Organic Agriculture and the Environment

Article · January 2002

Source: OAI

8 authors, including:

Thomas Alföldi
Forschungsinstitut für biologischen Landbau

Andreas Fliessbach
Forschungsinstitut für biologischen Landbau

Uwe Geier
Forschungsring e.V., Darmstadt, Germany

Lukas Kilcher
Forschungsinstitut für biologischen Landbau

Alfoeldi, Thomas and Fliessbach, Andreas and Geier, Uwe and Kilcher, Lukas and Niggli, Urs and Pfiffner, Lukas and Stolze, Matthias and Willer, Helga (2002) Organic Agriculture and the Environment, in El-Hage Scialabba, Nadia and Caroline, Hattam, Eds. *Organic agriculture, environment and food security*, chapter 2. Environment and Natural Resources Series 4. Food and Agriculture Organisation of the United Nation (FAO).

Organic Agriculture and the Environment

1 Ecosystem approach in organic agriculture

Agriculture, especially in its most extreme modern form of industrialized monoculture, modifies landscape and damages the ecosystem's goods and services, including biodiversity at all levels. Agricultural encroachment, agricultural pollution and agricultural intensification are responsible for contributing to soil and water degradation and to biodiversity extinction.

An **ecosystem approach to agriculture** manages soil, water, plants and animals as parts of a functional whole. It recognizes that the agricultural "system" is itself an intrinsic part of a larger ecological system and as such, has direct connections (positive or negative) with ecosystem dynamics. An ecosystem approach to agriculture allows extraction of socio-economic goods (e.g. food) while preserving and/or enhancing the natural functions provided by ecosystems. An ecosystem analysis includes both a studies of natural systems characteristics and management, in time and space, of interactions between socio-economic and natural variability, where ecosystems and the agricultural systems they support can exist side by side.

Integrated pest management (IPM), integrated plant nutrition systems (IPNS), conservation tillage (CT), and biodiversity management plans look into one aspect of the farming system components: pest ecology, plant ecology, soil ecology and biodiversity, respectively. The ability to define strategies that combine these management elements into a holistic approach is proper to organic agriculture.

Organic management focuses on the food web relations and element cycling with the aim to maximize the agro-ecosystem's stability and homeostasis.

Organic agriculture, through its systemic approach and avoidance of agro-chemical use, prevents natural resources degradation, loss of land and productive potential. In organic agriculture, nature is both instrument and aim. As organic agricultural farmers cannot use synthetic substances (e.g. fertilizers, pesticides, pharmaceuticals) they need to restore the natural ecological balance because **ecosystem functions are their main productive "input"**.

Examples are:

- Many unspecific pests like aphids, thrips, whiteflies or spider mites, economically damaging in many crops, can be kept under the economic threshold with naturally occurring or purposely released predators and parasitoids. The first ones are direct goods and services of hedges, botanically diverse field margins, inter-cropping or weedy undergrowth, the second ones do better when released in botanically and ecologically enriched habitats.
- The only way to suppress soil-borne pests and diseases in organic farming are wide crop rotations with several components of botanically different crops. Sticking to wide crop rotations is crucial in providing agroecosystem diversity.
- Diverse crop rotations or agroforestry systems guarantee a better uptake of nutrient elements from soil, a very efficient use of water and light, thanks to varying spatial and temporal root growth and leave dispersion.
- Soils with a high functional diversity of micro-organisms, which occur very often after decades of organic farming practice (Fliessbach et al. 2001), develop disease suppressive properties and can help to induce resistance in plants.

The direct economic value of ecosystem functions for organic farmers represents an excellent example of "**benefit-sharing"**. To master ecosystem functions in order to produce decent yields with high qualities, **adaptive management practices** are crucial, because growing conditions in organic farming are far from being in an optimal state, are never static and often unpredictable. To cope with these situations, farmers must become excellent observers and must be trained to react flexibly, often intuitively and appropriate to the local context. In contrast, other farming methods try hard to condition the environment of the plants to an optimal state of growing by using a wide range of inputs. Most recommendations and fertilization and spraying programs as well are highly standardized and not site-specific.

Organic farming is an approach, which is not reduced to the production sector. Inter-sectoral co-operation between farmers, environmentalists, processors and traders, quality management people and consumers as well is a very common characteristic of organic farming.

Most scientists agree on the conclusion that organic farming represents a very sustainable agriculture where ecosystem functions and socio-economic goods are well balanced. Critical questions have been raised by several papers recently:

Avery (1997) and Trewavas (2001) questioned the sustainable land use of organic farming fundamentally due to its smaller yields. Several papers show that organic farming is most efficient in using non renewable fossil energy and nutrient elements (see chapter 2.3 and 2.4). Together with the fact that the loss of natural resources like soil, biodiversity and water is considerably reduced, this indicates that Avery's and Trewavas' argument reflects only a very short term perspective. Not to forget that the performance of organic farming is still feeble due to a lack of research. More research funds could easily enhance output/input-ratio additionally.

Rigby and Caceres (2001) questioned the globalisation of organic markets. As far as the whole food chain is concerned, food miles contradict sustainability in all agricultural methods, organic or not. Globalisation of food and feed stuff production with its impact on energy efficiency and on self-reliant family farms might be favoured through organic farming, because of its clearly defined international standards and its well established certification procedures which easily permit trade. Hence, the organic movement is so far unique in adapting and implementing social standards in international trade.

Organic farming is criticised by many agronomists as the most regulated form of ecological agriculture. What seems to be an advantage for marketing (clear production standards that are granted price premiums) lacks flexibility for system designers used to making free choice of all possibilities science offers (such as genetically modified organisms). Consequently, some scientists reject the legally defined standards and norms of production, processing and labelling as ideology borne restrictions, not scientifically derived from an ecosystem approach. Why not make advantage of 100% of the progress of agricultural R&D to develop both a better economic performance and a higher ecological sustainability of agricultural production? Couldn't it be that some techniques like Integrated Pest Management (IPM) or Integrated Crop Management (ICM) offered not only better solutions to practical problems but also finer tuned approaches to stable agroecosystems (von Alvensleben, 2000)? But only by restricting farm inputs, farmers use preventive techniques consequently. The ban of herbicides e.g. makes ignoring good crop rotation principles disastrous in terms of yields and long term problems with weeds. The ban of soluble and cheap in bought-fertilisers makes nutrient-conserving crop rotations and using organic fertilizers sparingly by reducing losses economically interesting. The failure of IPM/ICM to reduce environmental encroachment is the result of rejecting consequent bans.

Doherty et al. (2000) described sustainable agriculture as "ecological engineering solutions aim to minimally manipulate and manage ecosystems for the benefit of both nature and humanity". To date, no other ecological farming scheme than the organic one has succeeded in providing ecosystem functions and socio-economic goods in a comparably equitable way.

2 Organic agriculture and abiotic resources

Matthias Stolze[1], Uwe Geier[2], Thomas Alföldi[3]

2.1 Soil

Being the central basis for all agricultural activity, soil is one of the most important natural resources. Due to the fact that organic farmers cannot compensate for a loss in soil fertility by inputs of synthetic nutrients, the building and maintenance of soil fertily is a central objective of organic agriculture (Lampkin 1990, Stolton et al. 2000, International Federation of Organic Agriculture Movements 2000). The impacts of organic farming on soil properties have been covered extensively by research with a special focus on the relevant parameters organic matter content, biological activity and soil erosion.

2.1.1 Organic matter content

The environmental relevance of organic matter content is based on its capacity to limit physical damage and to improve nutrient availability as well as biological activity. Research on organic matter concentrates on measuring the parameter soil organic carbon content.

The review of relevant research conducted by Stolze et al. (2000) concludes that under European conditions organic farming has beneficial effects on the characteristics of soil organic matter because the soil organic carbon content is higher on organically farmed soils than on conventional ones Organic farming practise bases fertilisation on organic substances, such as farmyard manure, compost, green manure, plant residues and commercial organic N-fertilisers. Consequently there is an extensive supply of organic matter passing through aerobic decomposition processes. Mineralisation and decomposition processes are influenced by humidity, temperature and oxygen. This means that under humid tropical conditions these processes run faster and all year long whereas under Northern conditions they are slower and come to a halt during the colder months. Soil type also plays a role. Sandy soils dry out fast which slows down decomposition processes, ferralitic soils on the other hand are generally not very fertile, but they encourage fast decompostion and the building-up of stable organic matter.

[1] Dr. Matthias Stolze, Research Institute of Organic Farming (FiBL), Ackerstrasse, CH-5070 Frick
[2] Dr. Uwe Geier, Research Institute of Organic Farming (FiBL), Ackerstrasse, CH-5070 Frick and Institut fuer Organischen Landbau, Bonn, Germany
[3] Thomas Alfoeldi, Research Institute of Organic Farming (FiBL), Ackerstrasse, CH-5070 Frick

2.1.2 Biological activity and soil micro-organisms

A high biological activity promotes metabolism between soil and plants, and should be a focus of a sustainable plant production and fertiliser management. In contrast to conventional farming, organic farmers depend more on a high and sustained supply of organic substances. Organic farming practise aims therefore at an organic fertilisation management which is based on crop rotations with clover/grass ley, underseeds, catch crops, green and animal manure (Stolze et al. 2000). Not surprisingly, under European conditions organic farming performs better than conventional farming with regard to relevant parameters:

- 30 to 100 per cent higher microbial activity (Diez et al. 1985; Niederbudde & Flessa 1988; Beck 1991).
- A significantly higher biomass (+30 to 40 per cent), density (+ 50 to 80 per cent) and species diversity of earthworms, the key species for soil-macro fauna (Pfiffner 1997, see also section on biodiversity).

Soil is the habitat for plants, animals and micro-organisms. As plant build up organic matter, soil animals feed on them and their debris whilst microbes decompose the complex organic compounds to their mineral component and to CO_2. The living soil is a central part of soil fertility because the activity of soil organisms render available the elements in plant residues and organic debris entering the soil. Part of this material however remains in the soil and contributes to its stabilisation by humus build up. Earthworms work hand in hand with fungi, bacteria and numerous other micro-organisms in soil.

Various research results show that the activity of micro-organisms is higher in organically than in conventionally managed soil. As a consequence of the higher activity of micro-organisms, in organically managed soils nutrients are recycled faster and soil structure is improved.

Fliessbach et al. (2001) for example found in Switzerland up to 90 per cent higher total mass of micro-organisms in organically managed soils. As concerns soil fungi, Elmholt (1996) found a higher number and abundance of saprophytic soil fungi with a higher potential of decomposition of organic material. An important representative of soil fungi are mycorrhizae that build up symbiosis between fungus and plant. The degree of mycorrhizal root colonisation was found to be distinctly higher in organic plots as compared to conventional plots (Mäder et al. (2000) 2000; Smith & Read, 1997).

As mineralisation processes run much faster on ferralitic soils of the tropics and subtropics than on soils typical for temperate and continental zones, a high organic matter content and high biological activity are the pre-requisite for sustainable soil fertility. The positive impacts of organic farming on biololgical activity, micro-organisms and soil organic matter content reported in the paragraphs above, are therefore also valid for soils in the tropics and subtropics.

2.1.3 Soil erosion

Soil erosion is assumed to be the main cause of soil degradation around the world. The loss of fertile top soil by erosion results in a lower yield capacity on the onehand and in a undesired transfer of nutrients, pesticides and sediments in surface water on the other.

Reganold et al. (1987) found during a long-term comparison a 16 cm thicker topsoil depth on the organically managed plot due to lower erosion This was most probably due to inclusion of a green manure legume crop in the third year of rotation and fewer tillage operations on the organic field. In this trial the long-term effects of organic (since 1948) and conventional farming on selected properties of the same soil had been compared on to farms near Spokane in Washington, USA. The organically farmed soil did not only have a thicker topsoil but had also a significantly higher organic matter content and less soil erosion than the conventionally farmed soil. The authors concluded that the organic farming system was more effective than the conventional farming system in reducing soil erosion and in maintaining soil productivity.

Generally, organic soil management techniques like organic fertilisation, mulching and cover cropping improve soil structure and therefore increase the water infiltration and retention capacity and thus reducing the erosion risk substantially. These management techniques are also of special relevance on porous feralitic soils of the tropics and sub-tropics to reduce the soil erosion risk as a consequence of frequent heavy rainfall.

2.1.4 Synthesis of research results on soil and organic agriculture

A thorough comparison on relevant soil parameters of conventionally and organically managed soils is provided by the long-term DOC-trial[4] carried out by the Swiss FiBL (Mäder et al. 1999; Fliessbach et al. 2001). The results of the DOC trial can be summarised as follows:

- Organic matter content is usually higher in organically managed soils than in exclusively minerally fertilised conventionally managed ones, due to the organic fertilisation methods. A high organic matter content also helps to avoid soil acidification.
- Organic soil management improves soil structure by increasing soil activity, thus reducing the risk of erosion.
- Organic crops profit from root symbioses, and they are better able to exploit the soil.
- Organically farmed soils have significantly higher biological activity (earthworms, fungi, bacteria, micro organisms) than those of conventionally

[4] The DOC trial was started in 1978 in Switzerland. In this long-term (more than 20 years) trial the three farming systems are compared in a randomised plot trial: bio-dynamic (D), bio-organic (O) and conventional (K) (Fliessbach et al., 2001).

managed. Thus nutrients are transformed more rapidly and soil structure is improved.

