly on farm specific conditions, thus housing conditions seem not to differ significantly between organic and conventional farms. Health status seems to be closely related to economic relevance of animal husbandry on the farm: Significantly fewer incidences of metabolic disorders, udder diseases and injuries were found when dairy production was properly managed. Prophylactic use of synthetic, allophatic medicines is restricted by some national standards and recently also by EU standards. Organic dairy cows tend to have a longer average productive life than conventional dairy cows. Although the application of homeopathic medicines should be preferred, conventional veterinary measures are permitted and used in acute cases of disease.

Quality of food produced: No clear conclusions about the quality of organic food in general can be reached using the results of present literature and research results. The risk of contaminating food with pesticides and nitrate can be assumed to be lower in organically rather than in conventionally produced food. However, neither with respect to mycotoxin, heavy metal and PCB contents, and radioactive contamination, nor with respect to the contents of desirable food substances such as vitamins, nutrients, and aromatic compounds can significant differences between organic and conventional food be demonstrated. Given the discussed factors specific to animal products, a strong argument exists for the superiority of animal products from organic in comparison to conventional farming. The lack of comparative investigation of organic versus conventional farming is compensated by existing research results on the risk associated with conventional farming, such as antibiotic residuals in food and their effects on humans.

Conclusion on the indicator assessment

The review of the relevant literature with respect to organic farming and its impacts on the environment and resource use showed that organic farming performs better than conventional farming in relation to the majority of environmental indicators reviewed. In no indicator category did organic farming show a worse performance when compared with conventional farming. While detailed information is available as far as the two categories of soil and nutrients are concerned, a research deficit was ascertained for the indicator categories climate and air, animal health and food quality. Due to the lack of information, it was only possible to completely assess the performance of the different farming systems with respect to their environmental and resource use impacts on a per hectare scale.

Policy relevance of the results

One question among the many possible relevant policy ones can be answered firmly. How would an increase in the area organically farmed (e.g. doubling of the area) influence environmental and resource performance? Answer: an increase in the area of organic farming would clearly improve the total environmental and resource use performance of agriculture.

It is not easy to answer further questions only using the material available about the influence of organic farming on the environment while maintaining constant food production levels or wether organic farming is part of a least-cost solution to meet agri-environmental goals. However, for policy purposes, the question of whether there are other agri-environmental means of achieving a desired level of environmental and resource performance that might be cheaper for society than organic production is of high relevance. A tentative answer to this question can only be based on theoretical reasoning. There are convincing arguments that the support of organic farming can be a useful part of the agri-environmental tool box, however, other, more specific instruments are also needed. Organic farming seems especially useful if broad environmental concerns are to be addressed, because it results in improvements for most environmental indicators.

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Abbreviations

^{14}C	Carbon 14
AGÖL	Arbeitsgemeinschaft Ökologischer Landbau
AGROBIO	Associação Portuguesa de Agricoltura Biologica
AMAB	Associazione Marchigiana Per L`Agricoltura Biológica
ANL	Akademie für Naturschutz und Landschaftspflege
ATP	Adenosintriphosphat
BSE	Bovine Spongiform Encephalopathy
BTO	British Trust for Ornithology
C	Carbon
CAP	Common Agricultural Policy
CH_4	Methane
CO_2	Carbon dioxide
HCO_3	Hydrogen carbonate
CRAE	Consejo Regulador de Agricoltura Ecológica
C_t	Total carbon
DOC	Dynamic-Organic-Conventional
DSR	Driving Force-State-Response
EC	European Community
EC Reg	EC Regulation
FU	Fertiliser Unit
GJ	Gigajoule
GMO	Genetically Engineered Organisms
ha	Hectare
IFOAM	International Federation Of Organic Agriculture Movements
K	Potassium
kg	Kilogram
KRAV	Organic Biologique Ekologisk (certified by KRAV)
LØJ	Landsforeningen Økologisk Jordbrug
LU	Livestock Unit
MECU	Millions of ECU
N	Nitrogen
N_2O	Dinitrogenoxide

NH_3	Ammonia
N_{min}-N	Mineralisable nitrogen
NO_x	Nitrous oxides
N_t	Total nitrogen
OECD	Organisation for Economic Co-operation and Development
P	Phosphorous
PCB	Polychlorinated biphenyls
SIR	Substrate Induced Respiration
t	Metric tons
USLE	Universal Soil Loss Equation

1 Introduction

Agri-environmental policy is a European policy area in which organic farming has become a notable aspect. Since the implementation of EC Reg. 2078/92, the EU promotes organic farming explicitly due to its positive effects on the environment. In 1997, the EU expenditure on organic farming support through agri-environment programs (EC Reg. 2078/92) increased to 261 MECU or 10.7% of the total EU agri-environment budget (Lampkin et al. 1999). In 1997, Belgium, Denmark, Greece and Italy have spent more than 20% of their agri-environment budget on organic farming. This support of organic farms is substantial in some European countries. Official government statements issued in 18 European countries testify to the growing importance of organic farming in agri-environment policy. For the majority of European governments (CH, DE, DK, ES, FI, FR, GB, IE, NL, NO, and SE) the environmental effects of organic farming are indeed policy relevant, while at least in one quarter of the countries mentioned above, organic farming plays the central role in national agri-environment policy. A major reason for the policy support of organic farming is that the environmental effects of this system are assumed to be positive. These factors give rise to the following pivotal question:

Is EU support of organic farming justified on the grounds of the environmental benefits to be gained?

This report specifically focuses on the assessment of organic farming's contribution to the policy objective of decreasing any negative and enhancing any positive effects of agriculture on the environment and resource use. Thus, in order to contribute to a better understanding of organic farming’s environmental effects and to help clarify the question asked above, this report pursues the following objectives on an European level:

- to give an up-to-date inventory of the environmental impacts of organic farming;
- to identify the positive and negative environmental effects of organic farming and their extent;
- to evaluate the system organic farming with respect to environmental and resource use impacts; and
- to discuss the results gained in the context of the EU agri-environment policy.

The following section of this report focuses on the discussion of methodological questions. In the third section both international and national level organic farming standards are presented and discussed with respect to their contribution to environmental and resource use effects of organic farming. In section four the environmental and resource use impacts of organic farming are analysed according to the concept of environmental indicators developed in section two. The section results in a matrix of environmental and resource use effects of organic farming. This leads to an evaluation of the system of organic farming. In the last section, the results gained are discussed in the context of organic farming as an agri-environment policy option.

2 The methodological challenge

A number of methodological questions which are essential for the outcome of this study arise as the objective of this report, to assess the environmental and resource use effects of organic farming, is approached:

- Which methodological basis should be chosen for an analysis of the environmental and resource use effects of farming systems?
- How can detailed information be collected on a European level?
- What are the correct environmental variables to be considered?
- How can detailed information be aggregated to become relevant to policy?

These questions constitute the methodological challenge of this study and therefore require a more detailed discussion.

2.1 The methodological basis

Generally, there are two possibilities of evaluating the environmental and resource use effects of organic farming. First the system can be assessed by evaluating the degree to which certain goals based on target values are met. This environmental impact assessment approach requires the definition of target values for the whole area of concern. As such target values are not sufficiently available, this first approach is currently not applicable. Another, more policy relevant approach is the evaluation of organic farming's environmental and resource use impacts relative to a reference system. Such a comparison allows a judgement as to which extent organic farming performs ”better” or ”worse” in comparison to the reference system. There is no question about the fact that conventional farming is the appropriate reference system. The methodological dilemma starts with the definition of the correct set for comparison. Neither of the terms organic or conventional farming describe a stable state or a constantly valid process. Farming systems develop dynamically providing room for a range of system variations. The essential point which needs to be discussed in more detail is the selection of the specific systems to be compared as these have a strong influence on the results.

Table 2-1 illustrates the variety of different conventional and organic systems which are likely to differ with respect to their environmental and resource use effects. In simplified terms, three different degrees of environmental friendliness can be distinguished for each farming system:

- typical as found in practice;
- using best management practice; and
- using best management practice plus specific measures to reduce environmental and resource use impacts.

These different categories develop nine possible paired comparisons. But, which of these possible paired comparisons between organic and conventional farming is the right one? The important point here is that the correct comparison in Table 2-1 depends on the question asked. Therefore, C1-O1 would be the right comparison if information is desired on how conventional and organic farming perform in practice, or if the consequences of an increased extent of organic farming were to be assessed.

In the European context, each farming system or variation respectively has characteristics and nuances specific to each country. Consequently, we find varying definitions among European countries with respect to both organic (organic standards, implementation of EU Reg. 2092/91) and conventional (integrated farming) farming systems. For integrated systems especially, a clear and distinct definition is not possible on a European level. Thus, although it is generally possible to distinguish precisely enough what is organic and what is conventional, in the overall context it is not possible to define the boundaries of farming systems exactly for a in-pairs comparison.

Table 2-1: The complexity of farming system comparisons

Conventional systems			**Organic systems**		
Conventional	**C1**	as typically found in practice	**Organic**	**O1**	as typically found in practice
Integrated	**C2**	using best management practices	**Best organic management**	**O2**	using best management practices within the organic system
Integrated plus specific agri-environ-mental measures	**C3**	integrated plus specific measures decreasing environmental and resource use, e.g. providing exclusive areas for ”pure nature”	**Best organic management plus specific agri-environ-mental measures**	**O3**	best organic management plus specific measures decreasing environmental and resource use, e.g. providing exclusive areas for ”pure nature”

To make matters even more difficult, the environmental and resource use impacts of agriculture not only depend on the varieties in the system and the environmental management levels but also on the following factors: farm type, degree of specialisation, level of intensity, site specific aspects, and individual management abilities of the farmer. The inclusion of all these factors mentioned would enhance the complexity of the analysis considerably. Furthermore, the analysis would, of course, require a complete basis of information about all existing variations of farming systems and about all factors affecting the environment and resource use. However, we cannot begin to assume this ideal case. Hence, one major problem this study faces is that of data availability.

The fact of insufficient information forced us to simplify the definition of organic and conventional farming. Thus, in this study, all variations of conventional and integrated farming are combined in the term conventional farming. Analogously, we use the term organic farming for all types and national variations of organic farming systems which correspond in the broader sense to EC Reg. 2092/91. Therefore, the important factor ‘data availability‘ finally determined the precision of the comparison.

2.2 Information sources

The primary sources of information for this study are documented research results published in the countries investigated, accompanied by investigations to clarify the country specific policy background and including expert assessment. The methodology of an expert survey has been chosen for data collection. The expert survey conducted in 18 European countries (all EU-member states, plus Norway, Switzerland and the Czech Republic) uses a questionnaire that consists of two types of questions: questions that are to be answered on the basis of literature reviews and expert knowledge, and those based on additional surveys that are to be performed by national experts.

In order to ensure the inclusion of both on-going research and grey literature, as well as country specific aspects in each country investigated, a recognised expert in organic farming native to that country has been contracted. These national experts are primarily responsible for responding to the questionnaire but also for performing further data collections in the respective country. Thus, the national experts act as both respondent and surveyor. In order to deal with this situation, the questionnaire’s design included guidelines and an example of how to fill in the questionnaire.

Because of the challenges faced by covering 18 European countries (e.g. the resulting language problems), and in order to increase work efficiency, the national experts were asked to review and summarise the relevant literature. Due to this fact, data analysis was confronted with the problem that only research material documented in English and German could be double-checked by the authors of this report. The reviews of material written in other languages represent the individual focus of the contracted expert. Data quality delivered is correlated with both data availability and expert knowledge. A comprehensive literature review in international scientific databases was part of each expert survey.

It would be highly desirable to be able to disaggregate information on the relative performance of organic farming compared to conventional with respect to an environmental dimension (subject) by farm type and region. However, the quality of data mainly allows data analysis and interpretation by subject. Only in some parts of this report could country specific aspects and differences be analysed. The reason for this is that the studies reviewed have been conducted independently and do not follow a common methodology. Thus, they often support or reject general statements on a given subject, but the results can in many cases not be used for quantitative comparisons. In addition to uneven methodology, information is missing on several topics because no studies have been conducted. Therefore, another aim of this study will be to identify those areas where information and research is lacking with respect to environmental indicators.

2.3 Environment and resource use variables

The selection of variables is of central importance for the outcome of a system comparison on environmental and resource use impacts. The ideal variable or set of variables respectively provides information and describes the state of environmental phenomena with certain significance. Thus, applying a set of variables should make it possible to monitor and assess the state of the environment, to identify changes and trends, to transmit scientific data to become relevant for policy, and to evaluate already implemented policy measures. The concept of environmental indicators is broadly accepted as an adequate tool. Accordingly, an indicator is defined as a parameter or a value derived from parameters, which indicates the state of the environment with significance extending beyond that which is directly associated with a parameter value. A parameter’s definition in this context is a property that is measured or observed (OECD 1994). Pieri et al. (1996) states that the purposes of indicators are as follows:

- to select the most significant information;
- to simplify complex phenomena;
- to quantify information, so that its significance is more readily apparent; and
- to communicate information, particularly between data collectors and data users.

2.3.1 Concepts of indicators

After initiation by the AGENDA 21 various institutions started working on environmental indicator concepts. A comprehensive report on existing approaches of environmental indicator concepts is given by Walz et al. (1995). They describe that most of the concepts already published and available for international comparisons suffer from

a) a status of immaturity with regard to data availability, definition of target values, conceptual uncertainty about aggregation level and indicator definitions, and indicator ambiguity;

b) an explicit regional focus on either industrial, fast-developing, or developing country problems; and

c) a restriction to indicators that can be measured only monetarily.

Currently the most important and the most advanced indicator concept in the area of environment and resource use has been presented by the OECD. The OECD concept has been developed with regard to environmental and resource use effects in order to enable the analysis of country-specific situations, to evaluate environmental policies and to measure environmental quality. Furthermore, the OECD provides a set of environmental indicators adapted exclusively for the agricultural sector. This concept is based on the Driving Force - State - Response framework (DSR). The advantage of such a framework is that environmental indicators can be identified and developed upon solid concepts and methodology. In this context, the term "Driving forces" describes those elements that cause changes in the state of the environment. The term "State" or condition refers to changes in environmental conditions that may arise from various driving forces. "Responses" refer to the reaction by groups in society or policy makers to the actual and perceived changes in the State (OECD 1997). Generally, the DSR-framework aims at providing a system that makes a reduction of the parameters investigated possible. This simplification results in a more workable communication structure.

There is a general agreement within the research community that the DSR-framework is the most perfected and therefore the highest internationally accepted framework. This enhances the international standard of environmental indicators (Münchhausen and Nieberg 1997, Walz et al. 1995). Due to these reasons and due to the international approach of the project, this study relies on the set of environmental indicators for the agricultural sector developed within the DSR-framework by the OECD.

Approach

2.3.2 Indicator adaptation

The OECD set of environmental indicators for the agricultural sector contains several sub-categories assigned to each of the three DSR-elements (OECD 1997):

Driving Force sub-categories:

- Environment
- Economy and social
- Farm inputs and outputs

State sub-categories:

- Ecosystem
- Natural resources
- Health and welfare

Responses sub-categories:

- Consumer reaction
- Agro-food chain responses
- Farmer behaviour
- Government policies

These sub-categories have been defined in accordance with the OECD's intention of analysing country-specific situations, evaluating environmental policies and measuring environmental quality. The purpose of this study, however, is somewhat different from that of the OECD. In this study, we want to assess the environmental and resource use effects of organic farming relative to conventional farming in a European context. Thus, we need to concentrate on analysing and evaluating system effects rather than evaluating policies. For our analysis we need to narrow down and adapt the original OECD indicator set.

Figure 1 illustrates this adaptation. The agricultural sector in Europe provides the external frame within which the sub-categories are affected by the DSR-elements. Focusing on the farming system as a part of the whole sector requires limiting the analysis to those variables which are directly linked to the characteristic of a farming system and those directly influenced by a farming system. These variables are to be identified on the basis of those sub-categories, which are enclosed in the evaluation frame shown in Figure 1.

Accordingly, as far as driving forces are concerned, external factors are those which actually have a general effect on the farm because of the condition of the farm site (environment) and the economic and social framework. These factors might indubitably be beneficial or detrimental to a farming system. Both factors are, nevertheless not a defined characteristic of a farming system nor does a farming system generally affect these factors. According to the OECD concept, the only driving force to be

considered is farm inputs and outputs, including the impact of chemical use, energy use, water resource use, level and mix of farm crop and livestock outputs, as well as farm management practises.

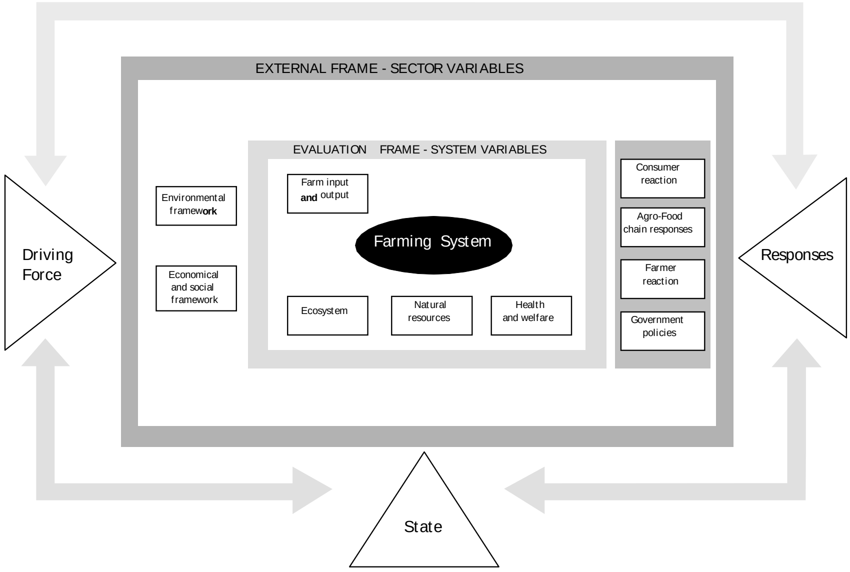


Figure 1: Evaluation frame: environmental indicators for farming systems

In contrary to the driving forces, all State sub-categories are included in the evaluation frame because farming systems have an effect on the ecosystem, the natural resources and on health and welfare. Thus, biodiversity and natural habitats are parts of the ecosystem category, while the variables soil, water, climate and air are considered under the natural resources category. The health and welfare category has been expanded and now includes system effects on the farmer (e.g. pesticide spray), and on consumers as part of the food quality indicator. Animal health and welfare is included in this sub-category, too. Therefore, this study is not limited to an analysis of physical parameters of environment and resources but includes the analysis of certain kinds of (sometimes partially) public goods like health and welfare as well.

While the distinction between internal and external categories is unambiguous for the State and Driving Force categories, the situation is more complicated as far as the Response categories consumer reaction, agro-food chain responses and government policies are concerned. These Response categories can influence the legal framework of farming systems both directly and dynamically, for example by changes in EC Reg. 2092/91.

However, measuring these impacts would result in measuring indicators, which are already evaluated in the Driving Force and State categories. Thus, no Response category will be directly discussed. Because the organic farming system is evaluated in comparison to that of conventional farming, the most important differentiating element the legal framework of organic farming can not only be considered in the Response category, but as some sort of Driving force as well. Therefore, in this special case, the organic standards and regulations are discussed partially in section 3.

The regulatory and policy environment as well as its institutional and marketing aspects, are separate questions of concern which will not be dealt with in this study. Information about these subjects can be found in Lampkin et al. (1999) and Michelsen et al. (1999).

To summarise, the indicators to be looked at in this study adhere to the restrictions on indicators, which are in the evaluation frame shown in Figure 1. Basically, they correspond with the respective environmental indicators for agriculture suggested by the OECD (1997). The complete list of indicators, including the name of the section they will be analysed in, is shown in Table 2-2.

Approach

Table 2-2: Environmental indicators for organic farming based on the OECD list of environmental indicators for agriculture

Indicator category	Indicator
Ecosystem	
	Floral diversity
	Faunal diversity
	Habitat diversity
	Landscape
Natural Resources	
Soil	Organic matter
	Biological activity
	Structure
	Erosion
Ground and surface water	Nitrate leaching
	Pesticides
	Nutrient load
Climate and air	NH_3
	CO_2
	N_2O
	CH_4
	Pesticides
Farm input and output	
	Nutrient use
	Energy use
	Water use
Health and welfare	
Animal welfare and health	Husbandry
	Nutrition
	Health
Quality of produced food	Pesticide residues
	Nitrate
	Mycotoxins
	Heavy metals
	Desirable substances

2.3.3 Terms of reference

With the decision to analyse the environmental and resource use impacts of organic and conventional farming on the basis of environmental indicators, the next question to be answered is of how to correctly present the analysed environmental indicator data.

The most relevant way to present data on environmental indicators is to relate this data to:

a) the input (e.g. energy use per hectare land area), or to

b) the output (e.g. energy use per ton of wheat produced) of a farming system.

Relating data to the output takes the productivity of a farming system into consideration. If two systems differ in their productivity, the analysis of an environmental indicator leads to different results for the input and the output. This fact often causes some confusion about the results of an indicator analysis, its interpretation and its relevance.

To relate an environmental indicator to the land area makes sense in those cases in which the decision has been taken to maintain a stable agricultural land area. The only question is whether to farm it organically or conventionally. On the other hand, it is appropriate to relate an environmental indicator to the output if the quantity of food to be produced is set, while farmland is variable. In this case the productivity is the important factor. Output results can change depending on the assumed level of productivity and the potential of productivity. An interpretation of the per unit of output approach could be a difficult task as it would also have to consider whether a change in the agricultural land area has positive or negative effects on the environment and the resource use.

In terms of informed policy decision, it would be desirable to relate information to both the input and to the output. However, working with secondary data implies that many studies do not provide complete information. In most cases, though, data on an environmental indicator is only available on the input, the per unit of land area basis. Although in scientific terms it is deplorable that most information is not available on a per unit of output basis, this is less problematic for today's practical EU policy. Food surpluses are more of a problem in the current political environment than food scarcity and there seems to be a broad consensus to keep the amount of farmland relatively stable. Therefore, in the EU, in most cases, the policy relevant way is to apply the data on environmental indicators to the input on a the per unit of land area term.

2.3.4 Aggregation of information

In order to improve the policy relevance of the results, it is necessary to aggregate the indicators analysed to one final result, e.g. a sustainability index. Data aggregation currently faces the fact that there is no commonly accepted methodology to alleviate the problem of evaluating and summarising the environmental indicator data.