- Organic management promotes the development of soil fauna such as earthworms and above ground arthropods, thus improving the growth conditions of the crop. More abundant predators help to control harmful organisms (Pfiffner 1997, Pfiffner & Mäder 1997).

2.2 Ground and surface water

The detrimental effects of intensive agriculture on ground and surface water are largely due to erosion and to nitrate and pesticide pollution. The most important threats to water quality posed by agriculture are: a high organic fertilisation level in combination with high stocking rates, the excessive application of mineral N-fertilisers, the lack of a protective soil cover, a narrow crop rotation and frequent tillage, a high level of available nitrogen after harvest and contamination of water with synthetic pesticides. Below, the impact of organic farming on water quality will be evaluated by analysing the parameters of pesticides and nitrate leaching.

As organic farming does not use synthetic pesticides at all, there is no risk of ground and surface water pollution through synthetic pesticides.

As concerns nitrate leaching, Table 1 summarises relevant research results on nitrate leaching rates from Germany and the Netherlands. Table 1 shows, that under western European conditions, the nitrate leaching rates per hectare are significantly lower in organic farming compared to those of conventional farming systems.

Table 1: Nitrate leaching rates per hectare from organic farming compared to conventional farming systems (farm comparisons) (Stolze et al. **2000, expanded)**

Reduction of nitrate leaching rates in organic farming compared to conventional farming	Authors
> 50 %	Smilde (1989)
> 50 %	Vereijken (1990)
57 %	Paffrath (1993)
40 % (sand) / 0 % (loam)	Blume et al. (1993)
50 %	Reitmayr (1995)
40 %	Berg et al. (1997)
64 %	Haas (1997)

The reasons for the lower nitrate leaching rates in organic farming are the ban of mineral N-fertilisers and the lower livestock densities. These constraints set up by the organic farming standards lead to the situation, that quantitatively on organic farms nitrogen is – in economic terms - a scarce-factor. The economic consequences of nitrogen to be scarce on organic farms is quite impressive: the opportunity costs (costs to produce nitrogen on-farm) of 1 kg nitrogen on organic farms can amount from seven to sixteen times the costs of mineral N-fertilisers (Stolze et al. 2000). So it is not surprising, that in contrast to conventional farms, where manure and slurry are often a waste problem, organic farmers are forced to develop efficient nitrogen management strategies like intercropping, catch cropping, optimal ploughing in of legume crops or limiting the use of liquid manure to avoid nitrogen losses.

Due to these facts in some countries (e.g. Germany) waterworks subsidise conversion to organic farming in water protection areas as an economically efficient solution to reduce costs for cleaning-up drinking water through minimising the nitrate and pesticide contamination of groundwater.

Even though scientific results from other climatic zones are scarce, positive effects of organic farming on the nitrate leaching risk can be reported from a citrus farm in Cuba. Under organic fertilisation management based on compost with 60 kg available N per ha, the farm achieved exactly the same yield level like under conventional fertilisation management with 200 kg of mineral N. This example shows, that organic fertilisation management can help reduce the risk of nitrate leaching especially under extreme climatic conditions (Kilcher 2001).

2.3 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 could subsequently lead to water and air contamination and eutrophication. However, nutrient deficiency is synonymous with the overexploitation of soil nutrients in the long run, which consequently leads to a decrease in yield and crop quality.

Research done by Freyer (1997) in Switzerland shows that only 14 per cent of all organic farms have an N-surplus, and only 1.5 per cent had a P-surplus. Most of the organic farms have a negative N- and P-balance. Results from different European countries comparing phosphorous and potassium balances of conventional and organic farms are presented in Table 2: Even though the ranges between single studies vary a great deal, it can be concluded that the phosphorous and potassium surpluses of organic farms are significantly lower than on conventional ones (Stolze et al. 2000).

Table 2: Examples for P, K balances (kg/ha) comparing organic with conventional farms from different European countries (Stolze et al. **2000, modified)**

	P balance (kg/ha)		K balance (kg/ha)	
	Organic	Conventional	Organic	Conventional
Sweden	-12	+37	-4	+39
Netherlands				
Cash crop farm	+18	+23	+31	+25
Horticulture	+32	+60	+119	+110
Dairy farm	+8	+31	Na	Na
Germany				
Mixed farm	-4	+13	-27	+31
Dairy farm1	-2	+5	+7	+20

1) Haas & Wetterich (2001)

Due to negative nutrient balances as shown in table 2, the question arises whether organic farming methods cause gradual loss of soil minerals. First of all, the proportion of soluble nutrient fractions is lower on organic managed soils. On the other hand, Mäder et al. (2000) found no decrease in organic yields as an indicator for nutrient deficiency on farms which are managed organically for more than 30 years. As show in section 3.1, e.g. higher biological activity and higher mycorrhical root colonisation counteract nutrient deficiency, thus Oberson et al. (2000) state, e.g. for phosphorus, the aim of organic farming to increase nutrient supply through increased biological activity has been achieved.

2.4 Energy use

Energy consumption in agriculture includes the direct consumption of fossil energy (e.g. fuel and oil), as well as indirect energy consumption, e.g. from the production of synthetic fertilisers and pesticides. Ignoring indirect agricultural energy consumption, OECD statistics indicate that agriculture contributes to total direct energy used in OECD countries by two per cent. Nevertheless, limited fossil energy resources and the climatic relevance of its use require an efficient energy use even in agriculture. Relevant parameters to evaluate energy use in agriculture are energy consumption and energy efficiency.

Considering both, direct and indirect energy consumption, scientific calculations on energy consumption per hectare indicate that organic farms use less energy than conventional farms: Haas & Köpke (1994) and Lampkin (1997) calculated the energy consumption of organic farms to amount 64 per cent of conventional farms Recent research done by Zarea et al. (2000) in Iran and Fliessbach et al. (2001) in Switzerland confirm the figures mentioned above on a lower level, determing the energy consumption of organic farms to amount 45 per cent or 30 to 50 per cent of conventional farms, respectively.

Table 3 below shows figures on energy consumption (GJ) both per hectare and per output unit scale (t) for different crops, comparing organic and conventional farming systems in Sweden, Germany, Switzerland and Italy. The determining factor for energy consumption of a specific crop is its cropping management, which includes tillage intensity, manuring and weed control. On a per hectare scale, all authors determined a lower energy consumption on organic farms. For organic potatoes and apples, however, energy consumption per output unit is higher relative to conventional production. This is the result of a higher energy input for mechanical measures like weed control in organic production and of a lower mineral N-fertilisation use in conventional production.

Table 3: Calculations of energy consumption of different products (Stolze et al. **2000, expanded)**

Product	**Energy use GJ/ha**			**Energy use GJ/t**		
	Conventional	Organic	as % of conventional	Conventional	Organic	as % of conventional
Winter wheat						
Alföldi et al. (1995)	18.3	10.8	-41	4.21	2.84	-33
Haas & 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 & Köpke (1994)	24.0	13.1	-46	0.08	0.07	-18
Reitmayr (1995)	19.7	14.3	-27	0.05	0.07	+29
Citrus						
Barbera & La Mantia (1995)	43.3	24.9	-43	1.24	0.83	-33
Olive						
Barbera & La Mantia (1995)	23.8	10.4	-56	23.8	13.0	-45
Apple						

Geier et al. (2001)	37.35	33.8	-9.5	1.73	2.13	+23
Milk						
Cederberg & Mattsson (1998)	22.2	17.2	-23	2.85	2.41	-15
Wetterich & Haas (1999)	19.1	5.9	-69	2.65	1.21	-54

The second parameter appropriate to evaluate energy use isenergy efficiency. It, provides information about the ratio of energy input and output. Comparing rotations of different production systems in Iran, Zarea et al. (2000) found the energy efficiency of organic farming to be 81 per cent better compared to high input conventional farming. In a similar investigation in Poland Kus & Stalenga (2000) calculated a 35 per cent higher energy efficiency of organic compared to conventional farming. Under Mediterranean conditions, Ciani & Boggia (1993) and Ciani (1995) found for Italy a 25 per cent higher efficiency in organic wheat and a 81 per cent higher efficiency in organic vineyard production systems.

Even though the ban of synthetic pesticides might lead to higher fuel consumption on organic farms due to increased mechanical weed control (Haas & Köpke 1994), research results presented above show that with respect to energy consumption, organic farming is performing better than conventional farming. The most important reasons for this are:

- No input of mineral N-fertilisers on organic farms which require a high energy consumption for production and transport
- Lower use of highly energy consumptive foodstuffs (concentrates)
- Lower input of mineral fertilisers (P, K)
- Ban of synthetic pesticides

Because of the more labour-intensive production activities, especially for arable crops (mechanical weed control) and a higher share of more labour-intensive crops (e.g. vegetables, potatoes) and to more marketing and on-farm processing activities a higher labour requirements on organic in organic farms under European conditions may be expected (Schulze Pals 1994).

In Europe figures for labour use on organic farms in relation to comparable conventional farms vary between countries and studies (Offermann & Nieberg 1999). Most commonly, labour use per hectare of utilised agricultural area is on average 10 %-20 % higher on organic farms. In an European context the labour input is higher on organic arable and mixed farms, while organic dairy farms use the same amount of labour or less than comparable conventional farms. On horticulture farms, labour requirements are much higher than on conventional farms. Few data exists on pig and poultry farms, but labour per hectare of utilised agricultural area seems to be similar to conventional farms, as livestock density is reduced.

3 Organic agriculture and biodiversity

Lukas Pfiffner5 and Helga Willer6

3.1 Agriculture and biodiversity

For hundred of years agriculture has contributed substantially to the diversity of species and habitats, and agriculture has formed many of today's landscapes. Over the last century, however, modern intensive agriculture with its high input of synthetic pesticides and fertilisers, monocrop specialisation has been detrimental to the diversity of genetic resources of crop varieties and livestock breeds, to the diversity of wild flora and fauna species and to the diversity of ecosystems (Shiva 2001, Stanners & Bourdeau 1995). The 2000 IUCN Red List of threatened species of the world highlights habitat loss as the main threat to biodiversity, with agricultural activities affecting 70 per cent of all threatened bird species and 49 per cent of all plant species (IUCN 2000).

Because of the increasing loss of agricultural biodiversity at a global scale the Convention of Biological Diversity set up a work programme on this subject in 1996. This work programme states inter alia that farming practices that stop degradation as well as restore and enhance biological diversity should be encouraged, including organic farming (Convention on Biological Diversity, Decision III/11, 2001).

Organic farming is dependent upon stabilising agro-ecosystems, maintaining ecological balances, developing biological processes to their optimum and linking agricultural activities with the conservation of biodiversity. Wild species perform a variety of ecological services within organic systems: pollination, pest control, maintenance of soil fertility. Thus, higher levels of biodiversity can strengthen farming systems and practices. Organic systems also substantially reduce external inputs and do not use synthetic chemical fertilisers, pesticides and pharmaceuticals. Instead, systems are designed to manage nature in order to determine agricultural yields and disease resistance. By respecting the natural capacity of plants, animals and the landscape, organic agriculture aims to optimise quality in all aspects of agriculture and the environment (Stolton 2002).

Biological pest control on organic farms, for example, relies on maintaining healthy populations of pest predators. A study in California comparing conventional with organic tomato fields showed a higher natural enemy abundance and greater species richness in the organic tomato field. There was no significant difference for any type of damage to tomato foliage or fruit, showing that the organic system

[5] Lukas Pfiffner, Research Institute of Organic Farming (FiBL), Ackerstrasse, CH-5070 Frick
[6] Dr. Helga Willer, Research Institute of Organic Farming (FiBL), Ackerstrasse, CH-5070 Frick

achieves the same levels of pest control without having to apply synthetic chemical pesticides (Letourneau & Goldstein 2001).

Organic agriculture is thus committed to the conservation and enhancement of biodiversity within agricultural systems, both from a philosophical perspective and from the practical viewpoint of maintaining productivity. To this end the importance of biodiversity as part of a well-balanced organic system is part of the IFOAM International Basic Standards for Organic Agriculture Production and Processing for organic agriculture that have been developed worldwide for organic farming (International Federation of Organic Agriculture Movements 2000).

Biodiversity is generally assessed at three distinct levels (European Environment Agency 2002):

- Genetic diversity: the variation between individuals and between populations within a species;
- Species diversity: the different types of plants, animals and other life forms within a region; community
- Ecosystem diversity: the variety of habitats found within an area (grassland, marsh, and woodland for instance).

These levels have been used in this section to show the links between biodiversity and organic agriculture.

:

3.2 Diversity of genetic resources in organic farming

3.2.1 Higher crop diversity on organic farms

Organic farms display a higher diversity of domesticated species than conventional farms. This is because organic farms are mostly mixed farms, integrating animal husbandry with crop production, using vast and diverse rotations, intercrops and green cover crops, and maintaining soil fertility by cultivating nitrogen fixing legumes (Stolze et al. 2000).

Hausheer et al. (1998) evaluated crop rotations on 110 organic, integrated and conventional farms in a Swiss pilot farm project. They found a) more diverse crop rotations (4.5 different crops in organic as opposed to 3.4 different crops in integrated farming) and b) they found a higher number of crops, including perennials, vegetables and herbs (10.2 in organic and integrated farms; 7.4 in conventional farms).

3.2.2 The Maintenance of genetic resources in organic farming

Today the adoption of high-yielding, uniform cultivars and varieties has led to a considerable reduction in the number of species used in agriculture. There is evidence for the trend towards monoculture and uniformity is given for instance by the fact that in India under the impact of the Green Revolution the number of cultivated rice varieties has decreased from more than 100,000 to 10. In India 50 per cent of the goat breeds, 20 per cent of the cattle breeds and 30 per cent of the sheep breeds are in danger of disappearing (Shiva 2001).

Organic producers are looking for productive varieties that are suited to their local climatic and soil conditions and are not susceptible to disease and pest attack. Research has shown that in these characteristics might be found in the older native cultivars, and the organic farming standards recommend the cultivation of site adapted crop varieties (International Federation of Organic Agriculture Movements 2000). This does, however, not necessarily mean that organic farming sets narrow limits to the use of modern maximum yield varieties, which are often chosen for resistance reasons. Still the preservation of old varieties and breeds is an important initiative of the organic movement, but activities depend on the initiative of individual farmers (Stolze et al. 2000).

There are many schemes and projects worldwide working to conserve seed banks and indigenous varieties, many of which are linked to organic agriculture projects (Stolton 2002). For instance, the Sustainable Agriculture and Rural Development Project (SARDI) in Kenya is working with communities in the Gilgil district to develop organic systems to increase food security through a community indigenous seed conservation programme. Indigenous seeds have been shown to perform better in the harsh drought conditions (Wairegi, 2000, reported in Stolton 2002).

3.2.3 Genetic engineering, agricultural biodiversity and organic farming

Apart from the adoption of high-yielding, uniform cultivars a further possible threat to genetic diversity, and biodiversity in general, are the side-effects of the release of genetically engineered organisms into the environment (Soil Association 2001).

Genetically engineered plants, which are designed to control pests, can have negative side-effects on beneficial insects and further non-target organisms as well. It was found that oilseed rape with genetically induced resistance to insects also damages beneficial insects such as honey bees (Crabb 1997). The use of herbicide resistant plants could result in a higher use of herbicides, increasing the negative effects of intensive farming on natural biodiversity. Furthermore there is the danger that transgenic plants could become feral and thus suppress indigenous flora. Feral oilseed rape populations in Canada are resistant to three herbicides and have become one of the most troublesome weeds (Spears 2001). As organic farming is dependent upon maintaining ecological balances and diverse agro-ecosystems genetic engineering is a contradiction to the principal aims of organic agriculture.

Organic agriculture does not allow genetic engineering in its standards as genetic engineering focuses on the genetic makeup without taking into account the complete organism or farming system in which the organism functions (Soil Association 2001).

3.3 Species diversity and organic agriculture

Floral diversity has been shown to contribute to ecosystem stability whilst the invertebrate community associated with field boundaries performs many ecosystem functions including biological control of pests and diseases, pollination and food resource for higher trophic levels (Altieri 1999).

3.3.1 Floral diversity

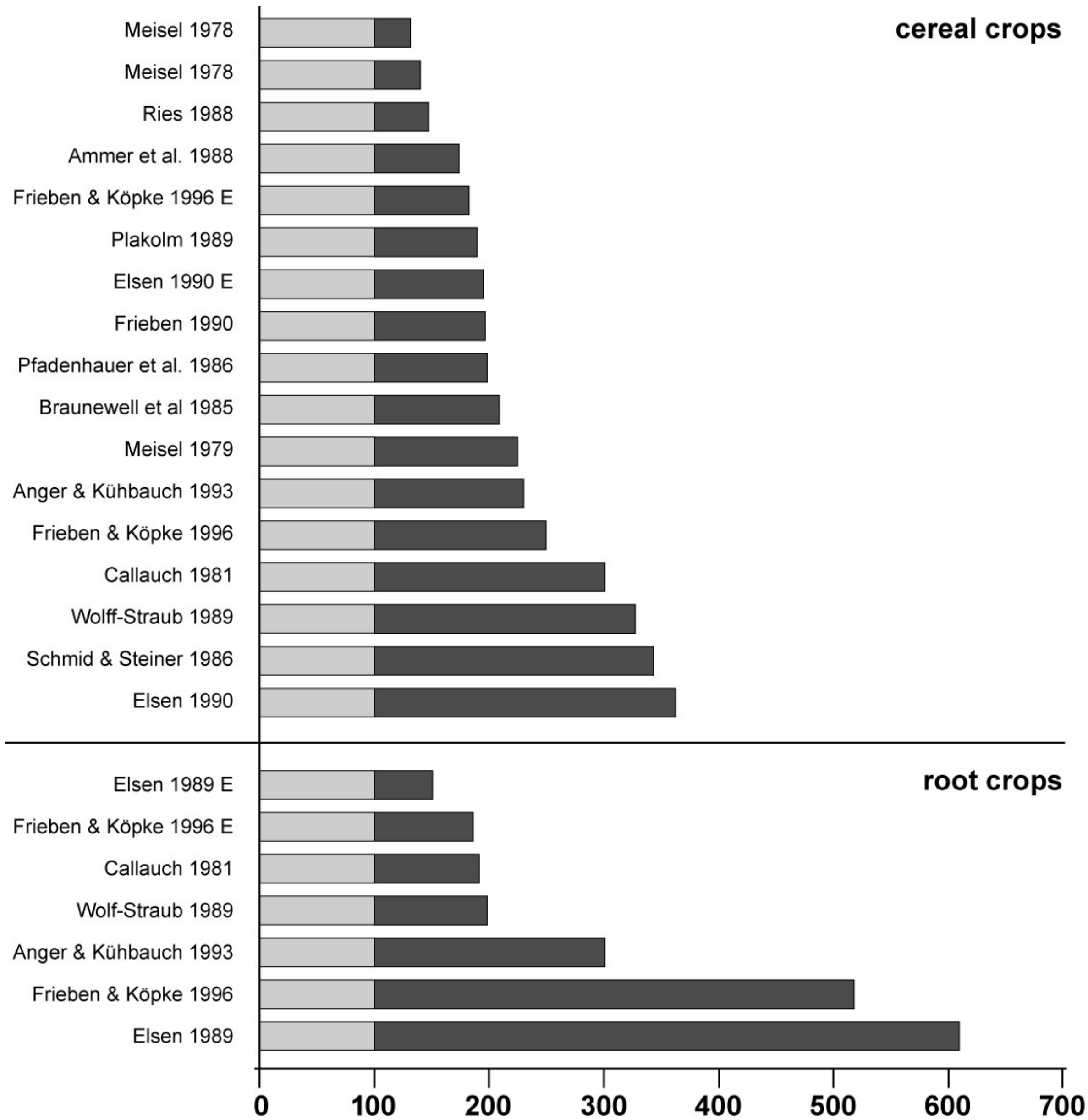
Today the diversity of the typical wild flora on arable fields, which are the main habitat for a wide range of species, is at risk. Many species are endangered, due to agricultural intensification, including the intensive use of mineral fertilisers and of herbicides, intensive soil management and the destruction of habitats. In grassland species diversity is decreasing, too, caused by intensification of grazing management and by high inputs of fertilisers.

Whereas in conventional farming weeds are considered competitive to the crop and are eliminated by herbicides, in organic systems some of the accompanying plants are desired to a certain degree and considered useful, as they provide a wide range of ecological services. These services include protection from soil erosion, an alternative food resource for pests as well as habitat and food for beneficial organisms and pollinators.

Several comparative analyses carried out in Europe have shown a higher plant species diversity in organic arable fields, which can be 30 to 350 per cent higher than in conventional ones (see figure 1 below compiled by Frieben 1997 and modified by Köpke 1999). In field edges the number of plant species can be twice as high as in conventional fields, and the inner parts of the fields can have up to six times as many species compared to conventional fields (Frieben & Köpke 1996). Figure 1 shows the results of several studies comparing floral diversity on organic and on conventional fields. 100 per cent represents the conventional field; in all cases organic farming performed a higher floral diversity.

Figure 1: Studies comparing species numbers of arable weed flora in organic and conventional arable fields in Central Europe (Frieben 1997, modified by Köpke 1999) © Frieben / Köpke

The number of species found in organic fields is shown in per cent compared to the conventional variants (conventional = 100 %) E = field edge



© Frieben -1997 / Köpke 1999

In Sweden a number of endangered, rare or decreasing species were recorded on organic arable fields, showing that organic farming can contribute to maintaining biodiversity (Rydberg & Milberg 2000).

In Romania a weed survey in maize fields showed a significantly higher diversity of weed species in the organic maize field. This study had been carried out within the framework of a research project assessing the feasibility of organic farming in three

Danube river countries. In this study positive effects of the organic system had also been recorded for further biodiversity indicators (e.g. ground-dwelling arthropods and earthworms) (Znaor & Kieft 2000).

Organic farming conserves the site-typical plant community of floral species of arable land in most cases more than conventional farming does (Frieben 1997). A survey which compared organic fields with conventional fields showed that in the organic system the share of the fields with endangered floral species was 79 per cent as opposed to 81 per cent 27 years earlier, showing that the share had almost not changed. In the conventional fields the rate had dropped from 61 per cent to 29 per cent (Frieben 1997).

The higher floral diversity and abundance in organic arable fields is generally due to the ban of synthetic N-fertilisers and herbicides. The limited availability and input of nitrogen, the application of mechanical and thermal weed control as well more diverse crop rotations and a higher crop diversity lead to more favourable conditions for many wild plant species.

In organic grassland the average number of species was found to be higher in organic than in conventional grassland, amounting to around 25 per cent more, including some species in decline. The plant community structure in organic grassland is more even and more typical for a specific site than in conventional farming (Frieben 1997). The higher floral diversity is often caused by lower stocking rates and lower fertilisation levels in organic farms. Additionally the mowing date is often delayed in organic grassland, especially in meadows, which means that grass species can reach the flowering stage and species thus have a higher reproduction, leading to plant communities which are rich in species and structure (Frieben & Köpke 1996).

3.3.2 Effects of vegetation on faunal diversity

Weeds influence the diversity and abundance of arthropods (e.g. beetles, ants and spiders), acting as natural food resource and shelter. Especially weeds like *Umbelliferae*, *Leguminosae* and *Compositae* play an important ecological role as they provide food and thus improve reproduction (Altieri 1999). Research carried out in tomato plots on the effects of weed control on surface-dwelling arthropod species found the abundance of species clearly influenced by weed biomass. Species numbers were lowest where mulching with rye straw was controlling the weeds. However, removing weeds within 20 cm of each plant reduced weed biomass but retained higher arthropod populations than in the plots treated with herbicide or mulch (Yardim and Edwards 2000).

In the context of pollinators, which greatly benefit from a richness of flowers, it is particularly important that flowering weeds are more diverse and more abundant in organic arable fields and in organic grassland compared to conventional fields, where only few species and numbers were found (Frieben & Köpke 1996). Many insect species which feed on nectar and pollen have a higher reproduction rate due to a better food supply through species rich plant communities.

It may be assumed that as found for the butterflies (Feber et al. 1997) the organic system favours also the abundance of further pollinators like bees and wasps. Flowering plants are also important for many beneficial arthropods such as predators and parasitoids (Hald 1999).

It has been shown that orchards with rich floral undergrowth have a lower incidence of insect pests than orchards treated with herbicides, mainly because of an increased abundance and efficiency of predators and parasitoids (Altieri 1999). Also in other permanent crops, cover crops do not only provide erosion control and nutrient supply but also a high floral and faunal species diversity. This is reported for organic olive production (Kabourakis 1996) and for organic vine growing, for instance in California (Bugg & Hoenisch 2000).

In order to diversify the farming system and attract beneficial arthropods and pollinators wild flower strips are sown in organic farming orchards. In a Swiss organic orchard, it was found that the strip management favoured beneficial insects and spiders, which reduced the density of aphids. The density of aphids was reduced due to a higher mortality caused by increased numbers of predators feeding on aphids (Wyss 1994, Wyss et al. 1995). Appropriate habitat management measures increasing floral and structural diversity is a key strategy to improve natural pest control.

3.3.3 Faunal diversity

Organic farming displays in most cases a higher faunal biodiversity than conventional farming. Apart from the better food resources in organic fields the key factors are a more fauna compatible plant protection management, the organic fertilisation regimes, the more diversified crop rotation and the more structured landscapes with semi-natural habitats and field margins.