For this study, we have chosen a step by step qualitative assessment approach for data aggregation. First, each parameter of an environmental indicator is analysed on the basis of secondary material. We then present the results of the studies reviewed on a detailed level. Subsequently, we aggregate the parameter results by indicators. The review of each indicator ends with a qualitative assessment of the respective indicator sub-category evaluated on a scale that rates the environmental and resource effects of organic farming in comparison to conventional farming (see Table 2-3). These results will finally feed into a qualitative assessment scheme in which we aggregate the indicators of each section according to indicator category. The assessment schemes applied could be described as a multi-criteria analysis based on the authors' expert knowledge. Because of the subjective element involved, we try to keep this part as transparent as possible. Thus, the reader will be able to follow exactly how the authors reach their conclusions.

The assessment takes a conservative approach. We assume no differences between organic and conventional farming unless research results provide clear evidence that such a difference exists. This implies that if the assessment scheme shows no difference between the farming systems, there could be the following two reasons for this:

a) it could be that research provides distinct evidence of no differences for an indicator or its category; or

b) that the research reviewed is insufficient from our point of view and that no final conclusion can be drawn.

Additionally, each indicator assessment will also provide the entirety of the information involved that has been aggregated to one single assessment on the scale shown in Table 2-3.

Table 2-3: Assessment scale used for indicator evaluation

Scale		Organic farming performs...
+ +	=	much better
+	=	better
o	=	the same
–	=	worse
– –	=	much worse
		... than conventional farming

As the interpretation of data in some cases is quite definite, while, in other cases, a wider range of assessments seems possible, the qualitative assessment scheme is complemented by providing a subjective confidence interval for each indicator. This subjective confidence interval is the result of critical discussion among the authors with respect to the possible margins of error of the assessment made.

Due to the fact that research studies applying environmental indicator data to output are scarce, the conclusions illustrated in the qualitative assessment scheme summarise our results for the input on a per hectare basis.

To summarise the methodological challenge: The data availability on environmental indicators is much less than ideal. Because of this, this report uses a rather broad classification of systems (organic vs. conventional) for comparison. The conclusions are scientifically found, but they are less precise and differentiated than we would wish them to be. Because of the above mentioned imprecision, the results can only be of a qualitative nature. In order to improve the policy relevance of the results gained, we aggregated the results by indicator categories following a qualitative assessment approach based on transparent subjective judgement.

Despite the shortcomings outlined, we believe that it is possible to draw general conclusions useful for policy purposes. The alternative would be to wait for the results of a major, co-ordinated European research effort before any statements are made. We would welcome such an effort and this study can also be regarded as a part of preparing for it. It is necessary, however, to review and evaluate current scientific knowledge since practical policy can not wait.

3 Definitions and standards of organic farming in relation to environment and resource use

Within the European Union, organic farming can be defined as a system of managing agricultural holdings that implies major restrictions on fertilisers and pesticides. This method of production is based on varied crop farming practices, it is concerned with protecting the environment and seeks to promote sustainable agricultural development.

It pursues a number of aims, such as the production of products which contain no chemical residues, the development of environmentally sensitive production methods which avoid the use of artificial chemical pesticides and fertilisers, and the application of production techniques that restore and maintain soil fertility.

Inspections are carried out at all stages of production and marketing, with a compulsory scheme, officially recognised and supervised by the EU-member states, involving regular checks on all operators (Baillieux and Scharpe 1994).

To the maximum extent feasible, organic farming systems rely on crop rotations, crop residues, animal manure, legumes, green manure, off-farm organic wastes, and measures of biological pest control to maintain soil productivity and tilth, to supply plant nutrients and to control insects, weeds and other pests. Therefore, organic farming is best defined by its principal ideological background based on the concept of the farm as an organism in which all components - soil, plant and animals - interact to maintain a stable whole (Lampkin et al. 1999).

A farming system based on these definitions and their accompanying measures claims to be more environmentally sensitive and to have less harmful effects than conventional farming. However, the most obvious factor distinguishing organic farming from other approaches to farming is the existence of both legislated and voluntary standards, as well as certification procedures to provide a clear division between organic and other farming systems.

The objective of this section is to provide an overview of the basic definitions of organic farming relevant to existing bodies and to discuss how this definition is implemented by different organic farming standards with respect to the environmental factors discussed in the following chapters. On this basis, a review of recent scientific investigations of the environmental effects of organic farming in comparison to conventional farming will then provide a realistic picture of the contribution of organic farming to an environmentally sensitive and sustainable use of resources.

3.1 International standards

3.1.1 IFOAM

The implementation of the definition of organic farming is based on the 'Basic Standards for Organic Agriculture and Processing' of the International Federation of Organic Agriculture Movements (IFOAM).

These basic standards provide a framework for certification programmes world wide to develop their own national or regional standards. These need to take local conditions into account and tend to be stricter than the IFOAM Basic Standards, which cannot soley be used for certification. Any product sold as organic must have been produced within and be certified by a national or regional certification programme in accordance with the IFOAM Basic Standards. All national and regional certification organisations must comply with existing legislation.

The key characteristics of organic farming have been considered in the regulations of the IFOAM Basic Standards. These usually consist of three levels of 'regulations':

1. minimum requirements or restrictions which exclude the use of certain substances or practices;
2. general rules describing necessary practices in general, or demanding more detailed rules by certifying bodies which outline strategies of avoidance and preventive measures; and
3. recommendations of how to achieve the objectives of these general rules.

The key points of organic farming outlined in the IFOAM standards are the following:

a) the increase, or at least maintenance of soil fertility on a long-term basis;

b) the exclusion of Chilean nitrate and all synthetic nitrogenous fertilisers, including urea;

c) the exclusion of synthetic pesticides;

d) the definition by national and regional certifying bodies of maximum total and outdoor stocking densities;

e) the regulation of animal husbandry according to the physiological and basic ethological needs of the farm animals in question in order to ensure maximum animal welfare; and

f) the exclusion of synthetic feed additives, such as growth-promoters and hormones.

Maintaining or increasing fertility on a long-term basis is to be achieved by:

- returning sufficient quantities of organic material to the soil;
- increasing or maintaining biological activity;
- only introducing material which is specified for use in organic farming;

- providing restrictions by certification bodies for the use of inputs which contain relatively high contents of unwanted substances so as to maintain the natural conditions of the soil with respect to, for example, pH values and heavy metal contents;
- having requirements declared by certifying bodies for the rotation of non-perennial crops in a manner that maintains or increases soil, organic matter, fertility, microbial activity and general soil health; and
- recommending that the certification programmes insist upon specific rotations, including legumes.

The exclusion of Chilean nitrate and all synthetic nitrogenous fertilisers, including urea, calls for the following:

- an avoidance of undesired inputs, i.e. by clear distinction between neighbouring organic and conventional fields, and by respecting a conversion period;
- only a supplementary use of mineral fertiliser (e.g. P, K, rock-powders for micro-nutrient supply) to organic fertilisation;
- the use of species and varieties, which are adapted to the soil and climatic conditions to the maximum extent possible in order to limit the necessity of fertilisation; and
- an insistence on diverse crop rotations with an inclusion of legumes by certification programmes.

The ban of synthetic herbicides, fungicides, insecticides, and other pesticides is to be supported by following additional measures:

- maximum avoidance of undesired inputs from outside (i.e. contamination of equipment, conversion period, distinction of neighbouring fields, etc.);
- all measures to avoid losses from pests, diseases and weeds (crop rotations, manure programmes, etc.); and
- the use of the recommended physical and thermic measures of crop protection, i.e. pheromone traps or thermic weed control.

The maximum total and outdoor stocking densities must be limited by national and regional certification bodies. This is supported by the limitation of fodder imported from outside the farm, which must also be specified by national and regional certification bodies.

Maximum animal welfare is to be ensured by providing sufficient free movement, fresh air and natural daylight, fresh water and feed, protection against weather conditions, and enough lying and resting area with natural bedding material according to the need of the animals. Clear rules are set for indoor housing conditions, i.e. poultry shall not be kept in cages, or that a maximum number of hours of artificial lighting has to defined by national organisations. Breeding goals shall secure natural birth, i.e. embryo transfer techniques and the use of genetically engineered species or breeds is not allowed. Furthermore, mutilations must be avoided.

For animal nutrition, the maximum percentage of feed from conventional farming systems and access to roughage is defined. The prohibition of synthetic feed additives, such as growth-promoters, hormones, and the prophylactic use of allopathic medicines is accompanied by the recommendation to direct all management practices to maximum resistance to diseases and to prevent infection. Even vaccinations are only approved by the certification programmes when no other form of management technique can control the respective disease. However, the use of allopathic drugs is allowed in the case of illness when no other justifiable alternative is available. The well-being of the animal is more important than the choice of treatment. Therefore, withholding periods are specified to be at least double the legal periods. All other standards for feed and feed ingredients must be defined by certification programmes.

3.1.2 European Union

In the European Union, organic farming is implemented, labelled, controlled and marketed according to EC Reg. 2092/91 and its updates. Within the European Union, IFOAM Basic Standards are replaced by EC Reg. 2092/91. Thus, EC Reg. 2092/91 provides a framework for organic farming within the EU based on subsidiary principle and its implementation. It is to a certain extent flexible with respect to adaptation, supplementation, and precision of technical details in respect to national conditions.

In comparison to IFOAM Basic Standards, EU regulation of plant production does not cover as many production areas. Animal husbandry and pollution control, soil and water conservation, storage and transportation of products, packaging and social justice are some of these. Instead of providing a wide range of diverse recommendations and regulations, the EU standards are based on a few fundamental regulations that focus on avoiding the use of fertilisers and pesticides and only permit the use of certain specified fertilisers and substances for crop protection. The list of specified substances does not differ substantially from the IFOAM list of substances. Human excrement, sewage sludge, and urban compost - although restricted in their use – are allowed by IFOAM Basic Standards. According to the EC Reg., however, the use of these substances is entirely prohibited. EC Reg. 2092/91 permits the use of clays for fertilisation and with a special permit, sulphur, trace elements and potassium sulphate as well.

As EC Reg. 2092/91 did not provide standards for organic animal husbandry until August 1999, some countries, i.e., Sweden's KRAV (1997), have based their animal husbandry standards on the IFOAM Basic Standards, whereas in other countries the production standards of national certifying organisations are of more importance. In August 1999 uniform minimum standards for organic animal production (EC Reg. 1804/99) were passed as an expansion to EC. Reg. 2092/91. Their central elements are the limitation of livestock density, the limitation of feed brought in from outside the farm, and the exact definition of minimum housing and outside area per animal. Furthermore, tied-stall husbandry for ruminants and cage keeping of poultry is forbidden, as well as the use of GMO.

Some elements of this recently introduced regulation for organic animal husbandry exceed the national standards of some countries, i.e. the exact definition of minimum housing area is less specific in Germany (AGÖL 1996). EC Reg.1894/99, however, permits the use of nearly all types of conventional feed within a given percentage of the total. This is more restricted by AGÖL (1996) in Germany. Again, the national governments need to adapt this regulation according to country specific situations, and create a range of diverse production environments within a common legal frame.

3.2 National Regulations

National organic farmers' associations establish their own standards, based upon the standards of IFOAM and EC Reg. 2092/91. The final form and coverage of these national standards may differ widely among countries. Some only pick up the requirements of IFOAM, others work in accordance with EC Reg. 2092/91. Spain and Portugal (CRAE 1994, AGROBIO 1988), have established their own production standards (CRAE 1994, AGROBIO 1988). Germany and Denmark (AGÖL 1996; LØJ 1996) have designed their own production standards. National standards often cover even more areas than the IFOAM standards. Sweden (KRAV) has declared standards for restaurants, industrial kitchens and pet food.

National regulations tend to be more specific than IFOAM standards or EC Reg. 2092/91 with respect to soil fertility. Bioland Germany states that rotations must include legumes, whereas Biopark Germany has set a clear minimum standard of 20% green manure within the crop rotation at any point of time (Bioland 1997; Biopark 1996). The Soil Association UK (1997) requires regular inputs of organic residues in the form of manure and plant remains and recommends maintaining a protective covering of vegetation of, for example, green manure or growing crops. In Sweden, KRAV gives upper limits of heavy metal contamination independently of what is applied to the soil. Industrial by-products - although allowed - must be analysed if any doubts arise about contamination. Topsoil can be imported to the farm if it comes from non-contaminated sites. Demeter in Germany and Luxembourg state that the natural soil pH must be maintained at all times (Demeter Germany 1995, Demeter Luxembourg 1997).

All national bodies are required to follow IFOAM Basic Standards in regard to the ban on synthetic N-fertilisers, etc. However, different certifying bodies have provided their own list of substances permitted for fertilisation. The use of human excrement, sewage sludge and urban compost is only permitted in some countries, i.e., by KRAV in Sweden, provided that the natural status of the soil is maintained. On the other hand, KRAV does not permit the use of guano. In Denmark, LØJ permits the use of separately collected human urine and wastes from the food industry, although human excrement as a whole is not allowed (LØJ 1996). In other countries, such as the UK and Germany, (Soil Association, Bioland, Demeter) these substances are not specified in the list of fertilisers that may be used.

A wide range of substances is permitted for alternative crop production. For example, LØJ, Denmark is the only certifying body reviewed so far that provides maximum concentrations of solutions of sulphur, soft soap and mineral oils. Furthermore, several substances permitted by IFOAM and EU standards are not allowed, such as pyrethrum, copper salts, chloride of lime and soda, or microbial pest controllers. Spain (CRAE 1994) stands on the other end of the spectrum with their exclusive focus on the EC Reg. 2092/91.

Strategies to prevent contamination by pesticides are specified quite differently in national regulations. The maximum percentage of fodder brought in from other organic farms and conventional farms must not exceed 10-50% and 5-15% i.e. for ruminants, respectively (KRAV; Soil Association; AMAB, Italy 1997) in order to avoid undesired inputs of pesticides to organic animal produce.

Definition of maximum stocking density is one of the obligations of each national or regional controlling body put forward by IFOAM. This may range from 1.4 LU/ha to 2.0 LU in Denmark and Germany, respectively.

Details on requirements for animal husbandry with respect to animal welfare differ widely. Bioland, Germany and the Soil Association, UK provide detailed housing and grazing requirements for various animals, whereas KRAV only specifies space requirements for hens.

The use of synthetic feed additives etc. is completely banned by all certifying organisations, as demanded by the IFOAM standards. The therapeutic use of allopathic medicines can not be banned completely at this point. However, retaining periods given by national organisations range from one to three times the legal retaining period (Biopark, Germany and Soil Association, UK or LØJ, Denmark, respectively).

From an overall perspective the country specific regulative environments in the EU are diverse, although in the future this range will be somewhat more limited due to the tightening of the common framework after the introduction of the EU livestock regulation in August 1999. However, due to climatic and structural differences among the countries, organic farming in Europe will remain characterised by diversity.

3.3 Summary and Conclusions

In general, organic farming is best defined by considering the farm or the agricultural production unit respectively as an organism in which all components – soil, plants and animals - interact to maintain a stable whole (Lampkin et al. 1998). All organic farming organisations world wide operate within the IFOAM Basic Standards, which provide the basic principles. Certifying organisations implement these basic standards according to specific national conditions. Thus, the farming system is being regulated world wide on a common basis, whereas production itself is only outlined in certain parts. National certifying organisations must specify details of the production methods in their standards. As long as production is practised within this defined range of action, all other farming activities are intrinsic to the organic farming definition and need not be specified in complete detail. This hierarchy of regulations among IFOAM and the national certifying bodies provides a common denomination, while maintaining certain aspects of national identity and permitting adoption to local conditions.

Within the European Union, EC Reg. 2092/91 provides the determining standard for organic farming. Again, specific national conditions can be accounted for in each country within this framework. Instead of providing a wide range of recommendations and regulations, the EU standards are based on a few basic rules and orders, which focus on avoiding the use of fertilisers and pesticides and permitting only the use of certain specified fertilisers and substances for crop protection. Comparable national or international definitions and regulations exists neither for conventional nor for integrated farming systems as it does for organic farming.

It is important to keep in mind that organic farming standards use two methods to achieve the desired environmental results:

1. the regulation of the use of inputs in order to attain an environmentally sensitive system; and

2. the requirement of specific measures to be applied or, in some cases, of specific environmental or resource use outcomes.

In general, the first method is of more importance. The second is more of a supplement. This is especially true in crop production, where the Driving force farm input is evaluated by the standards. However, on a national level, there seems to be a tendency to give more weight to the requirement of specific measures and outcomes than on the international level. The designing of national standards and the implementation of EC RE. 2092/91, which allow a certain margin of adoption to nation conditions, can lead to discrepancies in the regulative environments and the competitiveness of organic farms in the various EU countries.

4 Impacts of organic farming on the environment and resource use

This section forms the core of this report: The empirical evidence for each indicator described in Table 2-2 is reviewed. Currently, only few comprehensive research projects on environmental and resource use impacts have been set up. The most important studies in this context are the DOC trial (comparing biodynamic, bio-organic and conventional systems) and the Pilot Farm Network, both conducted in Switzerland. The Pilot Farm Network aims at developing farming systems economically, ecologically and technically. It evaluated about 110 organic, integrated and conventional farms between 1991 and 1996 (Hausheer et al. 1998). While the pilot farm network follows a more dynamical approach, the DOC trial focused more on the current state of farming systems. First conducted over 14 years ago, the DOC trial helps investigate differences in biodynamic, bio-organic, conventional/integrated systems, each in a rotation with special focus on biodiversity and soil fertility. Apart from these projects, most research results presented below represent more or less individual results with individual character. Several authors (e.g. Haas and Köpke 1994; Piorr and Werner 1998; Unwin et al. 1995) made efforts to review research results on a national scale. The studies mentioned above represent the most important ones in the subject at the moment, and are therefore cited frequently.

Gelöscht: bio-dynamic

Gelöscht: bio-dynamic

4.1 Ecosystem

Since its beginnings, agriculture has been a source of positive and negative effects on the ecosystem in terms of wildlife conservation and landscape. Ecologists agree that modern agriculture has, during the last decades in wide areas of Europe, reached a level of intensity resulting in a negative development of biological diversity of domestic and wildlife species. This has made important characteristics of the landscape vanish. The most important reason for the decreasing biodiversity is the destruction of biotopes (SRU 1996). Both the simplification of crop rotations and the increasing input of agro-technics, synthetic fertilisers and pesticides have been responsible for the fact that agriculture has become one of the main sources for changes in the habitat of many floral and faunal species (Knauer 1993).

Organic farming's impact on wildlife conservation and landscape is reviewed for the following indicator subcategories: species, diversity (floral and faunal), habitat diversity and landscape.

4.1.1 Species diversity

There are three relevant levels at which developments of species take place according to a widely used definition of biodiversity (OECD 1997):

- diversity within a species (genetic level);

- changes in the number of species and their population (species level); and
- changes in natural habitats providing the necessary conditions for populations of species (ecosystem level).

The OECD (1997) addresses biodiversity in agriculture and proposes to consider both domesticated and wild species. The diversity of varieties of crops and livestock breeds, the breadth of the genetic base and the state and trend in the genetic reservoir are the suggested indicators to measure biodiversity on domesticated species. Besides focusing on the number and population of wildlife species, key indicator wildlife species which are representative for certain habitats or are endangered or threatened respectively can be used (OECD 1997).

4.1.1.1 Floral diversity

According to the OECD's proposition, this section will consider floral diversity of both domestic and wild species.

As far as biodiversity of domestic floral species is concerned, research results concentrate on measuring the parameters crop rotation diversity, number of cultivated crops and grassland composition. Hausheer et al. (1998), evaluated crop rotations on 110 organic, integrated and conventional farms in a Swiss pilot farm project and determined the following situations on organic farms.

- More diverse rotations with more crops
  average for organic farms: 4.5 different crops
  average for integrated farms: 3.4 crops, and
- A higher number of crops, including perennials, vegetables, and herbs
  average of organic and integrated farms: 10.2 crops
  average conventional farms: 7.4 crops.

Furthermore, the analysis of 317 Swiss organic arable farms showed that 75.7% of the farms cultivated more than six crops, while 87.5% cultivated more than 4 crops in their rotation (Freyer 1997). A 14% higher diversity of organic arable land use after conversion is calculated for Brandenburg, Germany, using the Shannon index (Piorr, H.P. et al. 1997).

In permanent crops a higher species diversity can be attained by applying a cover crop rotation for weed control. This is reported for organic olive production (Kabourakis 1996).

The composition of organic grassland on 10 organic dairy farms showed increasing diversity of broad-leaved species such as *Ranunculus*, *Taraxacum* and *Urtica* at the expense of *Lolium perenne* during conversion (Hagger and Padel 1996).

Younie and Amstrong (1995) found a higher proportion of *Lolium perenne* and *Trifolium repens* comprising 95% of the sward on organic farms, as well as conventional grassland swards that were sown 7-9 years earlier. There was a higher presence of clover in the organic system. Conversion did not increase the species composition in grassland per se or in the short-term, even though a higher incidence of *Bellis perenne* and *Ranunculus* species was found in the final year of the survey on the organic fields. Investigations on about 100 organic grassland sites also showed that floral diversity decreases significantly with increasing productivity of grassland as a result of a higher proportion of white clover (Wachendorf and Taube 1996).

The northern European countries emphasise that it is very important for wildlife biodiversity that animals graze on unfertilised natural pastures. For example, grassland fungi as indicator species for diversity find better conditions for survival in extensive organic systems. Even endangered species are present if grassland composition is not influenced by fertilisation and plant growth limited by grazing (Jordal and Garder 1995). Nevertheless, organic fertilising can also reduce the number of herbs by half and incorrect organic fertilising strategies can have negative effects on biodiversity (Svensson and Ingelög 1990).

For wildlife floral species, research results are based mainly on the analysis of botanical composition, amount of species, occurrence of endangered species and on the frequency of certain floral species on arable land and grassland. Several authors found up to 6 times more species on organic arable land or grassland than on conventional ones (Ammer et al. 1988; Frieben 1997; Hald and Reddersen 1990; Mela 1988; Rasmussen and Haas 1984; Vereijken 1985). As far as endangered species are concerned, Cobb et al. (1998) and Frieben (1997) found a higher presence (50 - 80%) of one or more endangered species on organic farms, in comparison to 15 - 30% on conventional fields. Generally, ADAS (1998) and Mela (1988) stated that organic farms show a more diverse botanical composition and more botanical families.