The effects of organic farming on faunal biodiversity have been studied particularly for soil fauna and for birds. A review of 44 research studies about effects of farming systems on beneficial invertebrates and birds consistently shows a better performance of the organic system (see table 4). Of the faunal groups analysed (i.e. earthworms, arthropods and birds) in 49 out of 55 investigations organic farming performed better in terms of abundance. As regards species diversity in 15 out of 22 investigations organic farming performed better.

In some cases where biodiversity is not better this might be due to the presence of some robust species which do not have special requirements regarding their habitats like some spiders.

Table 4: Effects of organic and conventional farming on fauna – a review of 44 studies in Europe and the USA (on-farm and plot trials), compiled by Pfiffner et al. (2001, modified)

Animal group	Abundance – number of individuals			Species diversity – number of species		
	Better performance in organic farming	No significant difference between organic and conventional farming	Better performance in conventional farming	Better performance in organic farming	No significant difference between organic and conventional	Better performance in conventional farming
Earthworms	17	1	0	4	3	0
Arthropods						
• Carabids	13	2	0	6	2	0
• Spiders	6	1	0	0	0	0
• Myriapods	4	0	0	1	1	0
• Bugs	2	1	0	1	1	0
• Mites	2	0	1	1	1	0
Birds	5	0	0	1	1	0
Total of animal groups	49	5	1	15	7	0

3.3.3.1 Earthworms

Earthworms are highly suitable bio indicators of soil fertility, and they are known for their sensitivity to synthetic pesticides and to many agricultural practices (Mäder et al 1996, Pfiffner & Mäder 1997). Due to their biology, earthworm populations can indicate the structural, microclimatic, nutritive and toxic situation in soils. In conventional farming earthworms are affected by the use of harmful pesticides and intensive soil cultivation.

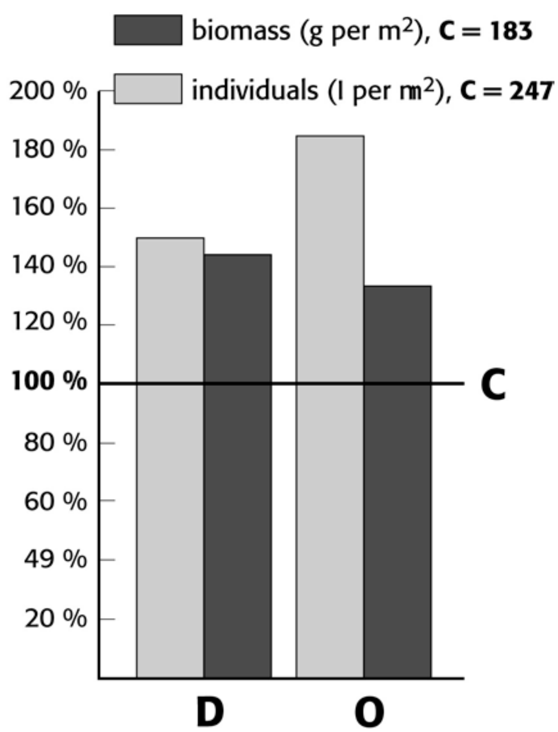
Earthworms generally increase nutrient cycling rates. Their casts greatly help to improve soil structure and have high concentration of nutrients in an accessible form to plants. The burrowing activity of earthworms enhances aeration, porosity and drainage of the soil, all of which are important factors in the development of healthy and well-developed crop root system. Earthworms play also an important role for many aspects of pest and disease control, including the reduction of leaf miner pupae and scab pathogens in orchards (Kennel 1990).

Many investigation in Europe and North America give evidence that generally, organically managed soils exhibit a higher abundance and species number compared to conventionally managed plots or farms (review in Pfiffner 1997, see also figure 2). The biomass of earthworms in the organic system in the Swiss DOC long-term trial was 30 to 40 per cent higher than in the conventional system, the number of individuals even 50 to 80 per cent higher (Pfiffner & Mäder 1997). Vertically burrowing earthworm species which are of high agro-ecological relevance (e.g. water infiltration, soil aeration, reduction of erosion) were enhanced by organic farming.

In Bulgaria in 1998 in an organic barley field in one cubic meter of soil 124 earthworms had been found compared to 21 in conventional soil (Znaor & Kieft 2000).

Figure 2: Biomass and density of earthworms in the DOC long-term trial in Switzerland (average of three years Pfiffner & Mäder 1997).

C = Conventional, D = Bio-dynamic, O = Organic. 100 % is the conventional system; set to 100 %.



Organic matter constitutes an important food source for earthworms and can be maintained by an appropriate fertilising and crop rotation system. Investigations have shown, that earthworms also benefit greatly from green manuring practices and the planting of grass-clover in the crop rotation (Pfiffner, paper in preparation). The less intensive farming practices (plant protection, soil cultivation), the more favourable fertilising management and the more diversified crop rotations on organic farms enhance specimen and species rich earthworm populations.

3.3.3.2 Arthropods

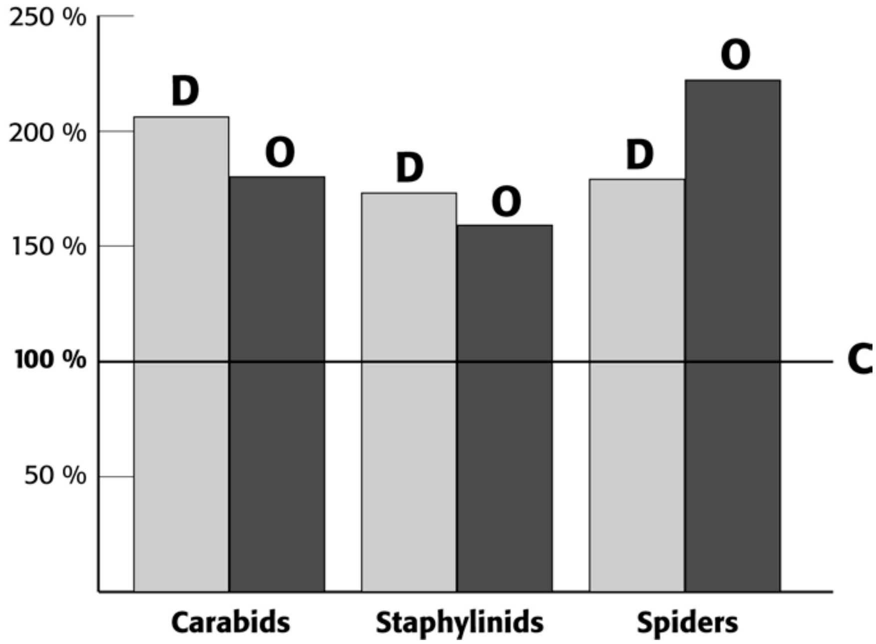
Beneficial arthropods that live above the ground are for example ground beetles (carabids), rove beetles (staphilinids) and spiders. Many of these polyphagous species, which feed on a wide range of food items, are important predators, and in arable crops these beneficial epigeic arthropods play an important role in the regulation of various pests (e.g. Luff 1983; Nyffeler and Benz 1987). In addition, certain arthropods, especially carabids, are considered as sensitive indicators of habitat quality (Steinborn & Heydemann 1990). Monitoring them yields useful information on the sustainability of different agricultural farming systems.

In conventional farming synthetic pesticides can have various negative impacts on beneficial arthropods. Pesticides affect arthropods either directly, via contamination or reduction of their prey, or through alterations of the microhabitat. The reproduction rate may be reduced by sublethal long-term effects of synthetic pesticides used in conventional farming. Foliar fungicides can lead to the mortality of springtails and thus negatively influence polyphagous predators (Burn 1989). The higher fertilisation input in the conventional fields leads to a higher density of crop, which can alter the microclimate and can also reduce the occurrence of species dependent on a warm micro-climate and on light. This phenomenon was found in the DOC long-term plot-trial as well as on farm level (Pfiffner & Niggli 1996; Pfiffner & Luka 1999). Organic fertilisation compared to mineral fertilisation can enhance epigeic arthropods through a richer supply of mesofauna decomposing organic compounds.

In several investigations of on-farm sites as well as in plot trials, a higher diversity and abundance of arthropods was found in organic and biodynamic plots compared to conventional plots (see table 4). The organic and biodynamic treatment had up to 100 per cent more carabids, 60 to 70 per cent more staphylinids and 70 to 120 per cent more spiders (see figure 3). The organic fields were also characterised by a generally more even species distribution, which means that the community is less dominated by few species only (e.g. Pfiffner & Niggli 1996).

Figure 3: Density of beneficial arthropods (carabids, staphilinids and spiders) in the Swiss DOC long-term trial (average over three years, Pfiffner & Niggli 1996).

C = Conventional, D = Bio-dynamic, O = Organic



Researchers have found greater diversity and abundance also of many other invertebrate species in organic farming systems (see table 4, Stolze et al. 2000). For example, an English study comparing spider communities in organic and conventional winter wheat fields found the abundance and diversity of spiders greater on the organic fields. It was concluded that the results were highly affected by the increased levels of understorey vegetation (i.e. broad-leaved and grass species) in the organic fields (Feber et al. 1998, reported in Soil Association, 2000). Significantly more non-pest butterflies were recorded on organic farms than conventional farms, there was however no significant difference in the abundance of pest species (Feber et al. 1997).

The quality and amount of food are key factors for the survival of the arthropod populations, which find a higher proportion of suitable food resources in organic fields including flowering non-grass plants (Hald 1999).

Various typical agricultural practices (e.g. ban of synthetic pesticides, organic fertilisation, habitat diversity) on organic farms are less detrimental for arthropod species compared with conventional farming, and they enhance beneficial arthropods.

3.3.3.3 Birds

Birds are well-suited indicator organisms showing the environmental status of nature and landscape infrastructure including agricultural land. Many bird species feed on insects, and an abundant presence may thus also contribute to a better natural pest control.

The breeding populations of a number of bird species in Western European farmland have declined in the past decades. This development is probably linked to intensified agricultural practises, including a general reduction in crop diversity, an increase in average field size, simplified rotations, cultivation of natural habitats, drainage and increasing use of fertilisers and synthetic pesticides (Christensen et al. 1996). Investigations have found a relationship between pesticide use and a decrease in quality and amount of food available for birds on conventionally farmed land. A consequence is a decreased breeding success of birds (Christensen et al.)

Several studies show that bird densities are higher in organic farms. A study by Rhône-Poulenc (1997) has shown 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.

A study by the British Trust for Ornithology (1995), funded by the UK Ministry of Agriculture, Fisheries and Food, compared breeding and over-wintering of birds on 44 organic and conventional farms. The study concluded that breeding densities of skylarks were significantly higher on organic farms and generally higher densities of birds, especially in winter, were found on the organic farms (British Trust for Ornithology 1995).

A three-year study in Denmark concentrated on the non-crop habitats, such as hedgerows, of conventional and organic farms and their effects on bird populations. The abundance of birds was 2 – 2.7 times greater on the organic farms. In total, 24 species where more prevalent on organic as opposed to conventional farms, of these 11 species had declined in number in Denmark since 1976 (Brae et al. 1988, reported in Soil Association, 2000).

Christensen et al. (1996) investigated a total of 31 farms comparing the bird densities on organic land with those on conventionally managed land. On one of the sites investigated they found a mean population density of 22.8 pairs of breeding birds per ten hectares on the organic land compared to 9.9 pairs on the conventional land. Also flora and invertebrate fauna in organically versus conventionally managed land had been compared on the farms selected for the bird survey. By late June the organic fields had 50 to 70 per cent more species of wild plants than the conventional fields, with significantly more weeds and biomass. These differences increased markedly during the growth season due to herbicide treatment in the conventional areas. The average biomass in the organic fields was significantly more stable than in conventional fields, resulting in a better security of food supply. These results suggest that the limited food availability is a key factor for the reduced number of birds in conventionally farmed areas.

In the coffee producing countries of Latin America, growing organic coffee and cocoa under shade can have a major impact on biodiversity. Research carried out by the Smithsonian Migratory Bird Centre in Colombia and Mexico showed over 90 per cent fewer bird species in sun-grown coffee plantations as opposed to shade-grown coffee (Alger 1998). Although organic standards do not explicitly state the need for coffee to be grown in the shade, shade-grown practice is recommended as it fulfils requirements to enhance soil fertility, pest and disease control and expands crop production option (Rice and Ward, 1996).

In summary it can be stated that reasons for the higher number and species diversity of birds on organic farms include better breeding habitats and better food conditions. Further reasons of the higher bird species diversity and abundance are the absence of synthetic pesticides, more semi-natural habitats (hedges, field margins) as well as a higher crop diversity on organic farms (Rösler 1997).

3.3.3.4 Other Animals

Little work is available on the effects of organic farming on further wild animal groups. This could, however, be an important research theme, particularly in regard to the questions of pollinators. Many plants require pollen from other individuals to set seeds and regenerate. Apart from wild bees and other insects, bats are the principal pollinators of fruit trees and major staple food crops, including potato, cassava, yams, sweet potato, taro, beans, coffee,and coconut. Declines in populations of pollinators now threaten both the yields of major food crops and the survival of wild plant species. Due to an epidemic of mites, a quarter of North America's wild and domestic honeybees have disappeared since 1988, with a cost to American farmers of US$ 5.7 billion per year (McNeely & Scherr 2001).

Currently, 82 species of mammalian pollinators, including bats, 103 species of avian pollinators and 1 reptile are considered threatened or extinct according to IUCN criteria, the ratio of threatened vertebrate pollinators to the total numbers of vertebrates in their genera being extremely high. Geographically, large numbers of vertebrate pollinators are at risk in Australia, Colombia, Ecuador, Indonesia, Madagascar, Mexico, Papua New Guinea, Peru, and the U.S.A. Common threats include: loss of nesting and roosting sites, habitat fragmentation by vegetation conversion or destruction, habitat fragmentation by excessive exposure of nectar plants to herbicides and pollinators to pesticides, overhunting, disruption of nectar corridors required by migratory pollinators, and competition by invasive species (Nabhan 1998).

As organic farming does not use synthetic chemical pesticides or herbicides and enhances ecosystem diversity, it may be assumed that organic farming benefits pollinators and contributes to their conservation and survival.

3.4 Ecosystem diversity

An ecosystem is made up of the organisms of a particular habitat, such as a farm or forest, together with the physical landscape in which they live (World Resources Institute 2001). Although little research has been carried out comparing agro-ecosystem diversity in different farming regimes, many of the principles of organic farming are likely to have a positive impact on ecosystem diversity (Stolze et al. 2000).

3.4.1 Ecosystem diversity in the standards for organic farming

The IFOAM Basic Standards for Organic Agriculture Production and Processing (IFOAM 2000) state that organic farming should contribute beneficially to ecosystems and facilitate biodiversity and nature conservation. The Swiss organic standards compel the organic farmers to use seven per cent of their land as semi-natural habitats (BioSuisse 2001). Many other organic certification organisation have included biodiversity requirements into their standards.

In Switzerland organic and low-input farmers receiving direct payments under the agri-environment schemes are obliged to use seven per cent of their farmland as semi-natural habitats or field margins. Direct payments of the state are linked to ecological performance which is controlled by inspection services.

In Sweden, a working group made up of organic farmers groups, nature conservationists, government agencies and universities have been working together since 1997 to strengthen the links between organic agriculture and biodiversity conservation, and they set up biodiversity plans for organic farms. The main objectives have been to help organic agriculture develop in such a way that it enhances biodiversity, to start co-operation and dialogue between the nature conservation and organic agricultural movements; and to spread knowledge about biodiversity in organic agriculture. From there, the discussions developed into a planning exercise leading to proposals for changes to the country's main organic standard (KRAV), to require all organic farmers to have a plan for the management of biodiversity on their farms from 2001 (Mattsson & Kvarnbäch 2000).

3.4.2 Semi-natural habitats as part of organic farming

The conservation and the management of semi-natural habitats plays an important role in organic farming. Semi-natural habitats are refuges for endangered plant species which in former times were found in meadows and arable fields. Semi-natural habitats and field margins are also essential for the survival of many invertebrates, especially due to favourable food and overwintering conditions. They also function as habitat cross-links between meadows, fallows and different field margins.

Quantitative data are available for Switzerland where Hausheer et al. (1998) found the proportion of semi-natural habitats and field margins per farm to be 16 per cent on organic farms compared to 3.7 per cent on conventional farms. Frieben (1997) found that organic farmers took specific measures to increase the habitat diversity (hedges, low-input orchards, ponds, corridors, habitat networks, wildlife refuges and devices) as well as to better connect farmed areas and the surrounding habitats.

3.4.3 The importance of combining semi-natural habitats with organic farming

A recent study by Pfiffner & Luka (2002) shows, how important the combination and integration of semi-natural habitats with organic farms is for the conservation and enhancement of species diversity and abundance.

In this study organic farming had been compared with low-input integrated crop management within the framework of a paired farm survey. Also nearby semi-natural landscapes had been used to compare the effects of organic farming and low-input farming system on carabid beetle and spider fauna. Many endangered or rare species which are enhanced by semi-natural habitats and field margins were more abundant in organic arable fields than in the integrated managed fields. Also agro-ecologically important carabid species and wolfspiders were found in higher numbers on the organic farms. This aspect indicates that the improvement of landscape infrastructure in combination with organic farming may be an important factor for the conservation and enhancement of species-rich communities on agricultural land.

Furthermore this approach can lead to a better natural pest control. This was shown by Thies & Tscharntke (1999) for a rape pest (the rape pollen beetle) in Germany and by Östmann et al. (2001) for the cherry oak aphid in Sweden.

3.4.4 Landscape development and organic farming

As organic farming needs a rich and diverse landscape infrastructure with semi-natural habitats organic farming has the potential for a positive landscape development (van Elsen 2000). By studying the whole farm, or even the whole landscape within which the farm operates, researchers are trying to find ways to characterise the ecosystems benefits of organic farming. A research project funded by the European Union found that the diversity of landscape and farming systems was greater in organic farms, regarding land use types, crops, livestock, plantings (hedges, solitary shrubs, trees) flora, sensorial information and labour. In terms of landscape diversity the organic types of agriculture have a good potential for positive contributions to a sustainable agrarian landscape (Mansvelt & van der Lubbe 1999).

3.4.5 Protected areas

Protected areas as defined by the World Commission on Protected Areas are areas especially dedicated to the protection and maintenance of biological diversity. Protected areas are not always strict nature reserves. Instead, they can fulfil many functions alongside biodiversity conservation. Because of its biodiversity benefits organic agriculture offers an important agricultural management option in several of these protected area categories (Stolton & Dudley 2000b).

In Italy for instance the Associazione Italiana Agricoltura Biologica (AIAB) project “Organic Agriculture and Agroecology in Regional Parks” has been working with the regional park authorities in the Emilia-Romagna region to promote organic agriculture in relation to the regional agri-environment programme. During the first two years of activity (1996-1997) there was an increase in the rate of adoption of the regional agri-environment programme, particularly of organic agriculture, by farmers in the park and the buffer zone. Between 1996 and 1997, 113 farms in the area applied for organic certification, compared with only 73 between 1994 and 1996 (Compagnoni 2000).

There are further examples from Italy (e.g. Tuscany) or Germany, where organic farming is promoted in the biosphere reserve Schorfheide Chorin (Stolton & Geier 2002).

The Estancia Itabo in Paraguay embodies a protected area of 5000 hectares of high quality Interior Atlantic Forest. The Estancia is a good example of sustainable rainforest use in line with the conservation goals of the protected area by cultivating organic Yerba Mate and the heart of palm *Euterpe edulis* (Pryor 2000).

3.4.6 Buffer Zones

A secondary and closely connected link between ecosystem diversity, protected area management and organic farming is in the buffer zones (the region near the border of a protected area). Buffer zones are by their nature areas where land management aims to help maintain the integrity of the ecosystem of the core protected area. Where agriculture is a dominant land-use in buffer zones, the detrimental effects of farming systems can be reduced by conversion to organic systems (Stolton 2002).

The use of organic farming in protected buffer zones has been explored in the Meso-American Biological Corridor, a projected complex of protected areas and sustainable management stretching over seven countries. The initiative envisages a range of sustainable land uses within the buffer zones and linking areas, including certified forest management and organic agriculture (Stolton & Dudley, 2000a, Miller et al. 2001).

In Peru in the buffer zone of the Ampay Forest Sanctuary organic farming practices are promoted. Due to information measures the awareness of the population for the biological importance of the sanctuary was increased, and as a result the area has converted into a high priority conservation area for ecotourism, governmental and private investment in infrastructure, promotion and conservation of natural resources (Flores-Escuerdo 2000).

3.5 Support for organic farming because of its biodiversity benefits

3.5.1 International support by conservation organisations

There is increasing recognition among nature conservation organisations that many species interact with agricultural systems, even if their primary habitat is in natural areas. The management of these agricultural systems can, thus, dramatically affect overall levels of biodiversity, as well as the success of particular species. The German conservation organisation BUND claims that the traditional concepts of nature protection have failed because not even in protected areas conservation goals have been achieved, due to agricultural intensification in the surrounding areas. Many conservation organisations are therefore calling for a general extensification of agricultural land use and promote organic farming for that reason (Weiger 1997).

In 1999, a joint workshop in Vignola, Italy, organised by IUCN – The World Conservation Union and IFOAM together with the World Wide Fund for Nature (WWF), was held to exchange ideas and information. A joint action plan for both the conservation and organic movements was drawn up, the so-called Vignola Declaration (Stolton et al. 2000).

Not only in developed countries but also in the developing world one of the driving force behind the growth of organic farming is the nature conservation agenda. Though less significant than market prospects and development chances, a recent literature survey highlights a number of examples where nature conservation organisations are working closely with local farmers who live in, or close to, areas of significant nature conservation interest (Parrot & Marsden 2002).

3.5.2 Government support

In the last twenty years there has been a gradual move towards policies aiming at encouraging the links between organic agriculture and biodiversity conservation also at a governmental level.

In the European Union environmental concerns have become more prominent within agricultural policy. The most notable contribution of the Common Agricultural Policy of the European Union towards more environmentally sustainable systems has been the introduction of the agri-environment programmes in 1993, which are now continued under Agenda 2000. The impetus for some of these initiatives comes from the Convention on Biological Diversity (Stolton 2002).

The implementation of agri-environmental measures over the whole of the European Union and also other European countries is the core of the Community's environmental strategy. So far, organic agriculture has played a central role in most countries' national agri-environment policy. The main reason for this policy support have been the perceived positive environmental effects of organic agriculture (Stolze et al. 2000).

Also in other parts of the world government and development agencies are beginning to promote organic farming, especially in protected areas, because of its biodiversity benefits.

4 Organic agriculture and climate change

Andreas Fliessbach[7]

Global climate change is considered one of the most urgent environmental problems. The most important negative impact to climate change is the emission of greenhouse gases (CO_2, CH_4, N_2O), which are directly or indirectly due to the burning of non-renewable resources (carbon bound in mineral oil or coal). Tropical rainforests hold the biggest living biomass on very delicate soils that may loose their fertility completely when clear cutting is performed as in the last decades. On a global scale, agricultural land use is responsible for roughly 15 per cent of the trace gas emissions with climate impact (Cole et al. 1997, Burdick 1994, Stolze et al. 2000). Moreover, agricultural intensification has had major detrimental impacts on the terrestrial and aquatic ecosystems of the world. The doubling of production during the last 35 years was associated with a 6.9 fold increase in nitrogen fertilization, 3.5 fold phosphorus fertilization and a 1.7 fold increase in irrigated land (Tilman 1999).

Agriculture, however, is not only contributing to global warming, but is also affected by it to a major extent. According to Burdick (1994) increasing global warming will shift cultivation zones polewards, plant growth and production being jeopardised by changes in the distribution of rainfall, the increase of UV-B radiation, and the changes in the chemical composition of the atmosphere. In regions with continental climate soils are subject to desiccation, which will lead to problems with salinity, erosion, and desertification. Extreme climatic events will occur more frequently. Pests and diseases favoured by a warmer climate will continue to proliferate. All these factors will have negative impacts on agricultural yields (Reilly et al. 1996).

Since climate change has a direct impact on agriculture, environmentally sound farming methods need to be developed and practiced. Organic farming does not only enable ecosystems to better adjust to the effects of climate change but also offers a major potential to reduce the emissions of agricultural greenhouse gases (Burdick 1994). Moreover, mixed farming and the diversity of organic crop rotations are protecting the fragile soil surface and may even counteract climate change by restoring the organic matter content (Haas & Köpke 1994). The carbon sink idea of the Kyoto protocol (article 3.4) may therefore be accomplished efficiently by farming organically. The potential pathways and the role of organic farming in counteracting global climatic change are summarized in table 6.

Relevant articles from the Kyoto Protocol

[7] Dr. Andreas Fliessbach, Research Institute of Organic Farming (FiBL), Ackerstrasse, CH-5070 Frick

> *Article 2.1:* Each Party … in achieving its quantified emission limitation and reduction commitments under Article 3, in order to promote sustainable development, shall:
>
> (a) Implement and/or further elaborate policies and measures in accordance with its national circumstances, such as:
>
> (ii) Protection and enhancement of sinks and reservoirs of greenhouse gases …; promotion of sustainable forest management practices, afforestation and reforestation;
>
> (iii) Promotion of sustainable forms of agriculture in light of climate change considerations.
>
> *Article 3.4:* … each Party included in Annex I shall provide … data to establish its level of carbon stocks in 1990 and to enable an estimate to be made of its changes in carbon stocks in subsequent years.
>
> … modalities, rules and guidelines as to how, and which, additional human-induced activities related to changes in greenhouse gas emissions by sources and removals by sinks in the agricultural soils and the land-use change and forestry … shall be added or subtracted

4.1 CO_2

Cultivation of land in the past with the clear cutting of natural forests has been the most important CO_2 emission that may be ascribed to the agricultural sector (Bockisch 2000). In the western world this process has ceased, however, it still proceeds in the tropical forests. Soil processes with respect to carbon are characterised by the dynamic equilibrium of input (photosynthesis) and output (respiration). Principally all the organic matter entering the soil is mineralised. Changing environmental conditions and land management may induce a temporary or definite change of the equilibrium to a new level that is considered stable. The following two sections explain the role of organic agriculture with respect to carbon stocks and CO_2 emission.