As farming systems not only influence the cultivated area but also the neighbouring sites, i.e. field edge strips and hedgerows, these were also examined. Preliminary results from a Finnish study (Aalto 1998) show that farming systems affect floral species on field edge strips. Although these effects are remarkably similar, there are differences in species composition. Field edge strips next to organically farmed fields showed more blooming vascular plants, which are insect- or bumblebee pollinated. Furthermore, while floral species contributed equally to biomass production on organic field edge strips, biomass production on field edge strips next to conventional fields was dominated by only a few species (Aalto 1998). Another study reports that the biomass of monocotyledonous weeds was similar in both farming systems, but that the total biomass of dicotyledonous weeds was markedly higher (50,1%) in the field edge strips next to organic fields (Holme 1996).

On the whole, the diversity of floral species is closely connected to local site conditions. In regions with a high potential for biodiversity, organic farming promotes numerous and highly varied flora. However, in regions with low potential for biodiversity where certain rare species are traditionally found, the positive impact of organic farming on wild herb or grassland diversity is less distinct (Baars et al. 1983; Smeding 1992).

To summarise, there are a number of research results which indicate that diversity and number of wildlife species is higher on organic than on conventional fields. However, as far as domesticated species are concerned, the situation is more complex: There is evidence that organic farms have a higher diversity of crops in their rotation. This can also be deduced from the major principles of organic farming, which aim at diversity of domesticated and wildlife species. Organic farming relies heavily on self-regulation processes of the production system without applying pesticides and synthetic N-fertilisers. Therefore, vast crop rotations are essential as a means of disease and pest prevention, and of maintaining soil fertility by cultivating N-fixing legumes. Additionally, due to its low intensive production system, organic farming standards recommend cultivating site-adapted crop varieties. This does not necessarily mean that organic farming sets narrow limits to modern maximum yield varieties as they are often chosen for resistance reasons. On the other hand, the preservation of old land varieties and breeds respectively (especially in terms of their appropriate breeding) is an important initiative within the organic farming movement. But this issue depends mainly on the individual activities of the farmer.

4.1.1.2 Faunal diversity

Research on farming system-dependent livestock diversity could not be identified in the conducted survey and literature reviews. However, comprehensive work has been done on wildlife faunal diversity comparing different farming systems. The parameters applied to measure wildlife faunal diversity were number, abundance, diversity, distribution and frequency of species.

Paoletti et al. (1995) counted species in peach orchards (Table 4-1). They found higher numbers in organic orchards than in conventional ones, especially for *Arachneae*, *Braconidae*, *Opiliones* and *Carabidae*. The results for *Carabidae* are corroborated by Pfiffner et al. (1995) and Mäder et al. (1996), who were both in the long-term field experiment of the Swiss DOC-trial, and by Rhône-Poulenc (1997). On the average 19-22 and 18-24 species, respectively were found in the organic system, whereas the conventional system had 13-16 *Carabidae* species (Mäder et al. 1996; Pfiffner et al. 1995). Four times as many *Carabidae* were found in organic systems than in conventional ones. On the whole, a higher abundance of beneficial arthropods was found (Rhône-Poulenc 1997).

Table 4-1: Number of species in six peach orchards of two organic and two conventional farms

	Organic 1	Organic 2	Conventional 1	Conventional 2
Arachneae	49	50	30	29
Carabidae	40	33	28	31
Formicidae	12	13	9	12
Braconidae	9	10	1	1
Chilopoda	6	6	5	6
Isopoda	5	5	4	3
Opiliones	4	3	1	2
Diplopoda	3	3	0	2

Source: Paoletti et al. 1995

Other investigations on organic farms and fields found:

- a higher diversity and/or a higher frequency of beetles (ground beetles, rove beetles, ladybirds and others), parasitic *Hymenoptera*, *Diptera*, *Hemiptera*, spiders, *Acarina*, *Millipede*, C*rustaceae* (*Isopoda*), *Collembolae* (several relevant studies compiled by Pfiffner 1997; also: Krogh 1994; Paoletti et al. 1995; Reddersen 1998); and
- significantly more butterflies and more species in organic fields, but primarily more in the uncropped boundary habitat than in the cropped edge habitat (in both systems) (Feber 1998).

Bird surveys have been conducted by the British Trust for Ornithology (BTO 1995) and by Rhône-Poulenc Agriculture (Rhône-Poulenc 1997). The British Trust for Ornithology compared breeding and wintering of birds on 44 organic and conventional farms over a period of three years. The study concluded that breeding densities of sky larks as a key species were significantly higher on organic farms than on conventional ones (BTO 1995). This result was corroborated by an intensive follow-up study on a pair of organic and conventional farms over two years. Generally, higher densities of birds, especially in winter, were found on the organic farms (BTO 1995).

The data from the BTO study mentioned above has been re-analysed more recently in connection with data from a Danish study (Chamberlain 1996; Fuller 1997). It concludes that the benefits derived from organic farming systems are ‘whole system’ benefits and greater than those gained from higher levels of non-cropped areas alone.

In the UK, the Common Bird Census conducted for seven years in a long-term project by Rhône-Poulenc Agriculture compared organic, integrated and conventional systems (Rhône-Poulenc 1997). The study showed a steady annual increase in the number of bird territories on the land converted to organic production and a higher overall number of territories on the organically managed land.

The following reasons are mentioned to explain the outcome of the studies cited above:

- better breeding and food conditions on organic farms found for key farmland species (Braae et al. 1988);
- a higher number of chick-food insects in organic than in conventional winter wheat fields (Moreby and Sotherton 1997);
- the existence of higher levels of non-crop areas, especially hedges and field margins, on organic farms (BTO 1995);
- a higher diversity of crops on organic farms than on conventional farms, including rotational grassland and spring cereals, which are likely to provide high quality breeding habitats for sky larks (BTO 1995); and
- more abundant and diverse food sources on the organic sites (BTO 1995).

In contrast, conventional farming can cause mortality in fledglings, as reported for starlings, due to the use of pesticides and synthetic fertilisers, which cause unbalanced diets, but also due to the change of the habitat through, for example, the reduction of ditches and pastures (Tiainen et al. 1989).

ADAS (1998) and Stopes et al. (1995) note the direct impact of farming systems on cultivated areas and state as well that the extent and management of non-cropped areas play an important role as a retreat for beneficial organisms, e.g. ”beetle banks”. At Elm Farm Research Centre in the UK, a survey on hedges during the conversion period showed a 10% increase in the overall richness of species and a wider range of such in all hedges (Stopes et al. 1995). As far as field edge strips are concerned, Helenius (1996) found a higher diversity in organic than in conventional strips in Finland. The genetic level, showed only 49% similar species in organic and conventional edges strips, although the habitats seemed to be equal. Also, the number of individuals of the dominant species was higher in conventional field edge strips (29% of all individuals versus 16% in organic edges). This indicates a higher diversity in the organic edge strips. The amount of very random species was bigger in organic margins (27% vs. 17%) (Helenius 1996). Small mammals on uncultivated strips were surveyed by Rhône-Poulenc: The field edge strips, predator strips and hedgerows next to organic fields yielded the highest overall levels of trapped small mammals. Uncultivated hedge areas in the integrated conventional system produced similar levels (Rhône-Poulenc 1997).

The amount and frequency of all relevant faunal groups was generally found to be higher on organically cultivated than, or at least similar to, that on conventional land. In the DOC-trial organic and biodynamic systems were characterised not only by a higher diversity and abundance (90 % higher than in the conventional system) but usually by a more balanced species distribution (Pfiffner and Niggli 1996). Many investigations showed that the variety of both flora and fauna species as well as the amount of individuals were higher on organic farms than on conventional farms (Braat and Vereijken 1993; Kabourakis 1996; Paoletti and Pimentel 1992). On the average, biodiversity is 35% lower in conventional orchards than in organic ones. Single species might be reduced up to 80% (Paoletti et al. 1995).

Gelöscht: biodynamic

A final assessment can conclude that organic farming creates "comparatively more favourable" conditions on the species and ecosystem level of floral and faunal diversity than conventional farming systems. This is due to a plant protection management (ban of synthetic pesticides) that is better for the biotic system, as well as extensive organic fertilisation, more diversified crop rotation e.g. higher levels of grass or clover grass leys, and a more structured landscape with semi-natural habitats (Feber 1998; Mäder et al. 1996).

4.1.2 Habitat diversity

A habitat is defined as a place where organisms of a species are found periodically, whereas a biotope is a uniform and more or less bordered area which is the living space of a biocoenosis (ANL 1994). Agricultural land use generally interferes with wildlife habitats. However, the point of interest in this study is to identify differences between conventional and organic farming systems with reference to habitat diversity.

To measure habitat diversity, the OECD (1997) proposes the following indicators:

- changes in selected large scale areas (as woodland, wetlands, pasture);
- fragmentation in agro-ecosystems and natural habitats; and
- length of contact zone.

These indicators were presumably chosen due to measurability and data logistics. However, they are not appropriate to provide causal links to farm management practice (OECD 1997). Furthermore, the proposed indicators assume a high proportion of organic land use, which only applies to organic farming in a few European regions. For the purpose of this study the following questions are of interest:

- Do organic farmed arable and grassland areas represent special habitats?
- Does management practice have particular implications on other habitats?
- Is there typical interaction with natural habitats and different forms of agriculture?

Research results which analyse habitat diversity of farming systems are scarce. Quantitative data is only provided by Hausheer et al. (1998), who evaluated pilot farms in Switzerland. They found more ecologically diversified areas on organic farms. The average number of 4.7 diversifying elements was found on organic farms in comparison to 3.9 on integrated farms. A significantly higher proportion of ecologically diversified areas in relation to the total farm land on organic farms was also determined (Table 4-2).

Table 4-2: The proportion of ecologically diversified land area per farm (%)

Area	Organic farms	Integrated farms	Conventional farms
Valley	16.0	10.3	3.7
Lower mountain	13.3	15.9	-
Upper mountain	84.0	17.4	-

Source: Hausheer et al. (1998)

Therefore, the habitat diversity of organic farm land is assessed to be higher than that of integrated farmed land due to a higher diversity of living conditions. Redman (1992) and Unwin et al. (1995) state that banning synthetic pesticides on organic farms improves the quality of both crop and non-crop habitats.

Even though habitat diversity is not a specific part of organic standards, organic management practice has a characteristic impact on habitat diversity, which is due to:

- the ban of chemical additives which equalise site-specific characteristics;
- more diverse living conditions on arable land and grassland e.g. for insects and birds with special nutritional demands;

- diversified crop rotations (see Chapter 4.1.1); and
- contact zones for neighbouring habitats and structural elements of landscape (hedges, waters) which are protected from nutrient or pesticide drift inputs and therefore guarantee a particularly low level of nutrient supply (Stachow 1998).

To summarise, there is some evidence that organic farming has a positive impact on habitat diversity. However, this result is closely related to site-specific aspects. For example, as a consequence of subsidising conversion on a per hectare basis, more farms converted in less favoured areas like grassland, mountain or low-yield regions than in more productive areas (Dabbert and Braun 1993; Schulze Pals 1994; Stolze 1998). In these regions, habitats such as woodlands, hedgerows or wetlands etc. might traditionally be established. Thus, higher habitat diversity observed on organic farms might be due to historical reasons and not to converting farmers starting to plant hedges or create biotopes (Clausen and Larsen 1997; Langer 1998). The motive for any form of agricultural land use is the production of goods. Organic farming cannot ensure an undisturbed environment, as found in native or wildlife protection areas. Thus, certain species find no habitat even on organic farms.

4.1.3 Landscape

The definitions of landscape refer to common agro-ecosystems and semi-natural habitats, as well as to their visual character. In this sense, landscape can be classified according to its intrinsic beauty, historical features, embodiment of cultural values, past and present impacts of land use, farm practices, composition of farming systems, distribution of habitats and man-made features like stonewalls or historic buildings (OECD 1997). Typical site-specific and diversified landscapes are of high value for regional identity and have important social significance.

The OECD continues to discuss appropriate indicator concepts to measure agricultural impact on landscapes because the value of landscape and the physical impact of agriculture is often subjective and other sectors contribute to rural landscapes as well (OECD 1997). Currently, there are two different indicator approaches based on the following:

- estimate of the monetary value of landscapes; and
- inventory of physical landscape features.

However, the development of methodology to evaluate landscape quality has just begun. Quantitative research investigating the impacts of different farming systems on landscapes could not be identified in this study. Some useful non-quantitative criteria for describing the influence of single organic farms on rural landscape quality are suggested by Hendriks et al. (1992):

- diversity in landscape components (land use, crops, husbandry, humans, planting, margins, sensorial impressions, age of the elements);
- site-related character (relationship to abiotic conditions and specific features);
- cohesion amongst landscape components (functional, spatial, cultural-historical and social);
- historical continuity;
- seasonal aspects;
- personal participation (visual demonstration of ecological and socio-economic development);
- particularities;
- aesthetic values (beauty);
- environmental quality (nitrate leaching, mineral balances); and
- ecological quality (biodiversity, soil fertility).

Because landscape is always a more or less large scale status of the environment, the individual farm influence on it is limited. The proportion of different farming systems within a region determines the land use pattern and the landscape characteristics.

In order to prevent plant diseases and pests, the shaping of landscape is supported by some characteristics of organic farm management, such as diversity of crop rotation and direct measures like planting hedges and creating biotopes (van Elsen 1997). However, these measures depend on the individual activity of the farmer. A British study in lowland regions indicates a greater presence of unmanaged bushy hedges, recent woodland and young and recent hedgerow trees on mixed organic farms than on conventional farms. But no differences between the farming systems were found in the more extensively farmed upland regions and on small horticulture farms (ENTEC 1995). Studies show that about ¾ of the organic farms in the Netherlands have woody elements like orchards and hedges (Vereijken and van Almenkerk 1994), and that small biotopes cover a greater percentage of area on organic than on conventional farms (Clausen and Larsen 1997). However, the conversion to organic farming does not presuppose an increase in small biotopes. Thus, in many cases, observed differences are due to spatial and historical reasons and not necessarily to the farmers' activities (Clausen and Larsen 1997). Langer (1997) states, that the changes in agricultural landscapes, affected by organic farming crop pattern and management, will depend on which type of organic farming the conventional farms convert to, the extent of conversion, the spatial aggregation of converting farms and the farm type dominating the local landscape before conversion.

As far as set-aside is concerned, several authors state organic farming provides a higher potential of biodiversity due to a higher proportion of land set aside compared with conventional farms (ENTEC 1995; Mäder et al. 1996; Stopes 1995).

Almost all national and private organic standards in the countries investigated contain statements regarding organic farming’s contribution to landscape conservation and biodiversity. However, these statements vary from objectives laid down in the standard's preamble to concrete requirements. The Swedish control association does not permit the removal of field islands or large ditching (KRAV 1997). An ecological compensation measure obliges Swiss organic farmers to leave 5% of their land unfarmed (Schmid 1997).

To summarise: the literature review shows that farming system-specific impacts on landscapes, individual activities and traditional reasons overlap. Nevertheless, organic farming provides some potential for positive impacts on landscape. This conclusion is supported by several authors. Van Elsen (1997) states that, in spite of many site-specific preconditions limiting the development potential between farm management and landscape development, the principle of organic farming provides a perspective for further development of high-quality landscapes. This includes the possibility of cautious utilisation of sensitive areas (Noquet et al. 1996), as well as re-qualifying the identity of rural sites (Pennanzi 1996).

4.1.4 Summary : Ecosystem

The reviewed research results indicate that organic farming provides more positive effects on wildlife conservation and landscape than conventional farming systems on a per area unit of land used for agriculture. While data on faunal and floral diversity allow an unambiguous and positive assessment, the available information on habitat diversity and landscape can only lead to the conclusion that organic farming has the potential to provide positive effects. The main findings are summarised as follows:

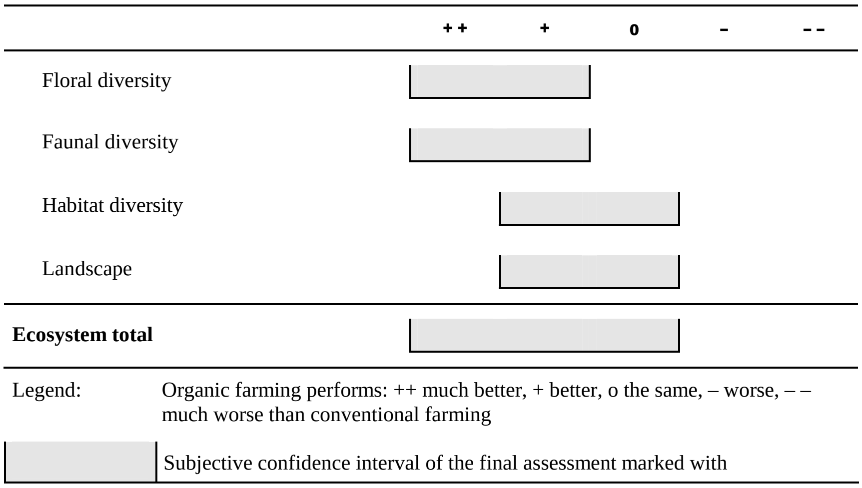
- floral and faunal biodiversity in organic field margins and neighbouring biotopes is higher than in conventional ones;
- floral and faunal biodiversity of wildlife species on organic arable land and grassland is higher than on conventional land;
- the diversity of cultivated species is higher on organic farms than in conventional farms;
- the organic farming system provides potentials, which lead to positive effects on wildlife conservation and landscape due to the ban of synthetic N-fertilisers and synthetic pesticides;
- potentially, organic farming leads to a higher diversity of wildlife habitats due to higher diversified living conditions offering a wide range of housing, breeding and nutritional supply;
- organic farming holds the perspective of re-qualifying rural sites;

- direct measures for wildlife and biotope conservation depend on the individual activities of the farmers; and
- a deficiency in available research was identified as far as indicators suitable for measuring habitat diversity and landscape are concerned.

However, the superiority of organic farming with respect to wildlife conservation and landscape is figured on a per hectare basis of agricultural land. Chapter 5 provides a discussion whether this is the correct basis of comparison for policy purposes.

To summarise: it can be stated that organic farming, as well as each form of agriculture, cannot directly contribute to wildlife conservation targets that require areas of unspoiled nature, as in the conservation of eagles. However, in productive areas, organic farming is currently the least detrimental farming system with respect to wildlife conservation and landscape (Table 4-3).

Table 4-3: Assessment of organic farming's impact on the indicator category "Ecosystem" compared with conventional farming



4.2 Natural resources

4.2.1 Soil

Soil is one of the most important natural resources because it is the central basis for all agricultural activity. Soil conservation is most important as it maintains the productive capacity of this resource. Environmental effects related to different uses of soil are equally important.

In order to address agri-environmental issues, the OECD (1997) developed soil quality indicators within their framework of environmental indicators. These focus on the following factors of soil damage:

- soil erosion;
- chemical deterioration (loss of nutrients, soil organic matter, accumulation of heavy metals); and
- physical damage (soil compaction, waterlogging).

Their main objective is to measure the potential risk and state of soil damages and emphasise aspects such as vulnerability and extent of degradation, rather than focusing on farming practises which cause these damages to the soil. Because this study focuses specifically on the impact of two farming systems on soil, the indicator list was adapted accordingly. It includes the following parameters:

Gelöscht: ¶

- soil organic matter;
- biological activity;
- soil structure; and
- soil erosion.

The impact of organic farming versus conventional farming will be discussed based on this extended list of soil parameters. This is an especially pertinent point because organic farming standards stress the importance of soil fertility. Analysing the environmental subcategory soil presents the problem that the indicators used were also suitable to evaluate soil fertility with respect to its productive potential. The evaluations in this report are not production oriented but focus rather on organic farming's impact on the environment and resource use. The environmental relevance represents the background for the following indicators, and parameters are evaluated as compared to conventional farming systems.

4.2.1.1 Soil organic matter

The soil's supply of organic matter plays a central role in the maintenance of soil fertility. Its environmental relevance is based on the capacity of soil organic matter to limit physical damage and to improve nutrient availability as well as biological activity.

Research on soil organic matter concentrates on measuring the parameter of soil organic carbon content (% C_t). As the C_t-content is highly soil and site specific, the dynamics of C_t -content (C_t changes) during conversion are more informative than absolute data. Besides measuring soil carbon content, results will be presented on soil carbon conservation, humic substances and microbial biomass.

Several long-term trials comparing organic farming to conventional farming have been carried out in various European countries. A summary of relevant results on soil carbon content and its dynamic is presented in Table 4-4.

Various comparison trials, farm comparisons and on-farm investigations showed that organically managed soils tend to have higher total soil organic carbon contents (% C_t) than conventionally farmed arable and horticultural soils (Armstrong Brown et al. 1993; Labrador et al. 1994; Petersen et al. 1997; Pomares et al. 1994). Furthermore, in organic plots, soil carbon content either decreased less (Bachinger 1996; Capriel, 1991; Mäder et al. 1993 and 1995) or resulted in a more pronounced increase in topsoil and subsoil than in conventional plots (Diez et al. 1991; Raupp 1995b; Welp 1993). This seems to apply especially to soils with low organic matter content before conversion (Løes and Øgaard 1999).

However, in several cases no significant differences were observed in the soil carbon content of soils on organic and conventional farms (Amman 1989; König et al. 1989). These contradicting differences might depend on the stocking density of the respective farms, as was observed by Weiß (1990). Furthermore, organic farm management practices may induce a temporary higher decomposition of soil carbon. Special mention must be made here of mechanical weed control (harrowing), which is used more often and more intensly in several crops than in conventional farming, because chemical weed control measures are not permitted.

Long-term investigations support the hypothesis that organic soil management better conserves soil organic carbon. This is indicated by a higher ratio of soil microbial biomass to total soil organic carbon and a lower metabolic quotient (characterising the biomass specific soil respiration) (Mäder et al. 1995). On-farm investigations also found a higher content of microbial biomass and humic substances (Labrador et al. 1994; Petersen et al. 1997). The proportion of organic material and of CO_3H in the soil saturation extract was higher in organic citrus orchards then in conventional ones (Pomares et al. 1994). Minimum tillage is seen as an important factor of soil organic matter conservation in permanent crops such as olives (Kabourakis 1996).