4.1.1 Emission

22 per cent of the greenhouse effect can be attributed to CO_2-emissions. CO_2 emissions from the agricultural sector play a minor role, in OECD countries they are estimated less than one per cent (IPCC 2001). In order to compare farming systems they are subdivided into the emission due to burning of oil and fuel (direct energy) and the use of oil and fuel for the production and transport of fertilisers, machinery and synthetic pesticides (indirect energy).

CO_2 emissions per hectare of organic farming systems are 48 to 66 per cent lower than in conventional systems (Burdick 1994, Stolze et al. 2000, Haas & Köpke 1994). Haas and Köpke (1994) calculated the CO_2 emissions of German organic farms to be 0,5 tons of CO_2 per hectare whereas in conventional farming the amount was 1, 3 tons - a difference of 60 per cent (Table 5). Main effects of organic farming that are responsible for this difference are:

- the maintenance and increase of soil fertility by the use of farmyard manure,
- the omission of synthetic fertilisers and synthetic pesticides, and
- the lower use of high energy consuming feedstuff,
  (Haas & Köpke 1994, Stolze et al. 2000).

In organic farming almost 70 per cent of the CO_2 was due to fuel consumption and the production of machinery, while in conventional systems 75 per cent of the CO_2 emissions are ascribed to N-fertilisers, feedstuff and fuels (Haas et al. 1995).

4.1.2 Soils as a sink for atmospheric CO_2

Soil carbon levels have decreased in the past under agricultural land use (Tilman 1998). Sustainable agricultural strategies comprising recycling of organic matter, tightening internal nutrient cycles, and low- or no-tillage practices may rebuild organic matter levels and reduce losses from the system. Mixed farming with manure amendment leads to higher organic matter levels in soil. Combined with other organic farming techniques Drinkwater et al.(1998) showed a considerable gain in soil organic matter as compared to a conventional system at comparable yield in a long-term experiment. Many long-term experiments in the world support the cognition that organic fertilization (animal manure, green manure, catch and cover crops) rebuild soil organic matter (Tilman 1998, Bockisch 2000). Accumulation of organic matter in soil is restricted by soil, climate and management factors and will reach a certain saturation level.

Haas and Köpke (1994) calculated that, despite generally (however this is not always the case) lower crop yields, plant productivity in organic farming accounts for almost the same organic matter return as in a conventional system (Table 5). This is due to the more diverse crop rotations and the longer period the soil is covered by plants. On the other hand, organic crop yields in Southern countries may be considerably higher than the national average, which has implications on organic matter return and carbon sinks (Busemann and Heusinger, 1999). A given increase in soil organic matter by 20 per cent as a result of organic farming would result in an estimated amount of 9 t carbon per ha, which is in line with the results over a 15 year period reported by Drinkwater et al.(1998). Smith et al. (1997) calculated a considerable potential increase of soil carbon when manure, straw-recycling, minimal tillage, reforestation and energy plant production are combined.

Table 5: Carbon sequestration by organic and conventional framing systems as a result of different crop rotations (Haas and Köpke 1994). (Manure is not included)

	Organic	Conventional t CO_2-C ha^{-1}	Difference
Cash crops			
- above ground biomass	3.76	4.95	-1.18
- root biomass	1.44	0.89	0.55
Catch crops[8]			
- above ground biomass	0.55	0.22	0.33
- root biomass	0.22	0.09	0.13
Weeds			
- above ground biomass	0.22	0.04	0.17
- root biomass	0.04	0.01	0.03
Sum	6.23	6.19	0.04
Energy input	0.15	0.29	-0.14
Total	6.08	5.91	0.18
Carbon-sequestration efficiency	42.8	21.6	

4.2 Nitrous dioxide (N2O)

The specific greenhouse potential of N_2O is 320 times that of CO_2. The emission of nitrous oxide not only contributes severely to the greenhouse effect but also to the depletion of stratospheric ozone. Almost 90 per cent of the global atmospheric N_2O is formed during the microbial transformation of nitrate (NO_3^-) and ammonia (NH_4^+) in soils and water. In OECD countries the agricultural contribution to N_2O emission is estimated 58 per cent (IPCC 2001). N_2O emission from soils is unproductive loss of mobile N. Any nitrogen input (mineral and organic fertilisers, biologically fixed N, crop residues) and also the mineralisation of nitrogen compounds in soils rich in organic matter contribute to the emission of N_2O. Especially in agricultural soils elevated N_2O production is depending on the nitrogen fertilisation level (Bockisch 2000). The above mentioned inputs are proposed as determinants of N_2O Emission by the IPCC (2001).

[8] Catch crops (intercrops) are son after the harvest of the main crop in order to capture the nutrients and to provide soil cover. They can also be sown between the main crop.

The ban of synthetically produced mineral nitrogen in organic agriculture is confining the productivity to the natural system limits (i. e. N-fixation) or the limits defined by the annual nutrient balance of the farm including imported fodder and organic fertilisers. Organic farming therefore is likely to emit less N_2O due to restricted intensity. This is because of a systemically lower 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 (Köpke and Haas 1994, Stolze et al. 2000). Moreover, the permanent plant cover in organic systems is more efficient with respect to the uptake of mobile nitrogen in soils and thus reducing the potential and risk for N_2O-emissions (Bockisch et al. 2000). As David Tilman (1998) points out "*sustainable and productive ecosystems have tight internal cycling of nutrients, a lesson that agriculture must relearn*".

4.3 Methane (CH_4)

Agricultural contributions to methane emissions are paddy rice fields, cattle feedlots and the burning of biomass. Aerobic agricultural soils, however, are considered sinks for atmospheric CH_4. Fertilisation with mineral nitrogen has been shown to inhibit CH_4-oxidation in soils. The lower N-fertilisation level in organic farming may therefore exhibit an advantage for CH_4-oxidation.

Agriculture is believed to account for roughly two third of the total man made CH_4 (Watson et al. 1996). However, no data exist on the effects of organic farming on methane emissions. The emission of methane by ruminants is probably not affected by organic production. The higher proportion and lower productivity of ruminants in organic farming may, however, lead to a slightly higher emission of CH_4. On the other hand, standards and breeding programs aim at longevity in order to prolong the productive period in relation to the unproductive life of young cattle. Correspondingly the "unproductive" CH_4-emission of calves and heifers may be reduced (Table 6).

Table 6: Pathways and possibilities of organic farming to directly or indirectly reduce agricultural tracegas emissions (according to Sauerbeck 2001; Cole et al. **1997).**

(◆◆ high, ◆ low, — no potential)			
	CO_2	CH_4	N_2O
1. Agricultural land use and management			
• Permanent soil cover	◆◆	—	◆
• Reduced soil tillage	◆ ◆	—	◆
• Restriction of fallows in (semi)arid regions	◆	—	—

• Diversification of crop rotations incl. fodder production	◆◆	—	◆
• Restoring the productivity of degraded soils	◆◆	◆	—
• Agroforestry	◆◆	—	—
2. Use of manure and waste			
• Recycling of municipal waste and compost	◆◆	—	◆
• Biogas from slurry	—	◆◆	—
3. Animal husbandry			
• Breeding and keeping for longevity	—	◆◆	◆
• Restriction of livestock density	—	◆	◆
• Reduction of fodder import	◆	◆	—
4 Management of fertilizers			
• Restriction of nutrient input (nutrient recycling)	◆◆	—	◆◆
• Leguminous plants	◆	—	◆
• Integration of plant and animal production	◆◆	—	◆
5. Change of consumer behaviour			
• Consumption of regional products	◆◆	—	—
• Shift towards vegetarian products	◆◆	◆◆	—

5 Organic agriculture and desertification

Lukas Kilcher[9]

The degradation of drylands is called desertification. Desertification is caused by overcultivation, overgrazing and deforestation and results in soil exhaustion and soil erosion. It diminishes soil productivity, reduces food production, robs the land of its vegetative cover, and also negatively impacts areas not directly affected by its symptoms, e.g. by causing floods, soil salinisation, deterioration of water quality, and silting of rivers, streams and reservoirs (UNCCD 2001).

Organic farming provides solutions to the problems associated with desertification because, as shown in section 3, organic farming techniques bear potentials to improve soil fertility, soil structure and moisture retention capacity. Relevant techniques in this context include composting, mulching, use of cover crops, intercropping, the use of supplemental organic fertilisers (like compost, farmyard manure, green manure, mulch) and mineral fertilisers (like rock powder, rock phosphate, potassium sulphate), the use of endemic species which are more

[9] Lukas Kilcher, Research Institute of Organic Farming (FiBL), Ackerstrasse, CH-5070 Frick

adapted to climate stress, as well as water preserving and agro-forestry techniques (Kotschi 1985, Djigma et al. 1990, Harris et al. 1998).

Organically managed soils have a high potential to **counter soil degradation** as they are more resilient both to water stress and to nutrient loss. Organic farmers feed their soils with organic fertilisers, and they can thus enhance degraded and problematic soils. With a high level of organic matter and a permanent soil cover the water and nutrient retention capacity is increased. Microorganisms have a good feeding base and create a stable soil structure. Due to the resulting high moisture retention capacity the amount of water needed for irrigation can be reduced substantially.

So far there is little scientific evidence demonstrating organic farming's potential for combating desertification; therefore practical examples of organic farming systems in arid areas are shown below. Organic farming can help bring degraded lands back to fertility. Sekem, founded in 1997, is an organic farm in Egypt cultivating 70 hectares desert near Cairo. By using organic and biodynamic agricultural methods (composting, mulching, cover cropping) the desert sands were converted into fertile soil, supporting livestock and bees. In the early 1990s, Sekem started applying biodynamic methods to cotton. The success in cotton pest control (by pheromones) raised authorities' interest in biological control: today, nearly 80 per cent of Egypt's cotton cultivation applies biological pest control, and the Ministry of Agriculture has forbidden aerial sprays of synthetic pesticides on cotton, with a view to promoting biological control. Organic cotton cultivation uses organic fertilisation like compost, wood ash, rock phosphate, clover-onion rotations and is based on intensive co-operation between farmers and scientists (Scialabba 2000).

There are other examples of how organic agriculture can create suitable micro-climates in dry areas, for example in Kenya, where the International Centre for Research in Agroforestry (ICRAF) runs organic farming projects to fight draught (Stolton 1997). Agro-forestry is one of the best uses of agro-biodiversity that also generate multiple benefits, including erosion control and moisture retention. In Tansania, the Chagga home gardens on the slopes of Mount Kilimanjaro, where certified organic coffee is produced, display an excellent example of agroforestry. The system includes a diversity of cash and subsistence crops (e.g. bananas, coffee, yams, beans) as well as livestock. Cattle and pigs are kept in stables ("zero grazing") and the manure is recycled, providing fertility. The home gardens are designed to maximise diversity. Elaborate patterns of vertical zonation provide a range of sunny and cooler conditions for different species (Parrott & Marsden 2002).

Organic farming can counter **erosion successfully**. While in conventional farming in the tropics even flat soil gets eroded due to the use of herbicides and the lack of soil cover, in organic farming a **permanently covered soi**l is an intrinsic part the system. In trials on a Cuban citrus plantation the Cuban Citrus Institute and Swiss FiBL use *Teranamus labialis*, *Arachis pintoi*, *Neonotonia wightii* and other legumes. These locally adapted leguminous crops can help restore degraded soils very fast, they successfully suppress weed, fix nitrogen and prevent erosion. FiBL-experiments have also shown that cover crops do not compete with the main crops for nutrients or water. The precondition is, however, that the system is set up in a suitable way and is adapted to soil and climatic conditions (e.g FiBL sandwich-system; see below). On the contrary: soil life is enormously enhanced, and water retention capacity are increased. The cover crop pants also serve as habitats for predators.

Graph: L. Kilcher (FiBL)	The sandwich-system was developed by the Swiss FiBL. It consists of a small strip with cover crops directly under the tree strip. Left and right of the cover strip the soil is tilled with relatively simple tools. Thus the local amount of weed-free soil is the same as with tillage of the whole tree strip. This system supports a fully organic nutrition concept (efficient application of compost on tilled strips). Compost and fertilisers are applied mechanically in the tilled strips and tilled 5 cm into the soil. The alleyway is covered by a leguminous cover-crop. In dry areas it is often not possible to have a permanent crop cover. In these areas it is therefore recommended to have a green cover crop during the rain season which should be supplemented with dead mulch. The advantage of this system it achieves several aims of organic farming. Soil cover with specially selected valuable crops, avoidance of erosion and desiccation, target-oriented organic fertilisation, avoidance of competition for water in the area of the fine roots.

This diagram (although not seen here) is not very clear, I would suggest colour coding it as this would remove the need to write on the diagram itself. You could then have a key to the colours with an explanation.

Organic farming can also counter **salinisation** problems: The Fazenda Tamanduà in Brazil is situated in an area severely hit by salinisation caused by inappropriate irrigation techniques. It is a certified organic farm with more than 3000 hectares of which 650 hectares are cropped with mango trees. Due to the arid conditions irrigation is the prerequisite to agricultural production. Conventional agriculture in the area uses the water from the rivers and causes further salinisation by overirrigation with already salinated water. The organic farm Fazenda Tamandua limits its water use to rain water, which is collected in rainwater collection basins, thus avoiding the depletion of the resource water. At the same time the salinisation of soils is considerably reduced. Fertilisation regimes include grazing of cattle under mango trees as well as application of composted manure. The organic substance acts like a sponge in the soil, and fields thus fertilised have a higher moisture retention capacity and therefore need less irrigation.

Even though the adoption of organic farming is such an obvious option in arid areas there are a range of constraints to adopting organic farming systems or even individual techniques as Harris et al. (1998) point out. Constraints include a lack of knowledge, , lack of organic materials, land-holding constraints,, the perception of organic farming as being old fashioned, that fact that the extension services promote chemical farming. Harris et al. (1998) therefore recommend to support schemes to produce or export organic products and increase the awareness, knowledge and appropriateness of the organic techniques through education and training. As the examples above have shown the promotion of organic farming of countries hit by desertification could be a key to bringing degraded land back into production and therefore significantly contribute to the solutions of the world food problem. Governments would need, however, to actively promote organic farming systems and land reform.

6 Organic agriculture and comprehensive evaluations

On the basis of important environmental impact categories, like the OECD indicator categories, comprehensive environmental impact assessments of agriculture can be carried out. One example is the life cycle assessment of dairy farm production systems done by Haas et al. (2001). The authors compared three dairy farm production systems of the Bavarian Alps, organic, low-input conventional, and high input conventional. Figure 4 present the results related to the area. In all categories organic farming showed the best results. Apart from the biotic and abiotic impacts, landscape and animal welfare were considered as well, because both issues are on high relevance in agriculture.

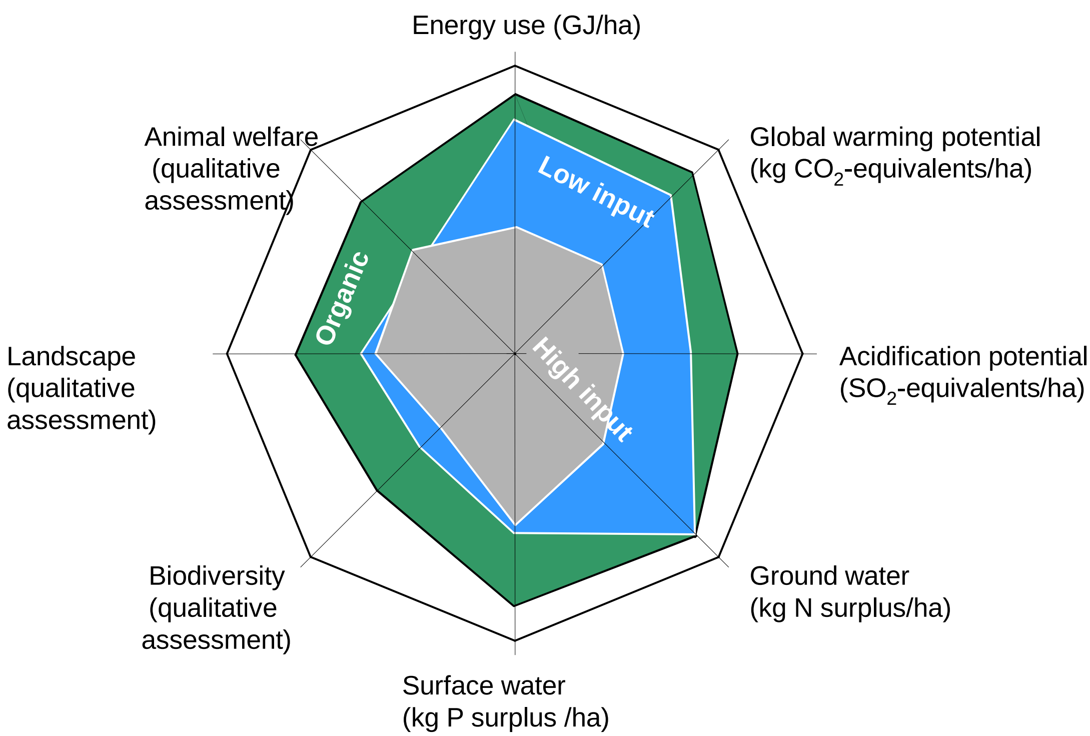


Figure 4: Relative environmental impact assessment of organic, low-input, and high-input dairy farm production systems in Bavaria (each system: average of 6 farms). The larger the area the better the environmental impact (Haas et al. 2001)

A recent study by compared organic, conventional and integrated apple production systems. The yields were similar in all three systems. The organic and the integrated system had higher soil quality and potentially lower negative environmental impact. The organic system had higher profitability and greater energy efficiency than the other systems. Significant differences between the three apple production systems considering environmental impacts of pesticide use were found. Organic apple production achieved a 4.7 times better rating than integrated production and a 6.2 better rating than conventional production (Reganold et al. 2001).

Another example of a comprehensive environmental impact assessment is given by Stolze et al. (2000) (Table 7). The table presents the evaluation of almost 400 studies comparing organic with conventional or integrated farming in Europe. The results show the final average assessment and the confidence interval. Compared to conventional farming organic farming in most categories performs better or much better.

Table 7: Assessment of organic farming's impact on the environment compared to conventional farming based on a multi-criteria analysis (Stolze et al. **2000, modified by Pfiffner et al. (2001)**

Organic Farming performs:	Much better	Better	The same	Worse	Much worse
Indicator:					
1 Biodiversity and Landscape		X			
• Floral diversity		X			
• Faunal diversity		X			
• Habitat diversity			X		
• Landscape			X		
2) Soil		X			
• Soil organic matter		X			
• Biological activity	X				
• Soil Structure			X[1)]		
• Soil Erosion		X			
3) Ground and surface water		X			
• Nitrate leaching		X			
• Pesticides	X				
4) Climate and air			X		
• CO_2		X			
• N_2O			X		
• CH4			X		
• NH3		X			
• Pesticides	X				
5) Farm input and output		X			
• **Nutrient use**		X			
• **Water use**			X[1)]		
• **Energy use**		X			

[1)] the assessment is difficult due to lack of data.

X Subjective confidence interval of the final assessment marked with X

7 Conclusion

The findings of this study show that organic farming provides a wide range of environmental services. The main results may be summarised as follows:

1. Organic matter content is usually higher in organically managed soils indicating a higher fertility and stability of organic soils, thus reducing the risk of erosion.
2. Organically farmed soils have significantly higher biological activity and a higher total mass of micro-organisms. As a consequence of the higher activity of micro-organisms, in organically managed soils nutrients are recycled faster and soil structure is improved.
3. Organic farming poses no risk of ground and surface water pollution through synthetic pesticides. Nitrate leaching rates per hectare are significantly lower in organic farming compared to conventional farming systems.
4. With respect to energy consumption organic farming is performing better than conventional farming on a per hectare scale.
5. The diversity of cultivated species and of agricultural genetic resources is higher in organic farming.
6. Floral and faunal biodiversity on organic land is higher than on conventional land. Furthermore a higher number of endangered and rare species are present.
7. Organic farming offers vast food resources for beneficial arthropods and birds, thus contributing to natural pest control.
8. With respect to pollinators we concluded that organic farming contributes to their conservation and survival, as organic farming does not use synthetic chemical pesticides or herbicides and enhances ecosystem diversity.
9. Organic farming systems have positive effects on ecosystem diversity and can thus contribute to positive landscape development. Combining semi-natural habitats with organic farming results in synergistic effects on agricultural land and thus contributes to species richness.
10. Organic farming enables ecosystems to better adjust to the effects of climate change and offers a major potential to reduce the emissions of agricultural greenhouse gases.
11. Organic agricultural strategies comprises recycling of organic matter and tightening internal nutrient cycles, thus contributing to carbon sequestration.
12. Organic farming techniques bear potentials to improve soil fertility, soil structure and moisture retention capacity and thus provide solutions to the problems associated with desertification.

As a final assessment we conclude that organic farming leads to more favourable conditions at all environmental levels. Organic farming counteracts resource depletion (water, energy, nutrients), contributes positively to the problems associated with climate change and desertification and can help to maintain and enhance biodiversity at a global scale.

Scientific evidence of the environmental benefits of organic farming for the Southern hemisphere is rare, but from many practical experiences may be assumed that the points listed above also apply to the tropics and subtropics. More research on the environmental services and benefits of organic farming in this part of the world is urgently needed.

8 References

8.1 References Section 1: Ecosystem approach in organic agriculture

Alvensleben, R von (2000) Aspekte der Nachhaltigkeit von Landnutzungssystemen aus umweltökonomischer Sicht. Tagungsband „*Nachhaltigkeit der Bodennutzung*" der Deutschen Bodenkundlichen Gesellschaft, Osterroenfeld, 3.5.2000. Available at http://www.uni-kiel.de:8080/Agraroekonomie/Abteilungen/agrarmarketing/Lehrstuhl/AGoel.htm.

Avery, T D (1997) Widespread Organic Farming – A danger to the Planet. BCPC News Release, 18.11.97. Available at http://www.bcpc.org/publications/newsreleases/avery2.htm.

Conway, G R (1987) The Properties of Agroecosystems. *Agricultural Systems* 24: 95-117.

De Groot, R S, Wilson, M A and Boumans, R M J (2001) A Typology for the Description, Classification and Valuation of Ecosystem Functions, Goods and Services. Ecological Economics (submitted April 2001).

Doherty, S, Rydberg, T and Salomonsson, L (2000) Ecosystem Properties and Principles of Living Systems for Sustainable Agriculture. In: Alfoeldi, Thomas, William Lockeretz and Urs Niggli (Eds.) (2000): *IFOAM 2000 – The World Grows Organic. Proceedings 13th IFOAM Scientific Conference*. Zuerich, 152-155.

Holling, C S (2000) Theories for Sustainable Futures. *Conservation Ecology* 4(2):7. Available at http://www.consecol.org/vol4/iss2/art7.

Ikerd, J (1993) Two related but Distinctly Different Concepts: Organic Farming and Sustainable Agriculture. *Small Farm Today* 10 (1): 30-31.

Johnson, B L (1999) The Role of Adaptive Management as an Operational Approach for Resource Management Agencies. *Conservation Ecology* 3(2):8. Available at http://www.consecol.org/vol3/iss2/art8.

Rigby, D and Caceres, D (2001) Organic Farming and the Sustainability of Agricultural Systems. *Agricultural Systems* 68: 21-40.

Scialabba, N (2000) Opportunities and constraints of organic agriculture: A socio-ecological Analysis. Course held at the 1999-2000 Socrates/Erasmus Programme on Ecological Agriculture (http://www.fao.org/organicag/doc/SOCRATES1999.htm).

Trewavas, A (2001) Urban myths of organic farming. Nature 410: 409–410.

8.2 References section 2: Organic farming and abiotic resources

Alföldi, T, Spiess, E, Niggli, U and Besson, J M (1995) Energiebilanzen für verschiedene Kulturen bei biologischer und konventioneller Bewirtschaftung. *Beitr. 3. Wiss.-Tagung okol. Landbau*, Kiel. Hrsg. Dewes, T. und Schmitt, L. Wissenschaftlicher Fachverlag, Giessen 1995, 33-36.

Arbeitsgemeinschaft Oekologischer Landbau (AGÖL) (1997) *Leitfaden zur Förderung des ökologischen Landbaus in Wasserschutzgebieten*, Darmstadt

Barbera, G, La Mantia,T (1995) *Analisi agronomica energetica. Filiere atte allo sviluppo di aree collinari e montane: il caso dell'agricoltura biologica.* Chironi G Vo. 1 RAISA-University of Palermo.

Beck, T (1991) Vergleichende Bodenuntersuchung von konventionell und alternativ bewirtschafteten Betriebsschlägen. - 2. Mitteilungen.II. Bodenmikrobiologische Untersuchungen.*Landwirtschaftliches Jahrbuch* 68 (4):416-423.

Berg, M, Haas, G, Köpke, U (1997) Grundwasserschonende Landbewirtschaftung durch Organischen Landbau im Vergleich zu integrierten und konventionellen Landbau. In: Kongressband 109. VDLUFA-Kongress Stoff- und Energiebilanzen in der Landwirtschaft, 15.-20. September 1997 in Leipzig. *VDLUFA-Schriftenreih*e 46.