Table 4-4: ***Changes of soil organic matter content from initial values in different farming systems***

Country	Organic	Conventional	Remark
Switzerland [1]			
$\%C_t$	1.53 to 1.68	1.41	comparative trial: 1980-91, differences already in initial values
Changes	-0.11 to –0.13	-0.14	
Germany [2,3,4,5]			
$\%C_t$	0.92 to 1.04	0.79	comparative trial: 1984-90, medium fertilisation level
Changes	-0.01 to –0.02	-0.04	
$\%C_t$	1.43	1.22	comparative trial: 1979-1988
Changes	+0.15	-0.03	
$\%C_t$	1.52	1.30	survey: 1985-87, 5 pairs of fields; 0-15 cm
Changes	-0.05	-0.23	
$\%C_t$	1.36	1.36	farm comparison: 1986-92; 1 pair of fields
Changes	+0.15	+0.07	
Sweden [6]			
$\%C_t$	2.53	2.51	comparative trial: 1958-1989
Changes	+0.09	+0.03	

1 Mäder et al. (1993, 1995)
2 Bachinger (1996)
3 Diez et al. (1991)
4 Capriel (1991)
5 Welp (1993)
6 Raupp (1995b)

On the whole, the conducted research review shows that organic farming provides beneficial effects to the characteristics of soil organic matter. This is due to organic farming's strong dependence on farm-internal nutrient supply (except P, K, Ca). Therefore, organic farms base their fertilisation on organic substances, such as farmyard manure from animal husbandry, compost, green manure, plant residues and commercial organic N-fertilisers. Consequently, there is an extensive supply of organic matter passing through aerobic decomposition processes. Well-balanced management helps meet nutrient demands and maintain soil organic matter supply as nutrient availability is provided by the microbial organic matter turnover. Nevertheless, the level of the soil's organic matter content, expressed in % $C_{t,}$ is primarily correlated to the site-specific conditions such as soil type, texture and precipitation. Different soils have different intrinsic capabilities to reproduce management effects in more or less changing C_t contents. The most important farm management elements for organic matter supply vary in different regions as European organic farm characteristics differ considerably between climatic zones. Organic farming in the Northern countries is characterised by a high percentage of leys in crop rotation because animal husbandry is the dominant farm type. Sustained soil organic matter content and composition on organic farms in the Mediterranean countries is based on plant residues and green manure as a consequence of low stocking densities and the resulting necessity of importing animal manure (Persson 1994, Pomares et al. 1994, Vizioli 1998).

4.2.1.2 Biological activity

Biological activity is an important indicator of the decomposition of soil organic matter within the soil. High biological activity promotes metabolism between soil and plants and is an essential part of sustainable plant production and fertiliser management. Earthworms, as a key species for soil macro-fauna, are an appropriate indicator of soil's biological activities due to their sensitivity to any kind of soil disturbance. Microbial activity of soils is an indicator of soil micro-fauna. Both indicators are reviewed below.

Earthworms and meso fauna

Research focusing on the earthworm as a key species investigates earthworm biomass, abundance, population characteristics and subspecies.

A high supply of organic material from plant residues and manure provides favourable living conditions for earthworms and other fauna in soils. A synthesis of relevant scientific results by Pfiffner et al. (1997), comparing organic and conventional farming systems, concluded that the following generally occurred:

- a significantly higher biomass and abundance of earthworms;
- a significantly higher diversity of earthworm species; and
- changes of population composition, indicated by more anecic and juvenile earthworms in organically farmed soils (Alföldi 1995; Bauchhenss 1991; Bauchhenss and Herr 1986; Braat and Vereijken 1993; Christensen and Mather 1997; Gehlen 1987; Mäder et. al. 1996; Maidl et al. 1988; Necker 1989; Paoletti et al. 1995; Pfiffner 1993; Pfiffner and Mäder 1997; Sommagio et al. 1997).

This is probably due to the fact that organic farming depends more on a high, sustained supply of organic substance from plant residues and manure than conventional farming which can rely at least partly on the mineral supply of nutrients. The inclusion of grass leys, preferably of several years (>2 years), into farming systems seems to be of special importance with respect to earthworm mass (Neale 1998; Rhône-Poulenc 1997; Scullion 1998).

Organic farming systems rely more on mechanical weed control and in certain crops on considerably more intensive soil tillage as the use of synthetic herbicides is prohibited. This can have negative effects on other key species of soil meso-fauna, i.e. a reduction of population of *Collembola* with organic cultivation (Krogh 1994).

Soil microbial activity

The parameters for characterising soil microbial activity used in the reviewed research results are total microbial biomass, diverse enzymatic parameters, carbon turnover parameters and mycorrhization.

Gelöscht: mycorrhisa

All relevant comparative trials and on-farm investigations conducted either to observe soil processes after conversion or to improve plant nutrition strategies found:

- an improvement of microbial activity correlated with the period the soils were farmed organically;
- a 20-30% higher microbial biomass than in the conventional systems (Alföldi 1995, Mäder et. al. 1996);
- a 30-100% higher microbial activity in organic plots in comparison to conventional plots (Beck 1991; Diez et al. 1985; Niederbudde and Flessa 1988), with a particularly positive impact of biodynamic treatments (Mäder 1997);
- higher microbial diversity in organic plots than in conventional (Fliessbach 1998; Fliessbach and Mäder 1997);
- higher efficiency in organic carbon turnover in organic plots (Mäder et al. 1995);
- organic plots showed a more efficient use of available resources by soil organisms as indicated by a lower metabolic quotient for CO_2 and a higher incorporation of ^{14}C labelled plant material than conventional plots (Fliessbach 1998; Fliessbach and Mäder 1998);
- higher mycorrhization in soil under organic than conventional winter-wheat, cover crops (vetch-pea-rye mixture) and clover-grass (Mäder 1997; Mäder et al. 1993);
- a higher level of mycorrhizal infection and spores in organic than in conventional grassland soils (Scott et al. 1996); and
- a higher number and abundance of saprophytic soil fungi with a higher potential of decomposition of organic material (Elmholt 1996; Elmholt and Kjøller 1989).

The results of one long-term investigation are listed as an example in detail in Table 4-5. The positive effect of the organic treatments was observed for almost all parameters of microbial activity.

Table 4-5: ***Soil microbiological properties after 12 years of farming - relative results to conventional (=100%), DOC-trial***

Parameter	Control[1]	Organic	Conventional[2]	Mineral[3]
Biomass (SIR)	78	117 – 134	100	82
Biomass (ATP)	94	110 – 125	100	95
Dehydrogenase	68	135 – 158	100	80
Catalase	88	121 – 130	100	91
Protease	58	134 – 168	100	87
Alcaline phosphatase	48	155 – 233	100	87
Saccharase	75	117 – 135	100	94
C-mineralisation	93	108 – 112	100	96
N-mineralisation	92	95 – 98	100	91
Metabolic quotient	123	82 – 92	100	117
Decomposition of cellulose				
Laboratory	80	85 – 89	100	105
Field	65	62 – 81	100	87
Mycorrhiza	208	130 – 139	100	95

Source: Mäder et al. 1995

[1] zero fertilisation
[2] organic and mineral fertilisation
[3] mineral fertilisation only

However, as the level of biological activity changes very slowly in response to varying fertilisation levels and cultivation techniques, no differences in microbial activity between organic and conventional plots were observed in several on-farm investigations (König et al. 1989, Maidl et al. 1988, Necker et al. 1992). Any experiment trying to assess these changes requires 8-10 years of post-conversion farming (Peeters and van Bol 1993; Rinne et al. 1993).

To summarise: the reviewed research results lead to the conclusion that with respect to the environmental indicator "soil activity", organic farming clearly performs better than conventional farming. The main reason for this is that organic farming aims at organic fertilising management based on crop rotations with clover/grass ley, underseeds, catch crops, green and animal manure.

4.2.1.3 Soil structure

The environmental significance of favourable soil structure lies in an improved resistance to structural soil damage, such as compaction and erosion. Soil structure can be measured by a diverse number of physical parameters, such as the stability of aggregates, coarse pores, air capacity and water holding capacity.

Maidl et al. (1988) and García et al. (1994) found a higher aggregate stability in organic than in conventional soils. This is a result of more phases of soil recreation, rotations including clover grass, application of organic manure and flat tillage. On the other hand, several research studies (Diez et al. 1991; Gehlen 1987; König et al. 1989; Petersen et al. 1997) found no differences in the aggregate stability of organically and conventionally managed soils.

A higher percentage of coarse pores on organically farmed soil than in conventionally farmed soils were found by Niederbudde and Flessa (1989). Research results by Diez et al. (1991) showed that compared with conventionally managed soils, the air capacity in the topsoil of organic farms tended to be higher, while it was lower in the subsoil. This can partly be due to compaction resulting from several years of clover grass cultivation with frequent passing of tractors. Also, negative results of a higher soil penetration resistance was found by Maidl et al. (1988) although no differences between the farming systems were found as far as water holding capacity is concerned (Diez et al. 1991).

However, in most relevant long-term trials, no differences in soil physical parameters between organic and conventional farming systems could be observed (Alföldi et al. 1993; Meuser 1989; Niggli et al. 1995). Even after 14 years, no difference in total and macro pore volume, bulk density, and soil stability was observed and no positive correlation of soil biological parameters and physical parameters was detectable (Alföldi et al. 1993). In almost all other cases a positive effect of organic farming on soil structure could not be confirmed, and, if at all, only for topsoil (Maidl et al. 1988). A significantly improved soil structure was only observed when soils were managed organically for decades (Malinen 1987). Therefore, on-farm investigations often cannot find any differences between the farming systems with respect to soil structure.

In organic farming systems, plant growth results from good rooting conditions, which, in turn, depends on the spatial and chemical availability of nutrients resulting from microbial activity and the exchange of water and air. Thus, favourable soil structure is of higher importance in organic farming systems than in conventional ones. The research results reviewed showed no distinct differences between the farming systems. An improvement in soil structure can only be observed after decades of farming organically.

4.2.1.4 Erosion

Soil erosion by wind and water is a world wide problem (Pimentel et al. 1995). It is assumed that erosion is the main cause of soil degradation around the world (Oldeman, 1994). The effects of soil erosion occur on eroded fields (on-site effects) and downstream (off-site effects). On-site effects include the loss of fertile topsoil and changes soil water dynamics, nutrient status, soil organic matter characteristics, soil organisms and soil depth, and thus result in lower yield capacity. The off-site effects are mainly undesired nutrient, pesticide and sediment inputs to surface waters. Although erosion partly depends on site specific risk factors, such as topography and climate, the extent of damages by soil erosion can be limited by farm management practices.

There are diverse indicators to measure the risk of soil erosion on different sites. The main interest of this study are the effects of the farming system, independent of site-specific risk. It focuses on the indicator agricultural measures, as expressed in the cropping factor of the Universal Soil Loss Equation (USLE).

Hausheer et al. (1998) developed a ”soil protection index” of selected parameters of soil erosion risk. Investigations of organic and integrated farms in comparison to conventional farms found a higher soil protection index on organic and integrated farms in 80% and 85% of the cases respectively than on conventional farms within only one year. There were more organic than integrated farms with a very high soil protection index. This soil erosion controlling potential of organic farming is due to:

- diverse crop rotations with a high percentage of fodder legumes;
- a high percentage of intercrops and underseeds, both aiming at year round soil cover;
- fewer row crops (e.g. sugar beet, maize); and
- a sustained supply of stable manure, resulting in higher soil intrinsic stability due to higher stability of aggregates and more biopores etc. (Arden-Clarke 1987; Auerswald 1997; Dabbert and Piorr 1998; Kerkhoff 1996; Piorr and Werner 1998; Pommer 1992; Unwin et al. 1995).

In permanent crops such as apples, citrus fruits or olives, the risk of erosion is usually reduced by vegetation cover and minimum tillage with a low frequency in soil disturbance (Kabourakis 1996, Pajarón et al. 1996).

However, in organic crop production, the following factors might increase the risk of erosion in comparison to conventional systems:

- frequent soil disturbance by mechanical tillage;
- wider row distances when seeding cereals;
- slower juvenile development of the crops due to lower N-availability; and
- premature breakdown of crops due to diseases (Auerswald 1997).

In total, these factors seem to contribute less to the erosion potential than the soil conserving factors mentioned above, as shown by calculations from comparative farm investigations. Usually, organic farming systems are characterised by a lower C-factor than conventional farming systems. The C-factor (tillage and coverage factor) describes soil losses at a slope relative to soil losses at full fallow (Schwertmann et al. 1990) as figured in the Universal Soil Loss Equation. This is due to the beneficial effects of typical organic crop rotations. Soil tillage effects remain minor in comparison to these beneficial effects (Dabbert and Piorr 1998). On the other hand, highly effective soil erosion minimising measures like direct drilling and mulch-drilling can be found more often on conventional farms than on organic farms as these measures require specific herbicide management.

As more area is needed to produce the same amount of food on an organic in comparison to a conventional farm, another factor concerning soil erosion must be noted. The fact that any kind of soil cultivation increases the risk of soil erosion in comparison to soil covered by natural vegetation could result in higher erosion potential. However, even though quantitative research results are somewhat scarce in this area, organic farming comprises a high potential to reduce soil erosion risk.

4.2.1.5 Summary: Soil

The maintenance and improvement of soil fertility is a central objective of organic farming, especially since many indirect regulation factors for crop management are based on a well functioning soil-plant relationship.

The impact of organic farming on soil properties has been covered comprehensively by research in most aspects. Information is somewhat scarce only with respect to soil erosion. Research shows that organic farming tends to conserve soil fertility and system stability better than conventional farming systems:

- Organic matter content is usually higher in organically managed soils than in conventionally managed ones. However, soil organic matter content is highly site specific.
- Organically farmed soils have significantly higher biological activity than those conventionally farmed.
- As far as soil structure is concerned, most research results found no difference between the farming systems.
- Although quantitative research results are scarce, the research review concluded that organic farming has a high erosion control potential.

Changes in soil fertility are long-term-developments and significant effects often do not result for 8 years. The assessment of organic farming's impact on soil is shown in Table 4-6.

Table 4-6: Assessment of organic farming's impact on the indicator subcategory "Soil" compared with conventional farming

	++	+	0	–	– –
Soil organic matter		■	■		
Biological activity	■				
Structure			■		
Erosion	■	■	■	■	
Soil total	■	■	■	■	

Legend:	Organic farming performs: ++ much better, + better, o the same, – worse, – – much worse than conventional farming
	Subjective confidence interval of the final assessment marked with

4.2.2 Ground and surface water

The protection of ground and surface water has major environmental priority because any contamination may cause a risk for its use in human and animal nutrition and may disturb aquatic biocoenosis. The OECD-indicator list (OECD 1997) subsummarises state and risk assessment approaches under this issue. We will confine our efforts to indicators that are appropriate to evaluate the impact of different farm management practices.

Detrimental effects of agriculture on ground and surface water are largely due to erosion and to the leaching or run-off of substances. Erosion has been covered in section 3.2.1. Phosphate leaching is an issue that is relevant in very few areas of the EU due to extreme high animal density. Because stocking density in organic farming is limited, it is highly likely that organic farming does not contribute to this problem. However, no detailed information was available on this issue.

In this section, we concentrate on indicators that are appropriate for evaluating the impact of different farming systems on water quality, such as nitrate leaching and pesticides.

Some of the most important threats to water quality are:

- high organic fertilisation level in combination with high stocking rates;
- excessive application of mineral N-fertilisers;
- lack of protective soil cover;
- narrow crop rotation and frequent tillage; and
- a high level of available nitrogen after harvest.

4.2.2.1 Nitrate leaching

Groundwater contamination by nitrate leaching from agricultural soils is a problem in many European areas. In contrast to other undesired environmental effects, water contamination with nitrate is mainly caused by agriculture. It occurs when more nitrate is available to the soil than plants can use, when water from rain, irrigation or snowmelt moves through the soil into the groundwater. Excessive nitrogen in the soil can be due to fertiliser or manure applications or nitrogen fixation by leguminous crops. Nitrate in waters can lead to eutrophication with excessive algal growth and toxic contamination of drinking water for humans and animals. In the last 15 years, many activities were undertaken to screen the problem of nitrate leaching and to evaluate measures of avoidance.

Following is an overview of the most important results from long-term trials, investigations and net screenings. Comparative long-term trials provide the most realistic picture of the effects of the risks associated with different farming systems. On-farm investigations give an overview of the range and permit conclusions with regard to local characteristics, referring primarily to the state of an indicator. Net screenings are based on broad monitoring activities and represent evaluations generally used for political assessments.

The most common parameters to describe the indicator ”nitrate leaching” are:

a) the nitrate leaching rate; and

b) the potential for nitrate leaching.

N-management practices to attain environmental sustainability are expected to have both low nitrate leaching potential and low nitrate leaching rate.

Nitrate leaching rate

The nitrate leaching rate can be described by the N-concentration in the leaching water and the amount of leakage water. Table 4-7 shows research results indicating nitrate leaching rates with respect to a per hectare and a per output unit scale.

Table 4-7: ***Nitrate leaching rates from organic farming relative to conventional farming systems (farm comparisons)***

Reference scale	Compared with conventional farming the nitrate leaching rates in organic farming systems are			Author
	lower	similar	higher	
per hectare				
	> 50%			Smilde (1989), Vereijken (1990)
	57%			Paffrath (1993)
	40% [1]	[2]		Blume et al. (1993)
	50%			Reitmayr (1995)
per output				
grain		[1]	[2]	Fink (1997)
milk			10%	Lundström (1997)

[1] sandy soil
[2] loamy soil

The results from relevant farm comparisons presented above show that the nitrate leaching rates in organic farming systems in most of the studies are significantly lower compared to those of conventional farming systems. Only on loamy soil did Blume et al. (1993) find nitrate leaching rates similar to conventional farming. Hege et al. (1996) corroborated these results of significantly lower nitrate concentrations in the leakage. In on-farm investigations, they observed a 50% decrease in nitrate concentration in leakage within 4 years after conversion (Hege et al. 1996).

It is interesting to note that if the nitrate leaching rate is related to the output of grain and milk, organic systems tend to perform similar or even worse than conventional systems.

Only modest losses due to leaching were observed during monitoring of a horticultural unit of an organic farm with more than 500 kg N/ha in one single application and often more than 300 kg N/ha and year through manure applications considering the large amounts applied. However, the drained water contained more than the admissible concentration of 11.3 mg/l in five out of the six consecutive sampling dates (Watson et al. 1994).

Potential for nitrate leaching

The appropriate parameters to measure the potential for nitrate leaching during the non-vegetative period are the N_{min}-N content in soil in autumn and the N-balance. As the latter will be the subject of Chapter 3.3.1, this section will concentrate on the impact of organic farming on the N_{min}-N content in the soil.

Results from relevant long-term trials seem somewhat contradictory in connection with nitrate leaching potential. This is due to the fact that most trials are conducted with Nt-equality of the compared systems or even equal organic manure application rates. While no differences between organic and conventional systems were observed in the Swiss DOC trial (Alföldi et al. 1992), another long-term trial (Darmstadt) showed varying tendencies: Wessolek et al. (1989) and Meuser et al. (1990) observed higher nitrate leaching potential whereas later investigations found lower potentials (Bachinger 1996).

Varying results were also obtained in comparative on-farm investigations. While Pfaffrath (1993) found no differences in the N_{min}-N/ha content in autumn between organically and conventionally managed soils in the five year investigations, Van Leeuwen and Wijnands (1997a and b) observed N_{min}-N/ha contents in autumn in organically managed soil at Nagele, Netherlands which were 50% higher than the conventionally (integrated) managed one (in field vegetable production with very high import of manure). Rinne et al. (1993) mention that the post harvest release of soluble nitrogen into soil might be higher in organic than in conventional farming. On the other hand Brandhuber and Hege (1992) conducted a deep layer analysis and reported that the N_{min}-N/ha content in autumn on the organic farms was 60% lower than on the conventional farms compared. Another investigation on three different sites over a period of three years observed a range from 23 kg/ha lower to 15 kg/ha higher soil N_{min}-N/ha content in autumn on organic farms in comparison to neighbouring conventional farms (Meyercordt 1997). Various other investigations also contribute to the assumption that organic farming has a lower nitrate leaching potential than conventional farming systems (Berg et al. 1997; Eltun and Fugleberg 1996; Hege et al. 1996).

Recently, extensive data has been published based on large scale surveys obtained by official national or country-specific nitrate screening of water protection areas in Germany and Denmark (Table 4-8). These screenings represent a broader picture based on profound data bases. They often include integrated farming systems focusing on reduced N-fertiliser application and advisory standards in their assessment. The results presented in Table 4-8 indicate that organic farming results in a lower or at least similar potential for nitrate leaching into ground and surface water. Furthermore, the absolute values generally do not exceed the critical level. Nevertheless, it has to be kept in mind that the difference in the nitrate leaching potential between organic farming and integrated systems, or systems using extensification measures, have become smaller in recent years due to improved conventional management of mineral N-fertilisation (Piorr and Werner 1998). This seems to apply especially to water reclamation areas with high advisory standards and extensive control measures.

Table 4-8: Nitrate screening in water protection areas: Results of kg N_{min}-N/ha content* of organic fields relative to conventional fields

Crop	Result	Relative to conventional conventional = 100	n	Country
Not specified	lower	80	1220	DE[1]
	lower	60	9	DE[2]
	similar	–	26	DK[3]
Cereals	similar	–	614	DE[1]
Potatoes	similar	–	71	DE[1]
	lower	75	7	DE[4]
Oil seeds	lower	70	14	DE[1]
Maize	lower	60	50	DE[1]
Fodder legumes	similar	–	174	DE[1]

* soil (0-90 cm) in autumn, conventional and organic with 20% N-fertilisation reduction
[1] Übelhör (1997)
[2] Kurzer et al. (1997)
[3] Kristensen et al. (1994)
[4] Baumgärtel (1997)

Estimates on nitrate leaching, based on model calculations, indicated losses of 27 kg/ha per year at a stocking density which corresponds with Fertiliser Units (FU) of 0.9 FU/ha and 32 kg/ha at a stocking density of 1.4 FU/ha (Askegaard and Eriksen 1997). A model calculation, which compared the complete conversion of the German state of Brandenburg to the current status, estimated a potential for the reduction of nitrate leaching amounting to 17 - 26 kg N/ha. These results are also valid under the assumption of an increasing proportion of legumes in the rotation of up to 40% (Piorr, H.P. et al. 1997).

Although not all the results reviewed support the hypothesis that organic farming results in less nitrate leaching than conventional farming, a strong tendency towards a decreased risk of and absolute levels of nitrate leaching can be deduced.

The nitrate load from organically cultivated soils tends to be lower than from conventionally cultivated ones because:

- the stocking rates and thus fertilisation levels are lower than in the conventional mean and overall N-input in organic farming systems is lower because their application is bound to organic manure and its incorporation into the soil, and nutrient availability of stable manure is lower than of slurry due to its mixture with straw (Dabbert and Piorr 1998);

Gelöscht: ¶

Gelöscht: ¶

- applied stable manure results in a lower risk from run-off than slurry; and
- extensive rotations of various crops, extensive soil covers during winter, intercrops, underseeds, and fallows of several years are more common in organic than in conventional farming (Leclerc 1995; Nocquet et al. 1996).

However, two critical areas for potential water pollution by organic farming have been identified and extensively investigated:

a) the composting of stable manure; and

b) the management of residual nitrogen from legumes.

Extensive storage and composting of farmyard manure on non-paved surfaces can result in leakage into and contamination of ground and surface water (Berner et al. 1990; Dewes 1997; Dewes and Schmitt 1995; Heß et al. 1992). As this depends on the dry matter content of the manure, leakage can be avoided by covering the manure piles, adding mineral powder (e.g. bentonite) and including a pre-rotting phase on paved ground (Dewes 1997; Dewes and Schmitt 1995).

Gelöscht:

Considerable nitrate leaching can also occur when the N-pool accumulated by legumes is poorly managed, i.e. by grubbing clover grass in early autumn and subsequently sowing crops with low N-demand. In this case, high mineralisation of up to 80-100 kg N_{min}-N/ha, and subsequent nitrate leaching rates of up to 50 kg NO_3-N /ha, may occur (Fiedler and Elers 1997; Heß 1989 and 1995; Heß et al. 1992; König 1995; NRA 1992; Piorr 1992 and 1995; Reents 1991; Reents and Meyer 1995; Stein-Bachinger 1993).

Generally, the element most susceptible to nitrate leaching of organic crop rotations are clover grass ley elements. Their nitrate leaching potential is 74 – 250 kg NO_3 –N/ ha (NRA 1992). However, the frequency of tillage of clover grass leys within a crop rotation is low (every 6-7 years). A non-comparative on-farm investigation of total nitrate leaching from arable crops and grass estimated a mean N-load of 10-21 kg/ha per year, depending on the farm and crop rotation. This leads to the conclusion that appropriate nitrogen management of individual crops can help considerably in reducing the nitrate leaching potential of whole rotations

(EFRC 1992, Phillip and Stopes 1995). Especially in recent years, efficient strategies of transferring leguminous born N into the nutrient cycle without losses were developed and put into practise (Dabbert and Piorr 1998; Heß et al. 1992; Justus and Köpke 1990 and 1995).

To summarise: the reviewed material showed that the nitrate leaching rate of organically managed soils is lower than that of conventionally managed ones. As far as the potential for nitrate leaching in terms of soil N_{min}-N/ha content in autumn is concerned, the studies reviewed came to varying conclusions. While long-term studies and comparative on-farm investigations show contrasting results, nitrate screenings indicate that the soil N_{min}-N/ha content in autumn is lower on organic than on conventional farms. Thus, it can be concluded that organic farming can contribute to water protection, especially with respect to the risk and actual rates of nitrate leaching. The growing consciousness of problematic phases, i.e. grubbing of clover ley, has resulted in improvements of organic management practices with respect to water protection targets. Especially in water protection areas sensitive to water contamination by nitrate, several national standards and special advisory services provide recommendations for organic farmers such as:

- reducing livestock density;
- using appropriate animal husbandry practices (NRA 1992);
- limiting the use of liquid manure;
- using compost with a high homogeneity and reduced spreading quantities; and
- increasing green manuring (Orgaterre 1997).

4.2.2.2 Pesticides

Toxic contamination of water by pesticides can result from leaching through the soil profile into ground water, by surface runoff, by erosion of contaminated soil particles, or directly by pesticide application close to surface waters. For a comprehensive evaluation of the risk of pesticide residues to the environment, the OECD (1997) recommends a risk as well as a state approach within the framework of environmental indicators.

Currently in the EU, total annual sales of pesticides per hectare amount to 4.2 kg of active ingredients/ha (Brouwer 1997). Independent of the farming system, it can be assumed that the best prevention of environmental risks associated with synthetic pesticides is not using them at all. In this respect, organic farming provides almost complete protection of natural resources as opposed to other farming systems, because the use of synthetic pesticides is completely banned (Heß et al. 1992; MAFF 1998a; NRA 1992). A trial comparing different agricultural systems observed a significant reduction of applied active ingredients per ha with an increased introduction of non-synthetic measures of pest control in integrated farming systems. Nevertheless, for most pesticides, the zero-risk that is realised in the organic system could not be reached (Table 4-9).

Table 4-9: Reduction of pesticide input in different farming systems

	Reduction of active matter/ha (%)	
	conventional[1]	organic[2]
Herbicides	46 – 80	100
Fungicides	26 – 93	100
Insecticides	25 – 89	100
Growth regulators	53 – 59	100
Nematicides	71 - 100	100

Source: Van Leeuwen and Wijnands (1997a, b), adapted

[1] data for 1986-90
[2] data for 1992-95, biodynamic

The risks associated with pesticides that are in use in organic farming have hardly been investigated. Most pesticides allowed in organic farming are of natural origin such as silicates or extracts of medicinal plants. As far as active ingredients are concerned, only three are permitted: Rotenone, pyrethroids and copper.

So far no water contamination by these active substances has been reported, although this might simply be due to the fact that they might not yet have been included in monitoring programs (Unwin et al. 1995). Most likely, however, this is due to the fact that both pyrethroids and rotenone are highly non-mobile in soil. Furthermore, pyrethroids are only slightly persistent and rotenone is impersistent. Therefore, the risk of water contamination by these substances is low, especially when other factors, such as the extremely low application rates, are taken into account. Copper occurs naturally in soils and water and is therefore difficult to monitor as contamination resulting from pesticide application. It is not clear whether copper from pesticide use can be identified in groundwater or have any significant impact on water quality and aquatic environments, although the influence of copper-based pesticides on metabolic processes can be deduced theoretically. In conclusion, it can be said that these might enter water resources only through misuse or accidental spill (Unwin et al. 1995).

Based on results published so far, a threat to water quality by the pesticides permitted in organic farming can not be assumed. Together with the fact of the complete absence of synthetic pesticides, however, a conclusive assessment of organic farming with respect to the environmental indicator "contamination of water by pesticides" has to be rated as highly superior as compared to conventional farming.

4.2.2.3 Summary: Ground and surface water

Based on a review of published and grey literature on this issue, it can be concluded that the ban of mineral N-fertilisers and synthetic pesticides on the one hand, and the low level of nitrogen cycling within the farm because of low livestock densities on the other, are important contributions which organic farming makes to water protection.

In detail, the following conclusions can be drawn:

- Organic farming results in lower or similar nitrate leaching rates than integrated or conventional agriculture, as shown by low autumn N_{min}-N residues in the soil of almost all relevant crops. However, the differences are becoming smaller with increasing implementation of water protection measures in conventional farming (Dabbert and Piorr 1999).
- Farm comparisons show that actual leaching rates per ha are up to 57% lower on organic than on conventional fields. The leaching rates per production unit (t of crop, kg of milk) were similar or slightly higher.
- Farm yard manure composted uncovered and on unpaved surfaces can be a focal point of nitrate leaching.
- Critical situations concerning nitrate leaching may arise from ploughing legumes at the wrong time or being followed by unfavourable crops. However, consciousness of the problem and its handling has increased recently and alternative measures have been developed and introduced in organic farming practise.
- Organic farming poses no risk of ground and surface water pollution by synthetic pesticides. The active ingredients of permitted pesticides have not been properly monitored nor their effects sufficiently investigated.

Even though incorrect organic farm management practices could indeed bear some potential risks of polluting ground and surface water, the detrimental environmental effects from organic farming tend to be generally lower than those of conventional farming systems. Thus organic farming is the preferred agricultural system for water reclamation areas.

A conclusive assessment of the effects of organic farming on ground and surface water is given in the following table (Table 4-10):

Table 4-10: Assessment of organic farming's impact on the indicator subcategory "Ground and surface water " compared with conventional farming

	++	+	o	–	– –
Nitrate leaching					
Pesticides					
Ground and surface water total					

Legend: Organic farming performs: ++ much better, + better, o the same, – worse, – – much worse than conventional farming

Subjective confidence interval of the final assessment marked with

4.2.3 Climate and air

The climatic change (greenhouse effect) is globally recognised as one of the most relevant environmental problems. The gases contributing to the greenhouse effect mainly include carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). These gases have varying global warming potentials, which can be expressed in CO_2 equivalents. The OECD (1997) prefers indicators for agricultural greenhouse gases on a net balance basis of the release and accumulation of CO_2, N_2O and CH_4, rather than measuring gross emissions. However, all methods for calculating emission and sink of greenhouse gases currently bear a high potential of uncertainty (OECD 1997).

The increase of greenhouse gases is caused anthropogenically. Agriculture contributes 15%, rain forest destruction 15%, chemistry (production and application) 20% and energy and traffic 50% (EK 1990). Agriculture also provides a sink for greenhouse gases, with soil as a major sink of CO_2 due to the fixation of carbon by crops and pasture.

Besides the environmental effects of greenhouse gases, agriculture also contributes to air contamination by ammonia volatilisation (NH_3) and pesticide sprays. Therefore, this section is entitled "climate and air", and focuses on the greenhouse gases CO_2, N_2O and CH_4, as well as on NH_3 and pesticide sprays.

4.2.3.1 CO_2

CO_2 is the most important gas relevant to climate and as such, is responsible for the greenhouse effect with 22% (Schönwiese 1995). CO_2 emissions are produced by burning fossil energy. Thus, agriculture's contribution to CO_2 emission derives from both direct consumption of oil and fuel and indirect consumption of energy (e.g. production and transport of fertilisers, pesticides).

Data available on CO_2 primarily deals with gross emission calculations on commodities and on a per hectare scale, whereas no research results can be presented on CO_2 net balances in agriculture.

Several authors (Haas and Köpke 1994; Lundström 1997; Reitmayr 1995, Rogasik et al. 1996) calculated and compared CO_2 emissions for different crops and for milk with respect to organic and conventional farming.

As far as crops are concerned, specific differences exist due to differences in the input of mineral N-fertilisers and tillage intensity. Table 4-11 shows different calculations both on the emissions per hectare and per production unit. Due to the high level of mineral N-fertilisation used in conventional farming, the organic production of winter wheat has significantly lower CO_2 emissions/ha than in conventional systems. Estimates on the CO_2 emissions per ton showed varying results depending on the assumption of yield levels. The production of potatoes in organic farming is associated with lower CO_2 emissions/ha but tends toward higher CO_2 emissions/t due to a high energy input for mechanical measures in both systems and a low conventional mineral N-fertilisation level.

Table 4-11: ***CO_2 emissions (kg) in winter wheat and potato production - comparative calculations from different authors***

Authors	CO_2 emission per ha			CO_2 emission per production unit		
	conventional	organic	%	conventional	organic	%
	winter wheat (kg CO_2/ha)			**winter wheat (kg CO_2/t)**		
Rogasik et al. (1996)	826	443	-46	190	230	+21
Haas/Köpke (1994)	928	445	-52	140	110	-21
Reitmayr (1995)	1 001*	429	-57	145*	100	-21
	potatoes (kg CO_2/ha)			**potatoes (kg CO_2/t)**		
Rogasik et al. (1996)	1 661	1 452	-13	46	62	+35
Haas/Köpke (1994)	1 437	965	-33	46	48	0
Reitmayr (1995)	1 153*	958	-17	30*	45	+50
	milk			**milk (g CO_2/kg milk)**		
Lundström (1997)	–	–	–	203	212	+4

* integrated farming

A case study of 6 conventional and 6 organic dairy farms in Sweden estimated that the average emission of CO_2/kg milk is somewhat higher on organic farms than on conventional ones (Lundström 1997). The main reason is that tractors were used for more hours (Lundström 1997). In comparison Lampkin (1997) estimated that the CO_2 emissions per kg milk were significantly lower on organic dairy farms using standard data and physical input and output coefficients for organic and conventional dairy farms in the UK. Lampkin reasons that this is due to reduced fossil energy inputs per kg milk.

More general calculations on CO_2 emissions per hectare, based on average farm characteristics (crop management, rotation), are provided by Dämmgen and Rogasik (1996), Rogasik et al. (1996), Haas and Köpke (1994) and SRU (1996) and are shown in Table 4-12.

Table 4-12: Mean CO_2 emissions per hectare: calculations for Germany (in t/ha)

	Conventional	Organic	As percentage of conventional
Haas and Köpke (1994)	1.25	0.50	40%
SRU (1996)	1.75	0.60	34%
Rogasik et al. (1996)	0.73	0.38	52%

Table 4-12 shows that CO_2 emissions/ha for organic farming are 48 - 66% lower than for conventional farming. On the other hand, although the yields in organic farming are lower, the sink capacity of conventional and organic plant production, amounting to 23 t/ha per year, is calculated to be equal in both farming systems (Köpke and Haas 1995). The reason is that specific crop rotations have higher proportions of crops with high root growth and a higher percentage of intercrops, catch crops, underseeds and weeds. Hence, on this basis, the input-output-relation for CO_2/ha in organic systems is twice that of conventional farming systems (Köpke and Haas 1995).

To summarise: on the basis of gross emission calculations, most studies find a lower CO_2 emission in organic systems on a per hectare scale. But on an output unit scale, varying results were presented. Organic farming tends to be lower on the one side but higher than conventional farms on the other. The most important factor in this context is the potential yield that can be achieved in organic systems. The reasons why on a per hectare scale, organic farming has positive effects on CO_2 emissions, are mainly due to the major characteristics of organic farming laid down in the organic standards:

- no input of mineral N-fertilisers with high energy consumption;
- lower use of high energy consuming feedstuffs (concentrates);
- lower input of mineral fertilisers (P, K); and
- elimination of pesticides.

But it needs to be emphasised that no research is available which analysed CO_2 emissions and accumulations of different farming systems in a net balance approach.

4.2.3.2 N_2O

N_2O contributes to the greenhouse effect with 4% (Schönwiese 1995). N_2O emissions from agriculture come from mineral and organic N-fertilisers and from leguminous crops. The emission levels depend on the kind of fertiliser and on the application technique. The N_2O emission factors for the most frequently applied forms of mineral N-fertilisers are < 0.5%, for organic manure 1.0 - 1.8% and for N from legumes, about 1% of the fixation rate.

Research that compares N_2O effects in agriculture of different farming systems is scarce. There is only one quantitative study available focusing on NO_x emissions of dairy farms on a production unit scale (Lundström 1997). However, no information is available on N_2O net balances.

Lundström (1997) estimated NO_x emissions in a case study on 6 conventional and 6 organic dairy farms in Sweden. He found slightly higher NO_x emissions per kg milk on organic dairy farms than on conventional dairy farms. The NO_x emissions in the organic farms amounted to 4.49g NO_x/kg milk, while for conventionally produced milk he estimated 4.31g NO_x/kg milk.

There are few analytical results from comparisons of converting farms, which show:

- no significant differences between the farming systems (Flessa et al. 1995); and
- a trend for slightly higher emissions in integrated farming systems (Reitmayr 1995).

As quantitative data is not available, several authors deduced the N_2O risk-reducing factor of organic farming on the basis of the organic standards (Kilian et al. 1997; Köpke and Haas 1997; Piorr and Werner 1998; Unwin et al. 1995) and stressed that organic farming has

- a low N-input;
- less N from organic manure due to lower livestock densities;
- a higher C/N-ratio of applied organic manure; and
- less available (mineral) nitrogen in the soil as a source for denitrification.

Certain farm management practices are assessed to have a diminishing influence on the N_2O emission rates. Unwin et al. (1995) argue that organic farming has the potential to reduce N_2O emissions because of the emphasis on improved drainage and reduced practice of minimal tillage and direct drilling without herbicides which have been found to release higher N_2O emissions.

The following factors may increase N_2O emissions, specifically in organic farming systems (Piorr and Werner 1998):

- the higher proportion of legumes;
- possible N-losses in the form of N_2O during the composition of manure; and
- a possibly higher intensity of tillage that stimulates the mineralisation of soilborn N and results in N_2O emissions. This potential, however, is estimated to be marginal (Kilian et al. 1997).

Several authors (Kilian et al. 1997; Köpke and Haas 1997; Piorr and Werner 1998; Unwin et al. 1995) concluded on the basis of these arguments that the N_2O emission potential per hectare is lower on organic farms than on conventional farms.

The literature review on N_2O emissions did not lead to a profound basis that would allow final conclusions on farming system effects with respect to N_2O emissions. Most information available is based on deduction, while only one study provides quantitative data. Data on N_2O net balances, however, is non-existent. Thus, currently no differences on N_2O between the organic and conventional farming systems can be identified.

4.2.3.3 CH_4

CH_4 is responsible for the greenhouse effect in about 2.5% of the cases (Schönwiese 1995). CH_4 emissions from agriculture derive primarily from ruminant livestock. Up to 80% of CH_4 emissions come from digestive metabolism, whereas 20% develop from excretion. In the latter context, liquid manure systems bear a higher potential of CH_4 release than stable manure systems.

Research results on CH_4 emissions comparing different farming systems are scarce. However, several authors estimated CH_4 emissions in organic and conventional farming systems on the basis of their expert knowledge. The important factors to be considered for deduction on a per hectare scale are:

- livestock density;
- production period per cow;
- manure system; and
- the percentage of ruminants.

Livestock density on organic farms is (see Chapter 3.1) lower than on conventional farms. The productive period of cows is higher on organic dairy farms. This is important, as the proportion of the non-productive juvenile phase is lower than on conventional farms. This results in lower CH_4 emissions (Sundrum and Geier 1996). The organic standards require, that straw-based housing systems be used in livestock production. A lower potential of CH_4 emission on organic farms is implied because stable manure has a significantly lower metabolic factor for methane than liquid manure. The percentage of ruminants on organic farms amounts to 80%, versus the 60% ruminants on conventional ones. This fact could lead to higher CH_4 emissions on organic farms, but is kept in balance as livestock density is generally lower in organic farming. Unwin et al. (1995), Köpke and Haas (1997), Lampkin (1997) and Piorr and Werner (1998) estimate the CH_4 emission per hectare to be lower on organic than on conventional farms as a result of this reasoning.

On an output unit scale information is available only on dairy farms which considers the factors of feedstuff, growth rate and production capacity. Metabolic methane emissions are stimulated because the fodder management is based on roughage and low energy concentration. On the basis of investigations on 6 conventional and 6 organic dairy farms, Lundström (1997) estimates that CH_4 emissions will increase by 8-10% on organic dairy farms due to the higher intake of roughage. The total energy uptake is lower and slower growth rates may result in more food consumption per production unit. Milk production capacity is 20% lower on organic dairy farms than on conventional ones (Unwin et al. 1995). Accordingly CH_4 emissions per kg milk are estimated to be higher on organic dairy farms (Piorr and Werner 1998).

Generally, a change from highly intensive agriculture to a more extensified level could have negative impacts on the emission of greenhouse gases. A study of the future farming system in Sweden states that CH_4 emissions will increase in environmentally adapted agriculture systems due to a higher number of CH_4 emitting animals (Naturvårdsverket 1997).

As far as CH_4 accumulation is concerned, soils can oxidise CH_4 and thus act as a CH_4 sink. Research indicates that CH_4-self-regulationt might be more efficient in organic farming than in conventional farming. Biological methane oxidation capacity is up to double the amount in organically fertilised soils without applications of mineral N-fertilisers in comparison to conventional soils (Hansen 1993; Hütsch et al. 1997). However, research on CH_4 emissions is so scarce that environmental resource use impacts of organic farming can neither be assessed on CH_4 net balances, nor on other quantitative data. The literature review conducted only allows making the following conclusions on the basis of expert knowledge:

- organic farming might have lower CH_4 emission potential on a per hectare scale;
- while on an output unit scale, the CH_4 emission potential tends to be higher than in conventional farming systems (only valid for milk production).

However, as there is no profound data basis available, no differences between the farming systems with respect to CH_4 emissions can be identified.

4.2.3.4 NH_3

Although NH_3 is not one of the greenhouse gases, NH_3-emissions cause negative environmental effects through soil acidification and uncontrolled nitrogen re-circulation. The latter is due to ammonia losses from organic and mineral fertilisers and re-import from the atmosphere to soil by precipitation.

In agriculture, the most important sources for NH_3 emissions are gaseous losses from three sources:

- surface application of mineral N-fertilisers on ammonia bases;
- surface application of liquid manure (not incorporated into the soil); and
- storage of liquid and solid manure, particularly the composting of stable manure.

As the application of mineral N-fertilisers is not permitted in organic farming systems, the following factors concerning the situation in organic animal husbandry (with regard to the emission of NH_3) have to be noted (Oomen and van Veluw 1994; Unwin et al. 1995; Vries et al. 1997):

- N-intake of feedstuffs;
- N excretion per animal;
- amount of time livestock spends in the stable;
- housing system;
- manure handling (storage and spreading method); and
- livestock density.

The N-intake from well-managed grass and clover by organic livestock is assessed to be equal to that of conventional farms (Unwin et al. 1995). However, as the N excretion is related to milk yield, which is lower in organic dairy production, the N excretion per animal subsequently may be lower (Unwin et al. 1995). The amount of time livestock spends in the stable is of concern since the ammonia losses in stables are assessed to be higher than on pasture. In this context, organic farming might have a lower potential in ammonia losses because the organic farming standards recommend maximum grazing. However, no comparative data exists on this issue.

Straw bedding manure systems do not enable the same potential of emission reduction as is technically feasible with slurry (liquid manure). Oomen (1995) argues that even though organic dairy farmers often use stall housing, the most common system is the cubicle housing system. Data from the Netherlands calculates NH_3 emission in stall housing at 5.8 kg/year and cow, which is a reduction of 34% as compared to a cubicle housing system without any environmentally beneficial measures. However, with environmentally beneficial measures, NH_3 emission from cubicle housing systems can be reduced by about 60% (Oomen 1995).

The highest NH_3-losses occur in straw-based housing systems when the manure is moved to storage (Hartung 1991). Aerobic decomposition (e.g. composting) is connected with higher losses (9-44% of N_t) than anaerobic (< 1% of N_t). NH_3

emissions from the field after the application of stable manure are negligible compared to those from slurry (Piorr and Werner 1998; Unwin et al. 1995).

A case study of six conventional and six organic dairy farms in Sweden estimates the emission of NH_3 -N per output. On average, it is slightly higher on conventional farms (4.8 g N/kg milk) than on organic ones (4.6 g N/kg milk) (Lundström 1997). For meat and milk similar NH_3 emissions per output unit are cited by Piorr and Werner (1998).

In organic poultry production, NH_3 emissions cannot be reduced in the same way as is possible using intensive battery-systems in conventional poultry systems, as battery systems with dry manure conveyor-belts result significantly lower emissions than free range systems (Oldenburg 1989). Organic pig farms can use almost the same housing system as conventional pig farms (Lenselink and Groot Nibbelink 1995). However, lower livestock densities reduce the potential of NH_3-emissions (Oomen 1995, Unwin et al. 1995). This means that lower NH_3 emissions can be deduced due to lower stocking densities both in organic poultry systems and in organic pig farms (Lenselink and Groot Nibbelink 1995).

There is a North-South gradient in absolute livestock densities in Europe. The ratio between organic and conventional livestock density is quite different between regions and countries, depending on the particular importance of organic and conventional husbandry. In the UK for instance, the mean conventional livestock density is 2.4 LU per ha, while in the organic sector livestock density amounts to 1.6-1.8 LU per ha. In Germany the mean conventional livestock density amounts to 1.6 LU per ha compared to 1.0 LU per ha on comparable organic farms. In some Mediterranean countries, organic livestock farming practically does not exist. Thus, NH_3-emissions are primarily discussed as an environmental risk in the northern countries. Livestock density in organic farming is generally lower than in conventional farming and therefore reduces the potential for NH_3 emissions. The most important reason for lower livestock densities in organic farming are maximum livestock densities defined by national and regional standards (1.4 - 2.0 LU/ha) and limited feedstuff purchase.

NH_3 emissions on a regional and national scale were calculated by Geier et al. (1998) and Haas and Köpke (1994). Geier et al. (1998) calculate approximately 30% lower total NH_3 emissions compared to conventional farming in a scenario for the conversion of the total agriculture area of Hamburg (5700 ha). Based on statistical data, Haas and Köpke (1994) calculate about 40% lower NH_3 emissions per ha in organic farming than for conventional farming in Germany. Both authors assume lower stocking densities in the organic system. The review by Unwin et al. (1995) provides a conclusive risk assessment upon which NH_3 emissions will not necessarily be lower in organic farming than in conventional. The studies reviewed in this section show that organic farming tends to bear a lower potential for NH_3 emissions than conventional farming systems.

4.2.3.5 Pesticides

Air contamination risk by pesticide agents is minimal in organic farming due to the ban of synthetic pesticides. Nevertheless, the application of powdered and fluid substances permitted by organic standards may cause a short-time impairment of air.

The exposure of certified biocides is measured at extremely low levels when compared to conventional systems in organic permanent crops, these being more prone to pests and diseases (Kabourakis 1996). Many indirect measures result in an obviously lower incidence of disease and pests. A similar or better health status of organic plants is described in greenhouses. Investigations on peppers under plastic showed less aggressiveness of the TSWV Virus in tomatoes, thus no protection treatments were necessary (Gimeno et al. 1994, Otazo et al. 1994).

Copper fungicides are of importance for blight control in organic potato production. Applying copper might cause long-term contamination of the soil, whereas effects on water quality are estimated to be marginal (see 3.2.2.2). Air contamination by spraying is connected with a comparatively negligible risk due to low volatility (Unwin et al. 1995).

4.2.3.6 Summary: Climate and air

Modern agricultural systems are accompanied by the consumption of energy and the emission of climate gases. The differences between organic and conventional farming are also reflected in varied impacts on climate and air protection taking the kind and amount of production means as well as livestock and cropping management input into consideration.

Research on CO_2 emissions show varying results:

- On a per hectare scale CO_2 emissions are 40-60% lower in organic farming systems than in conventional ones, due to the ban of mineral N-fertilisers and pesticides, low input of P and K fertilisers and lower use of food concentrates.
- On a per output unit scale CO_2 emissions are similar or tend to be higher in organic farming systems, depending on the yield assumptions of the respective crop.

Quantitative research results on N_2O emissions in different farming systems are scarce. Based on deduction, experts conclude that N_2O emissions per hectare tend to be lower on organic farms than on conventional ones, while N_2O emissions per kg milk are rather equal or higher respectively. However, due to the fact that almost no quantitative data is available, no definite differences between organic and conventional farming systems can be identified.

Quantitative research results on CH_4 emissions in different farming systems are scarce. Experts estimate that organic farming has lower CH_4 emission potential on a per hectare scale, while CH_4 emissions per kg milk are estimated to be higher in organic dairy farms than in conventional ones. However, due to the insufficient data basis, no definite differences between the farming systems can be identified.

Calculation on NH_3 emissions in organic and conventional farming systems conclude that organic farming bears a lower NH_3 emission potential than conventional farming systems. Yet housing systems and manure treatment in organic farming should be optimised towards further reduction, although they provide fewer opportunities for abatement of emissions than slurry based systems.

Significantly lower air contamination by pesticides is ensured in organic rather than in conventional farming, as synthetic pesticides are not permitted in organic farming.

A conclusive assessment of the effects of organic farming on air and climate is given in the following scheme (Table 4-13):

Table 4-13: ***Assessment of organic farming's impact on the indicator subcategory "climate and air " compared with conventional farming***

	++	+	0	–	– –
CO_2		■			
N_2O		■	■		
CH_4		■	■		
NH_3		■			
Pesticides	■				
Climate and air total		■	■		

Legend:	Organic farming performs: ++ much better, + better, o the same, – worse, – – much worse than conventional farming
■	Subjective confidence interval of the final assessment marked with

4.3 Farm input and output

The efficient and economical use of natural resources is the prerequisite for sustainable and environmentally sensitive agriculture. The resources detailed in this section are the growth factors nitrogen, phosphorus, potassium and water. Energy use will also be considered in this context as an indirect factor.

4.3.1 Nutrient use

An adequate and balanced supply of nutrients in the soil is essential for several reasons. Nutrient surpluses might result in nutrient losses which subsequently could lead to water and air contamination (see chapter 3.2.2 and 3.2.3) and eutrophication. However, nutrient deficiency is synonymous with the overexploitation of soil nutrients in the long run and leads to a decrease in yield and product quality.

Nutrient balances are the appropriate indicators for measuring nutrient use. The most important approaches in this context are the following:

a) soil surface balance; and

b) farm gate balance.

Soil surface balance measures the differences between the input or application of nutrients entering the soil (e.g. mineral fertilisers or organic manure) and the output or withdrawal of nutrients from harvested and fodder crops. Farm gate balances measure the nutrient input on the basis of the nutrient contents of purchased material (e.g. concentrates, fertilisers, fodder, livestock, biological N-fixation) and farm sales such as meat, milk, fodder, cereals (OECD 1997).

Most published results concerning on-farm balances refer to single examples which means they consider individual farm factors.

Halberg et al. (1995) calculated nitrogen flows for organic and conventional mixed dairy farms (Table 4-14). They found significant differences in N-surplus between the farming systems correlated with the stocking rate:
the N- efficiency of the investigated organic dairy farms was on average 25% higher than those of the conventional group.

Table 4-14: Nitrogen flow and efficiency on conventional and organic mixed dairy farms (in kg/ha/year)

	Conventional[1]		Organic[2]	
	mean	mean per LU	mean	mean per LU
Livestock units (LU)	1.5	–	1.06	–
Net purchase (input)				
fodder	77	51	39	37
animal manure	0	0	9	8
mineral fertiliser	161	107	0	0
atmosphere	50	33	108	102
Net sales (output)				
milk and meat	47	31	32	30
Surplus	**241**	**160**	**124**	**117**
Efficiency (%)				
not corrected	16.4	–	20.4	–
corrected for stocking rate	16.2	–	23.5	–
corrected for stocking rate + 50% N-fixation	15.5	–	28.8	–

Source: Halberg et al. (1995)

[1] n= 16
[2] n= 14

Watson and Younie (1995) compared the N balances of two organic and conventional grassland production systems with finishing beef production. They calculated a lower N surplus (103 kg N/ha) on the organic system in comparison to the conventional system (216 kg N/ha). They concluded that the practise of applying N-fertiliser to grassland for beef production is questionable and that organic farming could help reduce the risk of detrimental nutrient losses in beef finishing systems.

Examples of N balances on German organic farms are shown in Table 4-15. The studies presented in Table 4-14 found corresponding P and K balances, which were slightly negative, while varying values were observed for nitrogen. However, all studies result in lower nutrient balances on the investigated organic farms compared with the nutrient balance calculated for all of Germany due to reduced mineral nutrient input.

Table 4-15: Examples for N, P, K balances (kg/ha) from on-farm investigations in Germany

		Input	Output	Balance
Hege and Weigelt (1991)	N	82.9	45.5	37.4
7 long time organic farms	P	6.3	20.3	-14.0
	K	13.1	19.5	-6.4
Stein-Bachinger and Bachinger (1997)	N	0.9	16.8	-15.9
3 organic farms, 3 years, Brandenburg	P	0.2	3.5	-3.3
	K	0.6	4.3	-3.7
Nolte (1990)	N	12.6	27.0	-14.4
1 organic farm, 4 years, Rhineland	P	4.8	6.0	-1.2
	K	5.2	10.2	-5.0
Conventional farm: Bach et al. (1997)	N	196	110	+86
Actual nutrient balance of all of Germany	P	27	21	+6
	K	107	83	+24

Table 4-16 presents research results on N-P-K balances from different EU countries and compares organic and conventional farms.

Table 4-16: Examples for N, P, K balances (kg/ha) comparing organic resp. conventional farms from different European countries

	N balance (kg/ha)		P balance (kg/ha)		K balance (kg/ha)	
	organic	conventional	organic	conventional	organic	conventional
Sweden[1]	-15	+44	-12	+37	-4	+39
Netherlands[2]						
Cash crop farm	+98	+154	+18	+23	+31	+25
Horticulture	+106	+112	+32	+60	+119	+110
Dairy farm	+136	+364	+8	+31	na	na
Germany[3]	+42	+118	-4	+13	-27	+31

1 Granstedt 1990: 3 organic farms, 4 conventional farms, SE
2 IKC 1997: 1 organic farm, 1 conventional LEI farm (representative model farms), NL
3 Hülsbergen et al. 1996: 1 farm - pre and post conversion to organic farming

Even though the examples presented indicate that nutrient balances vary enormously, they also show that nutrient balances on organic farms are lower than on conventional farms.

Lower nutrient balances for organic systems compared with conventional systems were also found in two long term Swiss studies: the DOC-trial (Spiess et al 1993) and the pilot farm project (Hausheer et al. 1998). While the organic nutrient balances were negative throughout the whole investigation period (-33kg N/ha and -6kg P/ha), the integrated system started with highly positive N and P balances before they achieved an equal balance (Hausheer et al. 1998). Based on Swiss inspection reports, Freyer (1997) found that only 1.5% of the organic farms had a P surplus while most farms had a remarkable P deficit. As far as nitrogen balances are concerned, only 14% of the inspected organic farms had a nitrogen surplus (Freyer 1997). The three Swiss studies cited currently provide the most broad and reliable data base on nutrient balances.

In Norway, however, Solberg (1993) observed positive nitrogen balances on 17 organic farms. The main reason for this result has been a high level of biological N fixation in ley and green fodder in combination with good manure management. A reduction of fodder import did not seem to influence the N balance substantially. On the other hand, Solberg (1993) found negative N and K balances on farms that mainly grew vegetables and grains. Kerner (1993) calculated farm gate balances on 28 farms and came to conclusions similar to Solberg's (1993): ratios of nutrient import and export were well balanced. Farm gate balances only had negative values (potassium) when large amounts of potatoes and vegetables were sold.

Fowler, Watson and Wilman (1993) studied N, P and K flows applying farm gate balances on 2 organic dairy farms in detail for two years. On the first farm, sales of N were 1.3 times greater than purchases, whereas P and K purchases were 2.5 (P) and 2.2 (K) times greater respectively than sales. Major sources of nutrients were concentrate purchases, whereas the major sales product was milk. On the second farm, N, P and K were purchased in the form of poultry manure and concentrated feed. Nutrients were sold in the form of grain and milk. Purchases of N, P and K were about 3 to 5 times the sales, which seem excessive for an organic system. The study concluded that satisfactory forage yields can be achieved under organic management, whereas lower yields in cereal production might indicate some lost nutrients. Thus, nutrient budgets should receive greater attention, and more effective conversion of N into saleable produce is desirable.

Off-farm calculations, using computer models, allow the definition of optimal balance ranges and offer alternative measures of optimising the environmental adaptation of the production level of farming systems (Biermann et al. 1997; Hülsbergen et al. 1997).

Dalgaard et al. (1998) choose a scenario approach based on the empirical data by Halberg et al. (1995) of the nutrient cycles presented in Table 4-13. Daalgard et al. set up national scenarios for dairy farms converting to organic farming in order to quantify the national reduction of N-losses. The model calculations resulted in a 50% N-surplus reduction per hectare and a 25% N-surplus reduction per ton milk (Table 4-17).

Table 4-17: Calculated scenarios for N-surplus of dairy farms in Denmark (maintaining the present milk production level)

Unit	Intensive (1.7 LU/ha)	Conventional (1.1 LU/ha)	Organic (1.1 LU/ha)
kg/ha	234	199	118
kg/t milk	24	24	18
total 10^6 kg	110	140	84

Source: Dalgaard et al. 1998

Organic farming standards already set a narrow range for nutrient input by restricting mineral and organic fertiliser and feedstuff input. The consumption of limited resources is comparably low.

Most studies reviewed show that nutrient balances on organic farms are lower than on conventional ones. Thus, in organic farming, the risk of water and air contamination as a consequence of nutrient surpluses is low. The most important reasons for this is the limited livestock densitiy per land area, which results on organic farms in low livestock densities, as well as a general ban of mineral N-fertilisers. These restrictions cause nitrogen to be a minimal-factor on organic farms. Economically the opportunity cost (the cost to produce nitrogen on-farm) of nitrogen on organic farms can amount to from seven to sixteen times the cost of mineral N-fertilisers (Dabbert 1990; KTBL 1998; Stolze 1998). Avoiding non-productive nitrogen losses is of special economic interest for organic farmers. As far as nutrient deficiencies are concerned, Unwin et al. (1995) argue that medium term effects of non-balanced inputs and outputs are likely to take the form of a reduction in economic performance rather than environmental detriment.

4.3.2 Water use

Water shortage essentially restricts agricultural land use and can cause detrimental effects on aquatic habitats and wildlife (OECD 1997). In order to measure agricultural water use, water balances applicable for surface and ground water were developed.

Efficient water use is of special relevance in the Mediterranean countries, in areas with low precipitation due to continental climate effects, and on soils with very low water reception capacity. National standards for organic farming take this into account by setting up limits for irrigation in order to conserve water resources (David et al. 1996). A pilot study on organic olive production in Greece provides suggestions for ecological water management in order to improve water availability and to conserve ground and surface water. First results show that on most organic olive production systems, timing and budgeting of irrigation is sub-optimal due to a lack of consciousness by the growers (Kabourakis 1996).

However, no studies investigating the water use efficiency of organic and conventional farming systems could be identified.

4.3.3 Energy use

The question of environmental and resource use impacts of agriculture with respect to energy use contains two main issues:

1. the consumption of fossil energy resources; and
2. the climatic relevance of their use.

As the latter issue was a part of the climate and air section, which discussed in detail the effects of CO_2 emissions (Chapter 3.2.3.1), this section will now focus on energy consumption.

Energy consumption on agricultural farms includes the direct consumption of fossil energy (e.g. fuel and oil) as well as indirect energy consumption. Indirect energy consumption results from the production of synthetic fertilisers and pesticides, transport of imported feedstuffs and from investment goods such as buildings. The OECD (1994) proposed to use energy intensity and/or energy efficiency as an appropriate indicator to measure and evaluate energy use. The corresponding parameters are:

- energy consumption (per hectare and per output); and
- energy efficiency (input/output ratio).

Applying different calculation approaches, Lampkin (1997), Haas and Köpke (1994) and Kalk et al. (1996) calculated the energy consumption on a per hectare scale for organic and conventional farms, presented in Table 4-18.

Table 4-18: Calculations of farm energy consumption (in GJ/ha and year)

	Organic farms	Conventional farms	As percentage of conventional
Livestock farms, UK[1]	3.3	9.3	64%
Germany[2]	6.8	18.9	64%
Germany[3]	12.9 – 17.3	19.4	11 – 33.5%

[1] Lampkin (1997)
[2] Haas and Köpke (1994)
[3] Kalk et al. (1996)

The data presented shows the variety of calculated energy consumption values. However, all authors cited find lower energy consumption on organic farms compared with conventional farms. Rasmussen (1997) corroborates the results from Lampkin (1997) and Haas and Köpke (1994) and calculates 70% lower energy consumption on organic farms in farm level studies.

Table 4-19 shows data on energy consumption for different crops, both on a per hectare and per output unit scale. The determining factor for energy consumption of a specific crop is its cropping management, which includes tillage intensity, manuring and weed control.

Table 4-19: Calculations of energy consumption of different crops

Crop	Energy consumption GJ per ha			Energy consumption GJ per t		
	convent-ional	organic	as % of conv.	convent-ional	organic	as % of conv.
Winter wheat						
Alföldi et al.(1995)	18.3	10.8	-41	4.21	2.84	-33
Haas and Köpke (1994)	17.2	6.1	-65	2.70	1.52	-43
Reitmayr (1995)	16.5	8.2	-51	2.38	1.89	-21
Potatoes						
Alföldi et al.(1995)	38.2	27.5	-28	0.07	0.08	+7
Haas and Köpke (1994)	24.0	13.1	-46	0.80	0.07	-19
Reitmayr (1995)	19.7	14.3	-27	0.05	0.07	+29
Citrus						
La Mantia and Barbera (1995)	43.3	24.9	-43	1.24	0.830	-33
Olive						
La Mantia and Barbera (1995)	23.8	10.4	-56	23.84	13.00	-45

All authors determine lower energy consumption both on a per hectare as on a per output unit scale for winter wheat. This is the result of the N-fertilisation level on conventional winter wheat and the energy input required for producing mineral N-fertilisers. However, the production of organic potatoes shows lower energy consumption per hectare but higher energy consumption per output, which is the result of a high energy input for mechanical measures and a medium conventional mineral N-fertilisation level.

As far as permanent crops are concerned, La Mantia and Barbera (1995) compared the energy consumption on one organic and one conventional olive and citrus farm in Sicily, Italy. They found a lower energy consumption on organic farms for olive and citrus production, both with regard to energy consumption per hectare and per output. It needs to be mentioned that the investigated organic and conventional citrus farms each achieved the same yield, whereas the organic olive farm's yield was lower than that of the conventional system.

A study on future Swedish farming systems calculates a lower energy input on organic dairy and beef farms compared with respective conventional farms (Naturvårdverket 1997). But the energy input on organic pig and chicken farms was higher than on comparable conventional farms. Lower energy consumption on organic farms, both per farm and per kg milk, is confirmed by Eleveld (1984) and Scherpenzeel (1993).

The second parameter of concern applicable for measuring and evaluating energy use is energy efficiency. This provides information about the ratio of energy input and output.

In absolute terms, Table 4-20 presents energy efficiency of organic and conventional herbaceous crops, wheat and vineyards.

Table 4-20: Energy efficiency (input/output) of various crops

	Energy efficiency	
	conventional farming	organic farming
Herbaceous crops[1]	0.20	0.40
Wheat[2]	0.12	0.09
Vineyard[2]	0.43	0.08

1 Caporali et al. (1995)
2 Chiani and Boggia (1992), Ciani (1995)

Caporali et al. (1995) state that organic farming techniques require two times more energy input per output for organic herbaceous plants and six times more units for organic sugar beet than compared with conventional farming techniques. The lower energy efficiency of organic herbaceous crops shown in Table 4-20 is due to organic farming's substitution of chemical inputs with higher machinery labour and higher renewable input levels (human labour is not considered in this study). Lower energy outputs are the result of lower organic yields.

In contrast to Caporali et al. (1995), Ciani and Boggia (1992) and Ciani (1995) determined higher energy efficiency in organic wheat and in organic vineyards compared to conventional production systems (see Table 4-20).

Model calculations on organic dairy farms completed by Olesen and Vester (1995) considered the specific caloric value of the output. These found energy ratios (input of fossil energy/output in digestible energy) varying from 0.8 to 2.7. The main factors influencing the energy ratio were soil type, livestock density, yield level and the proportion of fodder production and recirculation within the farm. Meiers (1996) also states that these factors are the most important influence on energy ratios of farming systems. The energy efficiency calculated by Meiers (1996) for organic farms was lower (2.13) than for conventional farms (1.02). A study about the cultivation of peach orchards (del Giudice et al. 1995) compares the total energy balances of conventional, integrated and organic farms in the Forlì province (Table 4-21). Two ratios were calculated:

1. total IN/OUT is the ratio between total input energy (human labour, mechanical labour, nutrients, manure, plant protection products) and the total output energy (the caloric value of the peaches produced); and
2. partial IN/OUT is the ratio between the above indicated inputs energy without manure and the total output energy.

The calculations by del Giudice et al. (1995) concluded that both of the calculated ratios show an increase in energy efficiency from conventional to organic farming (Table 4-21).

Table 4-21: Ratio between energy input and energy output of different peach orchard farming systems

	Total IN/OUT	Partial IN/OUT manure excluded
Organic farms	2.94	0.26
Integrated farms	3.70	0.53
Conventional farms	5.00	1.01

Source: del Giudice et al. (1995)

The research studies reviewed show that in most cases, the energy consumption on organic farms is lower than on conventional farms. As far as single commodities are concerned, the energy consumption of growing permanent crops (olive, citrus, vineyards) and wheat is, with regard to a per hectare and per output unit scale, lower in organic than in conventional farming. However, growing potatoes organically requires equal or more energy per output and less energy per hectare than doing so conventionally. There are varying results on energy efficiency of the different farming systems.

The most important reasons for better energy use in organic rather than conventional farming are:

- no input of mineral N-fertilisers, which require high energy consumption for production and transport;
- lower use of high energy consumptive feedstuffs (concentrates); and
- banning of pesticides.

Nevertheless, it is important to note that no standardised scheme for balancing energy use exists. Thus, comparing individual research results in this context is only of limited value.

4.3.4 Summary: Farm input and output

The review of research studies investigating on-farm balances of nutrients, water and energy with respect to organic and conventional farming can be summarised as follows.

- Nutrient balances of organic farms in general are close to zero. In all published calculations, the N, P and K surplus of organic farms was significantly lower than on conventional farms. Negative balances were found for P and K.
- No research results on water use in organic and conventional farming systems are available.
- Most research studies reviewed indicate that energy consumption on organic farms is lower than on conventional farms. The energy efficiency calculated for annual and permanent crops is found to be higher in most cases for organic farming than for conventional farming.

A conclusive assessment on the effects of organic farming on resource balances is given in the following scheme (Table 4-22).

Table 4-22: Assessment of organic farming's impact on the indicator category "Farm input and output " compared with conventional farming

	++	+	o	–	– –
Nutrient use		■			
Water use			■		
Energy use		■	■		
Farm input and output total		■	■		

Legend: Organic farming performs: ++ much better, + better, o the same, – worse, – – much worse than conventional farming

■ Subjective confidence interval of the final assessment marked with

4.4 Health and welfare

The indicator category health and welfare, set up within the OECD framework for environmental indicators as a state category, only addresses the subject health and welfare from the farmer's side. From our point of view, the original OECD category lacks the two following important issues for the purposes of this study:

1. the impacts on animal health and welfare; and
2. the impact on the produce.

Although the first issue might be covered by the OECD framework through the indicator farm management practise, the main emphasis so far lies on arable and grassland use. Animal husbandry is only addressed with respect to its negative impacts on air (NH_3, odours) or water (nitrate leaching, pathogens). Animal welfare with its environmental and ethical elements is an important aspect of farming systems, which has not been addressed by the OECD framework yet.

The second aspect mentioned above considers the environmental impacts of farming systems on the produce from a more consumer-relevant point of view. Thus, the appropriate indicator to measure the impacts on the produce is food quality.

For these reasons the indicator category health and welfare has been enhanced, and now considers animal health and welfare and quality of the produced food.

4.4.1 Animal health and welfare

Animal welfare may be considered from two aspects. The first is concerned with the ethical treatment of animals, the second with the long-term biological functioning of animals. Generally speaking, both aspects should be given equal priority.

The attempt to evaluate animal welfare within organic farming systems in comparison to conventional farming systems will, first of all, lead to an analysis of the standards for animal welfare in the context of the standards of international and national organisation of organic farming. Generally speaking, organic farming systems distinguish themselves from conventional farming systems through the existence of standards and regular controls. Organic farming systems operate less intensively due to the restriction on stocking rates and feedstuff purchase. Although a general framework for animal husbandry is set by the IFOAM Basic Standards and a common definition of organic animal husbandry exists within the EU since August 1999, the standards of national organic farming organisations may differ considerably.

For an assessment of environmental indicators, the biological or health-related aspects of animal welfare will be taken into consideration. Most indicators of animal welfare reflect relatively specific problems, measuring different components of welfare rather than welfare per se. Some of the parameters that may serve to describe the indicator animal welfare are immune problems, occurrence of disease, reduced productivity, mortality, physiological stress and behavioural deprivation. These parameters are influenced by animal husbandry issues such as housing conditions, breeding goals, and health measures, i.e. veterinary medicine. These factors are the subject of the following sections.

4.4.1.1 Husbandry

Housing conditions for farm animals should satisfy their physiological and mental needs and support natural behavioural characteristics (Fölsch and Hörning 1996). Therefore, animal husbandry conditions are considered equally important for the present evaluation as wildlife conservation.

Comparisons of organic to conventional housing conditions and the results of investigations of housing conditions of organic farms provide a varying picture. On the one hand, about 50% of farms investigated in Germany were characterised by inadequate housing conditions (Andersson 1994; Krutzinna et al. 1996; Sundrum et al. 1995). Housing conditions on organic farms in Central Europe were rated as poorer by Konrad and Erlach (1993) than those of conventional farms. On the other hand, positive results have been obtained in the UK and Switzerland by Hovi (1998) and Hausheer et al. (1998). An evaluation of the cleanliness and dryness of bedding and floors, as well as ventilation of 16 organic farms in UK, inspected 20 times, resulted in 60% of the farms showing at least good conditions while none of the inspected farms showed very bad conditions (Hovi 1998). Of the surveyed Swiss organic farms, 91% participated in a national free-range program, which includes housing in controlled free ranges. In comparison, only 51% of the surveyed integrated farms participated (Hausheer et al. 1998). However, a general conclusive assessment of housing conditions in organic farming in comparison to conventional farming systems is difficult to draw, because only little research work has been done and housing conditions reflect considerable regional differences (Andersson 1998).

The breeding goals of organic farming try to target both productivity and longevity, in contrast to conventional farming, in which productivity is the basic goal. Traditional breeds adapted to local conditions, endangered species and the conservation of a high diversity of species are further tasks. An investigation in Norway in 1995 showed that the average age of cows on the organic farms surveyed was 10 months higher and the culling rate lower than the nation-wide average. This was a result of preferring a high level of milk production to rearing heifers. Due to a low disease rate in the herds, only a few cows had to be culled at an early age (Strøm and Olesen 1997). A longer average productive life of dairy cows was also observed by Spranger (1995): up to 6 years of lactation, an increase of 0.5 years compared to conventional farms. Contrarily, another investigation observed an average of 3.2 lactation both on organic and conventional farms in the UK (Hovi 1998).

It is difficult to assess whether or not organic dairy farming increases longevity of cows in comparison to conventional dairy farming. Appropriate feeding and culling schemes result in herds with a relatively higher average age, without harming animal health and reducing milk quality (Strøm and Olesen 1997).

4.4.1.2 Health

Animal health, on the one hand, is a factor of potential environmental significance because the application of medicines required for recovery from diseases may lead to undesired residue outputs into the environment. On the other hand, it is an important component of animal welfare.

In any type of farming system, the actual health status and the required medication in beef and dairy cattle, pig and lamb production varies widely and depends very much on individual farm conditions (Unwin et al. 1995; Vaarst 1995). In many cases no significant differences between organically and conventionally reared animals are observed (Spranger 1995). Organic dairy herds did not differ significantly from the national Swedish average or from a conventional comparison group in Central Europe with respect to health in general (Andersson 1994; Krutzinna et al. 1996; Landin 1995). Similar results were obtained with respect to hoof health (Vaarst and Enevoldsen 1996) which seemed to be due to the high variation among herds and generally poor housing conditions such as slatted floors. As housing should be on solid floors with straw bedding and access to grazing, these problems should decrease with an increased implementation of these housing systems. For example, Weller (1996) reported that 45% of surveyed dairy farms had a loose stall system and 55% a straw bedded cubicle system with solid concrete floors and usually access to grazing. In this case, the incidence of clinical mastitis, the major problem on conventional dairy farms (Short et al. 1996), was only slightly higher on organic farms as compared to the national conventional average, although no medication was used for dry cow therapy. No major fertility problems were recorded and the incidence of lameness was lower in loose housing systems than in cubicle systems.

Other investigations found general health and udder health to be significantly better in organic than in conventional herds (Hamilton 1995; Vaarst and Enevoldsen 1994) often even without any use of antibiotics (Vaarst 1995). Significantly less clinical acetonaemia, fewer cases of clinical mastitis and milk fever and post-partum energy deficiency occurred (Hamilton 1995; Strøm and Olesen 1997; Vaarst 1995; Vaarst and Enevoldsen 1997). A very high fertility rate and fewer problems with hooves were observed. These results are especially remarkable considering that a cow's susceptibility to these diseases increases with age, and that the average age of the surveyed cows often is higher than the national average (Strøm and Olesen 1997).

With respect to fertility, organic animal husbandry practices seem to be beneficial to the pregnancy rate after the first insemination and to the incidence of crippled animals (Snijders and Baars 1995).

Generally, possible reasons for positive health effects are:

- farm specific conditions, year and calving season;
- well-balanced feeding rations, and cows with moderate fatness at time of calving, moderate milk yields, favourable rumen conditions;
- daily outdoor exercise, which keeps the animals in good shape;
- ad libitum access to fodder; and
- predominantly clean or mixed grazing systems.

Single studies claiming generally bad conditions of organic animals with respect to welfare and husbandry, e.g. for organic pig fattening systems (Thielen and Kienzle 1994), are neither scientific nor representative (Andersson 1998). In some cases, certain health parameters of dairy cows were found to be significantly worse on organic farms, i.e. general health status (Hovi 1998) or udder health (Andersson 1994; Hovi 1998; Krutzinna et al. 1996). In an investigation of organic calves, a higher incidence of liver fluke was observed, although the overall health status situation was better on organic in comparison to conventional farms (Persson 1997).

As in organic animal husbandry, ruminants still play the most important role in most investigations referring to the health status of dairy cows. However, due to falling prices for cereals and increasing marketing difficulties, the fattening of pigs and poultry has gained importance in recent years (Andersson 1998). Common problems occurring in organic pig herds include a number of endoparasitic problems. A lower frequency of lung diseases was observed among organic pigs (Persson 1997).

Homeopathic measures to support and strengthen self-regulating processes play an important role in organic farming, because the prophylactic use of conventional medicines is not permitted (Sommer 1997). Treatment of diseases by natural medicines should be preferred over conventional medicines, although therapeutic reliability has not always been confirmed (Andersson 1997). The need for veterinary treatment is not eliminated for individual animals in the case of acute disease nor on an overall herd basis e.g. for ectoparasite control (Unwin et al. 1995). For example, 53% of German organic dairy farmers still use conventional medicines (Boehncke and Krutzinna 1996). Results from the UK show that on most farms, both forms of therapy are in use. Compared to 62 % of farmers who applied antibiotics, 65% used alternative methods of mastitis control, ranging from homeopathy to cold water massage (Short et al. 1996). In beef systems, only about a third of the producers relied on conventional medication on a routine basis, as disease problems were perceived as being low (Short et al. 1996). On the other hand, sheep producers relied more on vaccination and de-worming, often in combination with supportive grazing management (Short et al. 1996). In comparison to conventional farms, antibiotic use was significantly lower on organic farms, with an average 0.45 tubes per cow as compared to 5.9 on conventional ones (Hovi 1998).

Focusing on the quantitative differences in application of synthetic medicines between organic and conventional farming systems does not satisfactorily assess the impact of veterinary medicine on environmental quality issue. Other factors should also be taken into account.

Organic farming standards often stipulate the use of alternative products or the avoidance of a specific prohibited material. Some substances prohibited for organic farming, such as OP-dips, dietary supplements of copper and zinc and avermectins, for example, have an impact on the environment.

However, other permitted products may be more toxic, such as pyrethroids, which affect aquatic life (Unwin et al. 1995). It can be concluded that little overall environmental benefit results directly from the adoption of an organic approach to veterinary measures and disease control because the environmental risks associated with conventional veterinary medicine are rated as being relatively low, except for the risk resulting from the development of resistant organisms.

4.4.1.3 Summary: Animal welfare and health

Animal welfare issues generally seem to be of low priority. This is reflected by the fact that in 1990, animal husbandry was only the subject of 6% of all organic research projects performed in the German-speaking countries (Boehncke and Krutzinna 1996). Generally, only a few comprehensive scientific findings on animal welfare and health exist that are transferable to the

European situation. An overview of the complete situation in the EU-countries is still lacking (Andersson 1998). A comprehensive approach suggested to assess animal welfare is the elaboration of an animal welfare index, which would be made up of several different components (Bartussek 1988; Sundrum et al. 1994). Such an index could be defined in national and international standards and accelerate the development of standards and control measures for a common definition for organic animal husbandry.

However, the actual situation provides the following picture:

- housing conditions and health status depend highly on specific farm conditions, which seem to not differ significantly between organic and conventional farms;
- health status seems to be closely associated to the economic relevance of animal husbandry to the farm: significantly fewer incidences of metabolic disorders, udder diseases and injuries are found when dairy production was properly managed;
- prophylactic application of antibiotics is restricted only by some national standards;
- dairy cows tend to have a longer average productive life; and
- although the application of homeopathic medicines should be preferred, conventional veterinary measures are permitted and used in acute cases of disease.

Nevertheless the development of a broad spectrum of management routines for specific animal husbandry systems is one of the future challenges of organic farming. A number of examples are proposed by Vaarst (1997).

A conclusive assessment on the effects of organic farming on animal welfare and health indicators is given in the following scheme (Table 4-23).

Table 4-23: Assessment of organic farming's impact on the indicator subcategory "Animal welfare and health " compared with conventional farming

	++	+	o	–	– –
Husbandry					
Health					
Animal welfare and health total					

Legend: Organic farming performs: ++ much better, + better, o the same, – worse, – – much worse than conventional farming

Subjective confidence interval of the final assessment marked with

4.4.2 Quality of produced food

The quality of food is receiving increased public attention due to a growing consciousness of health and environmental problems. Food produced by organic farming is considered especially important in this respect (Woese et al. 1995). Among the main reasons for buying organically produced food are health aspects, the superior taste and environmental performance (Alvensleben and Werner 1982; Folkers 1983; Hutchins and Greenhalg 1995). The environmental performance of organic farming has been discussed in previous sections. In the following, the quality of food with respect to the human as part of the environment will be discussed as an indicator of environmental performance.

In this study, the term ”food quality” will be used in a very narrow sense. The term includes properties of food that can be directly measured by scientific methods. Of course, this is not an economic viewpoint on quality, as expressed in the quote "Quality is what the consumer thinks it is". The production process itself can be an important part of food quality for the consumer. A more environmentally sensitive production method might lead to higher food quality in the perception of the consumer while it does not change any measurable property of the food itself. Thus, to avoid confusion, it is important to keep in mind that the narrow, scientific definition of quality is used here.

Two major routes of food intake by human, each associated with different risks, will be considered:

a) crops and plant products; and

b) animal products.

4.4.2.1 Plant products

The potential risks associated with plant products can be the effects of pesticide residues, nitrate, mycotoxins, and heavy metals. The most evident potential risks of the consumption of animal products by humans are BSE, the effect of antibiotic and hormone residuals. The risks associated with plant produce also apply to most animal products because, due to bioaccumulation, the main pathway of contamination caused by undesirable substances to humans is food from animal sources. Milk and dairy products especially are potential agents of inputs to man (Ripke 1982). Given that the fact that organic livestock rearing is predominantly based on on-farm produced fodder, the quality of organic animal products depends primarily on the quality of the organic plant produce.

One of the most important quality criteria of organic products is the absence of pesticide residues, as synthetic pesticides may be not be used in farming or for storage or processing of food sold with the organic label (AGÖL/BNN 1995). In numerous studies, a higher incidence of pesticide residues was found in conventional products than in organic products (CLUA-Sigmaringen 1983; Kjer 1991; Minnaar 1996; Reinhard and Wolff 1986; Schüppach 1982; Top 1993). Other investigations detected no significant differences in the levels of pesticide residues (Andersen and Bergh 1996; Green et al. 1993; Reinken and Lindner 1983; Vetter et al. 1983). This lacking difference could have several reasons. Either the investigated conventional products were free of pesticides, or the examined organic products were accidentally contaminated during growth or storage by wind drift from neighbouring fields, by soil or water contaminated by former applications, or contaminated transport vehicles or storage rooms. The evidence presented in the existing literature, however, must lead to the conclusion that organic farming tends to have lower contents of pesticide residues than conventional farming (Ovesen 1995; Woese et al. 1995).

The argument appears void that all pesticides commonly used in conventional farming have been tested on animals with respect to their toxicity, carcinogenity, mutagenity, and teratogenity. Although they are recognised as potential health hazards, neither the extent and the long-term effects of a low-dose intake of pesticides nor their interaction with other substances has been satisfactorily investigated (Richardson 1996; Woese et al. 1995). Many pesticides commonly used in conventional farming are very persistent (i.e. chlorinated hydrocarbons) and accumulate in the body fat of animals or humans. Others, although not as persistent (i.e., organic phosphoric esters), are equally toxic and can seriously affect human health. Particularly mixtures of pesticide residues have been found harmful to humans (carcinogenic) (Pluygers and Sadowska 1995). These risks are especially relevant for persons being exposed to pesticide application, such as farmers. Organic farming endeavours to minimise the risk of pesticide contamination for consumers and producers.

On the other hand, the assumption that substances permitted as natural pesticides by the organic farming standards are harmless to non-target animals and humans still has to be proven. An urgent call for further investigation exists as recent studies of Neem (*Azadirachta indica*) extracts, for example, demonstrated their harmful potential by affecting abortion pregnancy of rats, baboons and monkeys (Talwar et al. 1997).

Nitrate is an undesirable ingredient of plant produce for humans. It can be reduced to nitrite by microbial activity, which may inhibit erythrocytes' respiratory function or can produce carcinogenic nitrosamines with secondary or tertiary amines. Nitrate accumulation in plant products depends on the supply of nitrate by fertilisation, on mineralisation of organic soil matter and a reduced availability of other assimilates. An excess supply of nitrate and low assimilation intensity can lead to high nitrate contents in plants. Nitrogen availability depends predominately on kept livestock and green manure as easily soluble mineral nitrogen fertilisers are not used in organic farming. Due to limited livestock density and economic restraints of green manure, nitrogen availability is a limiting factor in organic farming. Therefore, excess fertilisation is generally less frequent and organic plant produce usually has significantly lower nitrate contents than conventional produce (Barducci 1998; Dlouhy 1981; Fischer and Richter 1986; Geier 1995; Lairon et al. 1984; Raupp 1996; Schuphan 1974; Woese et al. 1995). This applies particularly to green, root and tuber vegetables, and potatoes. However, the content of nitrate in food depends highly on the variety of the crop, its growing conditions and fertiliser management.

Mycotoxins occurr naturally in chemicals produced by fungi growing on grain, feed or food. These fungal metabolites are detrimental to the health of both animals and humans and may enter the food supply through direct contamination as a result of mould growth on the food material or by indirect contamination through animal produce as the result of consumption of mouldy feedstuffs (Bullerman 1986). Toxicity ranges from acute death to chronic diseases, cancer and reproductive malfunction. Mycotoxins are frequently discussed in relation to the concern of higher incidences of contamination of organic food (Top 1993). However, the common argument that the ban of synthetic fungicides leads to a higher incidence of mould on organically cultivated crops and therefore to a higher risk of mycotoxins, cannot be confirmed by the reviewed investigations comparing the mycotoxin contents of organic and conventional produce (Geier 1995; Kjer 1991; Olsen and Möller 1995; Ovesen 1995; Pommer et al. 1993; Statens Mejeriforsog 1990). In some investigations even lower infestation rates of organically grown cereals with seed born pathogens as *Fusarium spp.* and mycotoxin contamination were found than in conventional cereals treated with pesticides (Piorr 1993; Schauder 1998).

Heavy metals can be essential trace elements or be without any physiological value. Although some elements are ubiquitous in nature, they can be toxic in higher concentrations, especially as they tend to bioaccumulate in animals and humans. Due to their origin and pathways into plants and animals, no significant differences are generally observed in the contents of heavy metals of organic in comparison to conventional food (Arnold 1984; Geier 1995; Green et al. 1993; Jorhem 1995; Oberösterreichische Landeskorrespondenz 1982; Statens Mejeriforsøg 1990; Vetter et al. 1983). This depends primarily on site-specific factors. As EU Reg. 2092/91 prohibits the application of sewage sludge on organic farms, higher cadmium contents can be expected in conventionally than in organically grown foods (Kjer 1991; Minnaar 1996).

Polychlorinated biphenyls (PCBs) and radioactive substances, predominantly emitted by industrial sources, are not specific to any type of farming activity. As with heavy metals, similar levels of contamination are to be expected in organic and conventional food sources.

With respect to desirable substances such as micro- and macronutrients, vitamins, organic acids and aromatic compounds, either no significant differences in contents between products from different farming systems are detected by traditional analyses (Arnold 1984; Wedler and Overbeck 1987), or contradictory results do not permit clear conclusions (Arnold 1984; Dlouhy 1981; Dost and Schuphan 1944; Fischer and Richter 1986; Kjer 1991; Naredo 1993; Ovesen 1995; Woese et al. 1995). Furthermore, in the case of minerals, it is rather difficult to judge whether certain contents are favourable or unfavourable to humans (Adölfli et al. 1996). Special attention, however, should be drawn to Vitamin C. In several cases, higher Vitamin C contents have been observed in organic vegetables in comparison to conventionally grown vegetables (Diehl and Wedler 1977; Elsaidy 1982; Pettersson 1982). Similar conclusions can be drawn from the reviewed literature with respect to organoleptic properties (Arnold 1984; Statens Mejeriforsog 1990; Ovesen 1995; Vetter et al. 1983; Woese et al. 1995).

4.4.2.2 Animal products

Besides the direct and indirect risks associated with the consumption of agricultural products by humans in general, several risks are specific to the consumption of animal produce from modern agriculture. These have received considerable public attention in the past, i.e. antibiotic and hormone residuals, or just recently, such as Bovine Spongiform Encephalopathy (BSE).

Antibiotics are routinely added to animal feed in conventional agriculture. This can have various effects on humans. Direct transmission of antibiotic residues in animal products to people may cause direct toxicity, i.e. allergies, or lead to the emergence of resistant strains of bacteria. Another threat is antibiotic-resistant forms of bacteria harmful to mankind that might appear in animals and pass from them to humans (Smith 1974), or may impart resistance to other bacteria by plasmid or transposon interchange (Franco et al. 1990). The resulting drug-resistant and harmful micro-organisms can then not be treated successfully (Silverstone 1993).

The treatment of animals with growth-promoting hormones is a common practice in conventional agriculture outside of the EU. The effects of this practice are still not predictable in an entirely reliable way with respect to the toxic and carcinogenic effects of their residuals on humans (Collins et al. 1989). Although their use was banned in the EU several years ago, satisfactory controlling mechanisms have not been established.

In organic farming, the sub-therapeutic application of antibiotics and the use of growth-promoting hormones is strictly forbidden and adequately controlled. Thus the resulting risks are not associated with animal produce from organic farming origins.

The risk of BSE is clearly limited in organic farming in comparison with conventional farming due to a predominant use of organically produced fodder from controlled origins and the ban of animal meal as feedstuff. Reared animals should be exclusively of organic origin. Only few exceptions exist in which animals might be brought in from non-organic sources. For imports of animals from countries with a critical pest status, a special permit is required (AGÖL 1996; Dussa and Lünzer 1997; Soil Association 1997).

So far, only traditional chemical analyses of food quality have been reviewed. However, the potential deficiency of analyses only considering food contents in describing food quality has been recognised by various authors. Therefore, several alternative methods of assessing food quality have been proposed, such as:

- electrochemical parameters (Hoffmann, 1988);
- low level illuminescence (Popp 1988);
- storage quality (Abele 1987; Ahrens 1988; Samaras 1977);
- picture-developing methods (Balzer-Graf and Balzer 1988; Schwenk 1988);
- food preference tests (Edelmüller 1984; Pfeiffer 1969; Plochberger 1989);
- sensory food evaluations by test persons (Meier-Ploeger 1988); and
- effects on living organisms, i.e. by feeding experiments (Edelmüller 1984; Plochberger 1989; Staiger 1986).

No common conclusion can be drawn at this stage as to the limited experience with and the extent of these alternative methods. Promising results, however, have been obtained with feeding experiments (Plochberger 1989). With humans these did not lead to definite conclusions (Woese et al. 1995). Feeding experiments with animals, however, revealed positive effects on parameters such as weight gain, egg number, egg, yolk and litter weight, perinatally dead offspring, and preference of organic produce in controlled experiments with mice and chicken (Grone-Gultzow 1931; McCarrison 1926; Pfeiffer 1931; Pfeiffer and Sabarth 1932 and 1934; Plochberger 1989; Plochberger and Velimirov 1992; Velimirov et al. 1992). Therefore, in the future it might be possible to obtain a better base for these results in an indicator assessment scheme.

4.4.2.3 Summary: Quality of produced food

The existing literature and research results presented in the questionnaires answered by experts from all European countries permit no clear conclusions about the quality of organic food in general. The risk of contamination of food with pesticides and nitrate can be assumed to be lower in organically than in conventionally produced food. However, neither with respect to mycotoxin, heavy metal, PCB contents, and radioactive contamination nor to the contents of desirable food substances, such as vitamins, nutrients, and aromatic compounds could significant differences between organic and conventional food be demonstrated. Given the discussed factors specific to animal products, a strong argument exists for the superiority of animal products from organic as opposed to conventional farming. The lack of comparative investigations of organic versus conventional farming is off-set by existing research results on the risks associated with conventional farming, such as the contents and effects of hormone and antibiotic residuals to humans.

A conclusive assessment on the effects of organic farming on food quality indicators is given in the scheme shown in Table 4-24.

Table 4-24: ***Assessment of organic farming's impact on the indicator subcategory "Quality of produced food" compared with conventional farming***

	++	+	o	–	– –
Pesticide residues	■	■			
Nitrate		■	■		
Mycotoxins			■		
Heavy metals			■		
Desirable substances		■	■		
BSE risk		■			
Antibiotics	■				
Quality of produced food total	■	■	■		

Legend: Organic farming performs: ++ much better, + better, o the same, – worse, – – much worse than conventional farming

■ Subjective confidence interval of the final assessment marked with

4.5 Conclusion

The sections 4.1 to 4.4 comprised a thorough review of the relevant scientific literature with respect to organic farming and its impact on the environment and resource use. While each section focused on one environmental indicator, this section will now conclude by bringing together the individual results documented in the summarising assessment scheme, which completed each subsection.

Table 4-25 provides a detailed overview of the qualitative assessment schemes of all analysed indicators. Table 4-26 summarises these qualitative assessment schemes and leads to a more comprehensive picture of the subject in question.

Table 4-25: Detailed assessment of organic farming's impact on the environment and resource use compared with conventional farming

Indicators	++	+	o	-	--
Ecosystem	■	■	■		
Floral diversity	■	■			
Faunal diversity	■	■			
Habitat diversity		■	■		
Landscape		■	■		
Soil	■	■	■	■	
Soil organic matter		■	■		
Biological activity	■				
Structure			■		
Erosion	■	■	■	■	
Ground and surface water		■			
Nitrate leaching		■	■	■	
Pesticides	■				
Climate and air		■	■		
CO_2		■			
N_2O		■	■		
CH_4		■	■		
NH_3		■			
Pesticides	■				
Farm input and output		■	■		
Nutrient use		■			
Water use			■		
Energy use		■	■		

Table 4-25: Detailed assessment of organic farming's impact on the environment and resource use compared with conventional farming (cont.)

Indicators	++	+	o	–	– –
Animal welfare and health		■	■		
Husbandry		■	■		
Health		■	■		
Quality of produced food	■	■	■		
Pesticide residues	■	■			
Nitrate		■	■		
Mycotoxins			■		
Heavy metals			■		
Desirable substances		■	■		
BSE risk		■			
Antibiotics	■				

Legend: Organic farming performs: ++ much better, + better, o the same, – worse, – – much worse than conventional farming

■ Subjective confidence interval of the final assessment marked with

Due to the fact that information about environmental indicator data applied to the output is insufficient, the conclusions shown in Table 4-26 are limited to environmental and resource use effects applied to the agricultural land area. Based on this restriction, the majority of indicators investigated show that organic farming performs better than conventional farming systems with respect to environmental and resource use effects. Two indicators show that the farming systems' influences on the environment are equal. However, no indicator found negative impacts derived from organic farming. Furthermore, only in one case does the range of final assessments touch the negative side of the matrix. The conclusion from this matrix is that when evaluated on a per hectare scale, organic farming indeed can be defined as the farming system which has less detrimental effects on the environment and to resource use than conventional farming systems.

Table 4-26: Assessment of organic farming's impact on the environment and resource use compared with conventional farming: Summary

Indicators	**++**	**+**	**o**	**–**	**– –**
Ecosystem	■	■	■		
Soil	■	■	■	■	
Ground and surface water		■			
Climate and air		■	■		
Farm input and output		■	■		
Animal welfare and health		■	■		
Quality of produced food	■	■	■		

Legend:	Organic farming performs: ++ much better, + better, o the same, – worse, – – much worse than conventional farming
■	Subjective confidence interval of the final assessment marked with

An interpretation of the results presented must take the fact into account that probably some environmental effects might derive from increasing specialisation of farms and from increasing productivity. We observe trends towards higher specialisation levels and improving productivity in organic farming. The effects derived from these factors could be both beneficial and detrimental. The environmental effects of farming systems should be monitored constantly due to their dynamic development.

An analysis of the data basis used for the indicators shows that research on the environmental issues of organic farming concentrates on specific subjects. Very detailed information is available for those parameters which are of special public interest and which show a close correlation to the production technique of organic farming. This is true for the parameters of soil, fertiliser, manure and nutrient management. The parameters nitrate leaching and nitrate contamination of drinking water represent both a highly relevant environmental factor and a certain kind of limiting factor for the production system. Thus, developing strategies to minimise nitrate leaching contributes first of all to the solving of an environmental problem. Secondly, it improves farming technique and is of positive economic relevance for the farmer (economic value of nitrate).

Things are a bit different as far as those indicators are concerned which show an equal influence on environmental issues. Little information about the impacts of organic farming on climate and air, animal welfare and health and food quality is available. The reasons for this might be that:

- there are no differences between conventional and organic farming systems; or
- there is a lack of research knowledge in this area.

While it could be argued that research in the indicator category climate and air might be of minor importance, this is definitely not true for animal welfare and health or for the quality of organic food.

Animal health and welfare represents a very complex subject in which the identification of cause and effect requires long-term studies. Furthermore, almost every change in the production system is connected to high financial investments by the farmer. Due to the complexity and practical reasons, organic livestock standards allow a relatively free interpretation of how animal health and welfare is to be obtained on organic farms. A common ground for organic animal husbandry has been created because the introduction of European organic livestock regulations has provided a base for future investigations of health and welfare issues.

Aside from animal health and welfare, the subject of organic food quality is also somewhat underrepresented in organic farming research. Again, this subject is not that important for the production system, however, it is the most important direct factor as far as the consumer is concerned. Thus, organic farming should take a more precise interest in promoting research on food quality in order to have fundamental arguments for the marketing of organic produces.

A similar scheme as drawn above (see Table 4-26) is used for looking at the experts' opinion as to which environmental issues of organic farming are of highest importance in the respective countries. The assessment for the main groups of environmental indications was marked using a rating scale from 1 (unimportant) to 5 (very important) and completed by a short argument for the particular reasoning. Table 4-27 gives an overview of the mean rating.

Table 4-27: Rating of the importance of environmental and resource use effects of organic farming according to country specific expert opinion. Mean data from 18 countries

Indicator	rating from ... to...	mean
Biodiversity	1 – 5	3.3
Landscape	1 – 4	2.8
Climate and air	1 – 5	2.7
Soil	2 – 5	4.2
Ground and surface water	2 – 5	4.0
Energy use	1 – 4	2.8

Legend: 5= very important, 4 = important, 3 = average, 2 = not so important, 1 = unimportant

Although the experts' assessments vary enormously by country, the mean values show that the most important subjects with respect to the environmental impacts of organic farming are landscape, soil, ground and surface water and biodiversity. Climate as well as air and energy uses are, however, assessed to be of only minor importance. Only two experts identified animal health and welfare to be of special importance for organic farming in this context. However, the experts' assessments are based on varying levels of country specific experiences, which are due to:

- the varying importance of organic farming (conversion rate);
- the different levels of farming intensity; and
- the extent of research work done and published on this issue.

Furthermore, as this expert assessment is not representative, only a trend can be identified.

The conclusions that can be drawn on the basis of the indicator assessment for organic farming are that there is a lack of information about the environmental effects of livestock production and about organic food quality. The recent, long overdue specification of organic livestock production in EC Reg. 2092/91 is the first step in providing a common ground for investigating the complex subjects of animal health and welfare. Furthermore, a clearer picture as far as food quality is concerned should be of prime interest to organic farming because this is one of the major marketing factors.

Even though it can be concluded that organic soil, fertiliser and pesticide management have positive impacts on the environment, it is possible to improve both the environmental and public performance: The application of which organic fertilisers and pesticides are to be permitted needs to be more transparent and the application of ”natural pesticides” should be reduced. Vries et al. (1997) suggest registering each pesticide application and including threshold values for nutrient losses. Landscape management should be explicitly included in organic farming standards. Furthermore, new technologies should be developed, such as non-ploughing-arable-systems, minimal-tillage-systems, slurry drilling. The issues of manure management and soil compaction still provide some improvement potentials for research. Advice and expansion can also contribute enormously to the adoption of the newest organic production technique by organic farmers.

However, even though potentials for improvements still exist and scientific knowledge is scarce in some areas, the scientific analysis of European research results shows that organic farming clearly performs better than conventional farming with respect to environmental and resource use.

5 Agri-environmental policy relevance of the indicator analysis of organic farming

In connection with a discussion of the policy relevance of organic farming with respect to the environment and resource use, it is interesting to look at the relevance European national governments attach to the subject in question. Four countries do not comment on environmental effects of organic farming. This leads to the assumption that in these countries, this issue is actually of minor importance. Two countries, in which organic farming is very important, state that environmental effects of organic farming are of increasing relevance. Market and the consumer demand, however, are the dominating reasons for the support of organic farming. Organic farming is seen as one environmentally sensitive farming system among others in eight European governments, of which four tend to give priority to organic farming. However, five European governments attach high relevance to the contribution of organic farming towards environmental policy goals. For the majority of European governments, the environmental effects of organic farming are indeed policy relevant, while at least in one quarter of the countries investigated, organic farming plays the central role in national agri-environmental policy.

So far, this report has largely been a synopsis of scientific evidence, but scientific findings are not necessarily the answer to policy relevant questions. A number of policy relevant questions are now raised in this section with respect to the environmental and resource use impacts of organic farming. Finally, it is discussed to which extent the outcome of this report can help answer these questions.

Of course, numerous questions can be asked in a political discussion of environmental and resource effects of organic farming. From an economic point of view, candidates for variables to be considered are the following:

- the proportion of agricultural land under organic management;
- the total agricultural land area in organic use;
- the quantity of produced food; and
- the budgetary cost for environmental and resource use performance.

In order to allow a concise and focussed decision, these variables form the basis for three questions we think are of political importance. All of these questions start with political decisions of different kinds and prompt the question of what the consequences would be for a certain variable. In order to facilitate the identification of the questions each group has been given an abbreviated name (Figure 2).

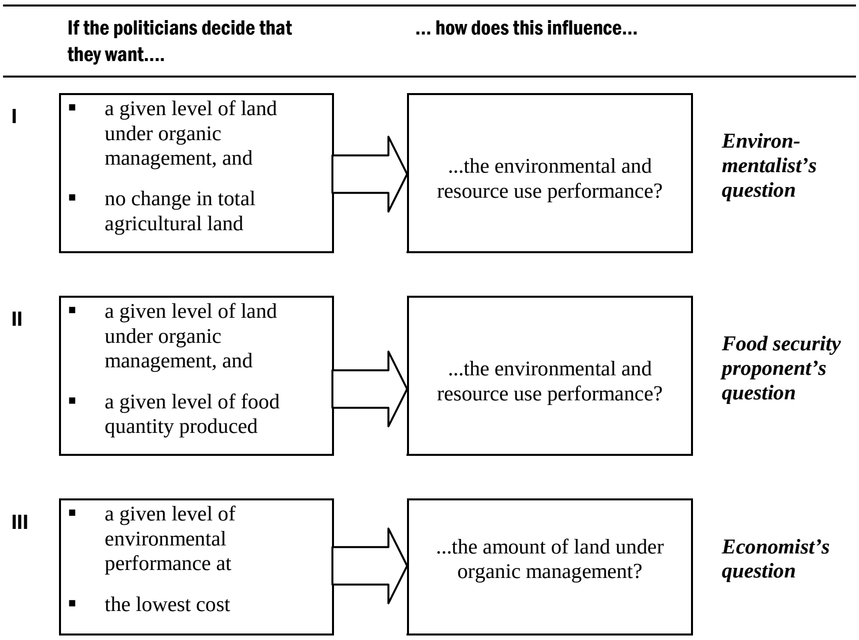


Figure 2: Policy relevant questions with respect to the environmental and resource effects of organic farming

The three questions raised shall be the subject of a detailed discussion in the following.

I. Environmentalist's question:

How would an increase in the area of organic farming (e.g. doubling) influence environmental and resource use performance?

This question assumes a policy decision of no change in the total agricultural land area and of an increasing proportion of organic farming (Table 5-1). This, of course, implies a decrease in food production but for certain reasons this is not important for the persons asking this question, e.g. due to surplus production.

The question raised can be answered from the conclusions this report has reached. Organic farming performs as well as conventional farming in some aspects and better in a number of others (Table 4-24). Organic farming performs particularly well in the categories wildlife, biodiversity and ground and water protection. Thus the short answer to the question is:

An increase in the area of organic farming would clearly improve the total environmental and resource use performance of agriculture.

It has to be pointed out, that the environmentalists' question could, of course, also be formulated in a way to ask for the consequences of a decrease in the area of organic farming from today's level. Here it should be noted that the question might be asked as to where the environmental and resource effects would be especially strong - either in which regions or on what farm types or a combination of both. This could be regarded as a more specified question of the same type. Of course, it would be highly desirable to be able to differentiate between the effects by regions and farms types. This question can not be answered based on the empirical material in this report.

However, it is possible to deduct that the effects would be stronger where problems of wildlife and landscape and ground and surface water are especially relevant. Areas of this type include water protection areas and those where specific protection zones for wildlife exist such as biosphere reserves. The acceptance of organic farming has been especially strong in the less favoured areas and those where conventional farming causes fewer environmental problems than on average. This means that the environmental and resource protection potential of organic farming would most likely be higher in regions with currently low adoption rates.

II. Food security proponent’s question

How would an increase of the area of organic farming (e.g. doubling) influence environmental and resource use performance assuming that the same amount of food is to be produced as today?

The food security proponent's questions supposes a policy decision of an increase in the organically farmed land area with a total food production fixed to the today's level (Table 5-1). The assumption that food quantity might become short in the EU sounds a bit exaggerated at times when surpluses are prevalent. It might be relevant in the future when food in the EU could possibly become scarce.

Organic farming's lower yield level is the relevant factor in this case. The positive environmental effects on the area in which conventional agriculture is substituted by organic farming are not the total environmental effect in this situation. With lower yields, organic farming would need more agricultural area than conventional farming to produce the same amount of food. The beneficial effects of organic farming would have to be weighted against the effects that derive from an increased demand for agricultural land. Here it is assumed that the food consumption pattern does not change at the same time (as a first step, this seems to be a reasonable assumption). This additional area would first of all come from land set aside but eventually even forests or wilderness areas would be demanded for farm use.

It is usually assumed by people asking the above question that the effects of using these areas for farming purposes are negative, especially in terms of biodiversity. This might or might not be the case, as farming might enhance environmental quality in comparison to pure nature (i.e., cultural landscapes). It is not possible to answer this question without specifying which areas are concerned and what would happen there. An answer to the latter question requires complete information about the farming system’s environmental performance per unit of output. Because especially this kind of information is scarce, the material in this report unfortunately does not permit a reply to this question. More specific research efforts in this area are necessary.

In order to answer the question as to how increased organic farming area and stable food amounts would influence the environment and resource use, it is *necessary to have detailed information about environmental indicators' performances in terms of per unit of output. This type of information is scarce and insufficient to answer the above question.*

Although it is scientifically deplorable that more information is not available on a per unit of output basis, it is less problematic for practical EU policy in today's political environment. In a policy environment in which broad consensus seems to be that the area of land used for agriculture should not drastically change and in which food surpluses are still more of an issue than the fear of food scarcity, the best way to express environmental indicators is in terms of per unit of land. Therefore, the food security proponent's question is currently politically irrelevant.

III. Economist's question

If a specific level of environmental and resource use is given as a policy target, what would be the lowest cost solution to achieve this level and what level of organic farming would be part of the solution?

The first two questions raised do not take cost as a variable into account. In these cases, the variable 'cost' is irrelevant. Economists as a group always seem to be preoccupied with cost and tend to look at organic farming not as an end in itself but as a means to reach certain environmental goals. But which farming system or which combination of farming systems respectively can provide a targeted level of environmental performance at least cost (Table 5-1)? This means, if other farming systems can reach the aspired level of environmental performance cheaper than organic farming, then organic farming should not play a role in the economist's view. Unfortunately, there is almost no direct empirical evidence for answering this question, only some theoretical reasoning is possible.

On the basis of the material reviewed in this report, organic farming's contribution to achieving a defined level of environmental and resource use goals at lowest cost cannot be identified.

If the economist's question is asked, it is often assumed that it is unlikely that organic farming as a ”fixed system” coincides in respect to environmental performance with the aspiration level of society for each indicator (Alvensleben 1998). This point of view follows the ”Tinbergen rule” of economic theory that tells us that the number of policy instruments chosen should at least equal to the number of targets set (Ahrens and Lippert 1994, Henrichsmeyer and Witzke 1994). This is theoretically sound if the following prerequisites are given:

- the environmental indicators are measurable and the cost of measurement zero (or low);
- the interaction between the indicators can be quantitatively specified; and
- transaction cost (cost of implementation and administration) of a multitude of political instruments is zero (or low).

In reality, not every indicator can be measured easily. For environmental indicators which are difficult to measure, measuring can cause substantial cost. Furthermore, detailed agri-environmental policy measures might be quite costly to administer. The interactions between different environmental indicators are not fully understood. In many cases, scientific knowledge of these interactions is purely qualitative. This means, of course, that an optimal mix of policies cannot be quantitatively specified.

Due to these reasons, this suggests relying on indicators which can be measured easily, can be administered at low cost and cause no negative side effects on any valued environmental attribute. Accordingly organic farming could be regarded as such an environmental indicator. Of course, other environmental indicators might be better suited in a specific situation to the problem at hand. However, the ”cost” of missing detailed targets using a broad environmental indicator must be balanced with the transaction costs saved in measuring detailed indicators and administering a multitude of policies. Thus, on the basis of this theoretical reasoning, the implementation of organic farming as a broad environmental indicator could indeed be both an effective and an economically efficient element in agri-environmental policy.

Conclusions

Table 5-1 summarises the typologies of the policy relevant questions asked above.

Table 5-1: Typology of policy relevant questions

	Environmentalist's question	Food security proponent's question	Economist's question
Policy relevant question to be asked	? Change in the environmental performance of agriculture?	? Change in the environmental performance of agriculture?	? Change in the organic agricultural area?
Given policy decision	* Organic agricultural area	* Organic agricultural area	* Level of environmental performance of agriculture
Fixed at today's level	* Total agricultural land area	* Total food production	* Public budget (least cost)

The environmentalists' question concentrates on the environmental effects per unit of land, while the food security proponent's question focuses on the effects per unit of output. The economists are concerned with lowest cost solutions for reaching a given target.

To express an environmental variable on a per unit of land basis is reasonable in those cases in which the decision has been made that agricultural land is fixed. The only question is whether to use it with organic or conventional technology. On the other hand, weighting the environmental variable in relation to unit of output is appropriate if the quantity of food to be produced is given, while farmland is variable, e.g. it might be devoted to other purposes. The per unit of output approach is more difficult to interpret because one would have to also consider whether the change in the agricultural area has positive or negative effects. Economists are usually searching for efficient allocations. One way to do this is to look for cost-efficiency in reaching a given target level. This view adds the cost issue and the need to set target values for environmental indicators to the discussion.

Comparing organic and conventional farming on a per hectare basis makes sense in the current political environment of the EU as can be seen from the above discussion. The environmentalist's question is politically relevant as answered on the basis of empirical research for most indicators used. There is not sufficient information to answer the two other questions in detail, based on the empirical research. However, for policy purposes the question of whether there are other agri-environmental means that might be cheaper than organic production of achieving a desired level of environmental and resource performance is of high relevance. A tentative answer to this question can only be based on theoretical reasoning. There are convincing arguments that the support of organic farming can be a useful part of the agri-environmental tool box. Further more specific instruments are also needed. Organic farming seems especially useful if broad environmental concerns are to be addressed, because it leads to improvements in most environmental indicators.

6 References

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