Blume, H P, Horn, R and Sattelmacher, B (1993) Dynamik lehmiger und sandiger Böden unter intensiv und alternativ landwirtschaftlicher und forstlicher Nutzung. *Schriftenreihe Inst. F. Pflanzenernähr. Bodenk*. Universität Kiel (21).

Cederberg, C, Mattsson, B (1998) Life cycle assessment of Swedish milk production – a comparison of conventional and organic farming. In: Ceuterick, D (ed.) *Proceedings of the international conference on life cycle assessment in agriculture, agro-industry and forestry*, 3-4 December, Brussels Belgium.

Ciani, A and Boggia, A (1993) Agricoltura biologica e qualita. In Zanoli, R (ed.) *I numeri del biologico*, Ancona, 1:26

Ciani, A (1995) Situazione attuale e prospettive della vitivinicoltura di qualità e a basso input. Agricoltura biologica in Italia, aspetti tecnici, economici e normativi 1:49.

Condron, L M, Cameron, K C, Di, H J, Clough, T J, Forbes, E A, McLaren, R G & Silva, R G (2000) A comparison of soil and environmental quality under organic and conventional farming systems in New Zealand*. New Zealand Journal of Agricultural Research.* 43: 443-466.

De Groot, RS, Wilson, M A, and Boumans, R J (April 2001) A typology for the description, classification and valuation of ecosystem functions, goods and services. Submitted to Ecological Economics

Diez, T, Borchert, H and Beck, T (1985) Bodenphysikalsiche Auswirkungen abgestufter Intensitäten im Pflanzenbau auf Lebensgemeinschaften des Ackers, Bodenfruchtbarkeit und Ertrag. IV. Auswirkungen abgestufter Pflanzenbauintensitäten auf Bodenwerte und Nährstoffbilanz, *Landwirtschaftliches Jahrbuch 68* (3) 354-161

Drinkwater, L, Wagoner, P and Sarrantonio, M (1998) Legume-based cropping systems have reduced carbon and nitrogen losses. *Nature* 96, 262-264.

Elmholt, S (1996) Microbial Activity, Fungal Abundance and Distribution of Penicillium and Fusarium as Bioindicators of a Temporal Development of Organically Cultivated Soils. *Biological Agriculture and Horticulture* 13: 123-140.

Fliessbach, A, Mäder, P, Dubois, D and Gunst, L (2000) *Organic farming enhances soil fertility and biodiversity*. FiBL Dossier No. 1. Research Institute of Organic Agriculture, CH-Frick

Fliessbach, A, Mäder, P and Niggli, U (2000) Mineralization and microbial assimilation of ^{14}C-labeled straw in soils of organic and conventional agricultural systems. *Soil Biology & Biochemistry,* 32, 1031-1039.

Fliessbach, A, Eyhorn, F, Mäder, P, Rentsch, D and Hany, R (2001) DOK long-term farming systems trial: Microbial biomass, activity and diversity affect the decomposition of plant residues. In : Rees, R, Ball, B, Campbell, C and Watson, C (eds.). *Sustainable Management of Organic Matter*. CABI, London. 363-369.

Freyer, B (1997) Kennziffern der Nachhaltigkeit von 317 ackerbaubetonten Betrieben des biologischen Landbaus in der Schweiz, ausgewertet auf der Basis von Betriebskontrolldaten. In: Köpke, U and Eisele, J A (eds.*)* *Beiträge zur 4. Wissenschaftstagung zum ökologischen Landbau*, Berlin, 103-106.

Geier, U, Frieben, B, Gutsche, V, Köpke, U (2001) Ökobilanz des Apfelerzeugung in Hamburg - Vergleich integrierter und ökologischer Bewirtschaftung. *Schriftenreihe Institut für Organischen Landbau*, Verlag Dr. Köster, Berlin, S. 130.

Haas, G and U Köpke (1994) Vergleich der Klimarelevanz Ökologischer und Konventioneller Landbewirtschaftung. Studie (H) im Auftrag der Enquetekomission des Deutschen Bundestages *Schutz der Erdatmosphäre*. D-Karlsruhe, Economica Verlag.

Haas, G (1997) Argumentationsleitfaden. Teil I. 2-69. In: Arbeitsgemeinschaft Ökologischer Landbau & Bund für Umwelt und Naturschutz (eds.) *Wasserschutz durch Ökologischen Landbau – Leitfaden für die Wasserwirtscha*ft. Darmstadt, Bonn, 148 S.

Haas, G, Wetterich, F, and Köpke, U (2001) Comparing intensive, extensified and organic grassland farming in southern Germany by process life cycle assessment. *Agriculture, Ecosystems & Environment* 83/1-2, 43-53.

Haas, G, Geier, U, Schulz, D and Köpke, U (1995)Vergleich Konventioneller und Organischer Landbau – Teil I: Klimarelevante Kohlendioxidemissionen durch den Verbrauch fossiler Energie. *Berichte über Landwirtschaft* 73, p. 401-415

Hansen, B, Fjelsted Alrøe, H and Steen Kristensen, E (1999) Environmental Impacts from Organic Farming. In Organic Farming in the European Union – Perspectives for the 21st Century, 27/28 May 1999, Conference Proceedings, Baden/Vienna, Austria, Session 1: Environmental Effects of Organic Agriculture Available at: http://www.eurotech.co.at/docs/kristens.doc

Hartnagel, S, Rennenkampff, K and Freyer, B (1999) Massnahmen zur Reduktion der Nitratauswaschung ins Grundwasser durch Anpassungsmassnahmen in der Landwirtschaft im Klettgau. *Mitt. Natf. Ges. Schaffhausen*, 44, 75-97.

Hess, J, Piorr, A and Schmidtke, K (1992) *Grundwasserschonende Landbewirtschaftung durch Ökologischen Landbau. Eine Bewertung des Leguminosenanbaus und des Wirtschaftsdüngereinsatzes im Anbausystem Oekologischer Landbau*. = Dortmunder Beiträge zur Wasserforschung Nr. 45, Dortmund 1992

International Federation of Organic Agriculture Movements (2000) Basic Standards for Organic Production and Processing. Decided by the IFOAM General Assembly in Basel, Switzerland, September 2000, Tholey-Theley. Available at: http://www.ifoam.org/standard/index_neu.html

Justus, M and Köpke, U (1993) Strategies to avoid nitrogen losses via leaching and to increase precrop effects when growing faba beans. 1. International Workshop on Nitrate Leaching, 11.-15.10.1993, Copenhagen, Denmark. In*: Biological Agriculture and Horticulture* (BAH), Vo. 11/1995, pp. 145-155

Kalk, W D, Heldt, S, Hülsbergen K-J (1996) Energiebilanzen im Ökohof Seeben und Vergleich mit anderen Standorten. In: Diepenbrock, W, Hülsbergen, K J (eds) Langzeiteffekte des ökologischen Landbaus auf Fauna*, Flora und Boden,* 59-69

Köpke, U (1999) Welchen Beitrag kann der Ökologische Landbau für eine Landbewirtschaftung der Zukunft leisten? Öffentliches Hearing der Bundestagsfraktion von Bündnis 90 / Die Grünen am 19.5.1999 in Bonn. Eigenverlag des Instituts für Organischen Landbau, Bonn 1999

Kilcher, L (2001) Organic agriculture in Cuba: The revolution goes green. *Journal of Agriculture in the Tropics and Subtropics,* Volume 102, No. 2, October 2001, pp. 185-189

Kus, J and Stalenga, J (2000) Comparison of economic and energy efficiency in ecological and conventional crop production system. In: Alföldi, T, Lockeretz, W, and Niggli, N (eds.) *Proceedings 13th International IFOAM scientific conference*. Vdf Hochschulverlag, Zürich.

Lampkin, N (1990) Organic farming. Farming Press Books, Ipswich, U.K.

Lampkin, N (1997) Organic livestock production and agricultural sustainability. In: *Resource use in Organic farming. Proceedings of the third ENOF workshop*: Ancona 5-6 June 1997, 321-330

Mäder, P, Alföldi, T, Fliessbach, A, Pfiffner, L and Niggli, U (1999) Agricultural and ecological performance of cropping systems compared in a long-term field trial. In: Smaling E, Oenema, O and Fresco, L (eds) *Nutrient Disequilibria in Agroecosystems: Concepts and Case Studies.* CAB International, Oxon, UK. 248-264.

Mäder, P, Edenhofer, S, Boller,T, Wiemken, A and Niggli, U (2000) Arbuscular mycorrhizae in a long-term field trial comparing low-input (organic, biological) and high-input (conventional) farming systems in a crop rotation. *Biol. Fertil. Soils* 31, 150-156

Marino, D., Santucci, F M, Zanoli, R and Fiorani, S (1997) Labour intensity in conventional and organic farming. Paper presented at the 3rd ENOF Workshop "Resource use in organic farming" in Ancona, Italy. Final version.

Niederbudde, E A and Flessa, H (1989) Struktur, mikrobieller Stoffwechsel und potentiell mineralisierbare Stickstoffvorräte in ökologisch und konventionell bewirtschafteten Tonböden, *J. Agronomy and Crop Science* 162: 333-341

OECD (Organisation of economic Co-operation and Development) (2001) *Environmental indicators for agriculture. Methods and results.* Volume 3. OECD, Paris. Available at OECD http://www.biodiv.org/doc/reports/agro-oecd-chap-vi-en.pdf

Oberson, A, Oehl, F, Langmeier, M, Fliessbach, A, Dubois, D, Mäder, P, Besson J-M and Frossard, E (2000) Can increased microbial activity help to sustain phosphorous availability? In: Alföldi, T, Lockeretz, W and Niggli, U(eds) *Proceedings 13th International IFOAM scientific conference*. Vdf Hochschulverlag, Zürich, p. 27

Offermann, F and Nieberg, H (199) *Economic Performance of Organic Farms in Europe.* Organic Farming in Europe: Economics and Policy; Vol 5. Stuttgart-Hohenheim.

Paffrath, A (1994) Geringere Stickstoffverluste durch Auswaschung im ökologischen Landbau. *Ökologie und Landbau*, 90, 9-10

Pfiffner, L and Mäder, P (1997) Effects of biodynamic, organic and conventional production systems on earthworm populations. Entomological Research in Organic Agriculture (Special edition of Biological Agriculture and Horticulture) 15, 3-10.

Pfiffner, L, Häring, A, Dabbert, S, Stolze, M and Piorr, A. (2001) Contributions of Organic Farming to a sustainable environment. In: Ministry of Food, Agriculture and Fisheries (2001) *European Conference: Organic Food and Farming - Towards Partnership and Action in Europe, 10.-11.5.2001, Copenhagen. Proceedings* [online]. Document available at: http://www.fvm.dk/kundeupload/konferencer/organic_food_farming/proceedings.pdf

Piorr, A and Werner, W (1998) *Nachhaltige landwirtschaftliche Produktionssysteme im Vergleich: Bewertung anhand von*

Umweltindikatoren. Frankfurt am Main

Pretty, J N, Brett, C, Gee, D, Hine, R E, CMason, F, Morison, JIL, Raven, H, Rayment, M D, van der Bijl, G (2000) An assessment of the total external costs of UK agriculture, *Agricultural Systems* 65 (2) pp. 113-136

Raupp, J (ed.) (1996) *Quality of plant products grown with manure fertilization. Fertilization systems in organic farming* (concerted action AIR3-CT4-1940) Proceedings

Reganold, J, Elliott, L and Unger, Y (1987) Long-term effects of organic and conventional farming on soil erosion. *Nature* 330, 370-372

Reganold, J, Glover, J, Andrews, P and Hinman, H (2001) Sustainability of three apple production systems. *Nature*, 410, 926-929

Reganold, J, Palmer, A, Lockhart, J and Macgregor, A (1993) Soil quality and financial performance of biodynamic and conventional farms in New Zealand. *Science* 260, 344-349

Reitmayr, T (1995). Entwicklungen eines rechnergestützten Kennzahlensystems zur ökonomischen und ökologischen Beurteilung von agrarischen Bewirtschaftungsformen - dargestellt an einem Beispiel. *Agrarwirtschaft Sonderheft* 147.

Reus, J, Lenndertse, C, Bockstaller, C, Fomsgaard, I, Gutsche, V, Lewis, K, Nilsson, C, Pussemeier, L, Trevisan, M, Werf, van der H, Alfarroba, F, Blümel, S, Isart, J, Mc Grath, D and Seppälä, T (1999) Comparing environmental risk indicators for pesticides. Results of the European CAPER project. Centre for Agriculture and Environment Utrecht, CLM 426 (ISBN 90-5634-106-5), 184 p.

Siegrist, S, Schaub, D, Pfiffner, L and Mäder, P (1998) Does organic agriculture reduce soil erodibility? The results of a long-term field study on loess in Switzerland*. Agric. Ecosystem Environ.* 69, 253-264

Smilde, K W (1989) Nutrient supply and soil fertility. In: Zadoks, J C (ed.) (1989) Development of farming systems: Evaluation of the five year period 1980-84. Pudoc, Wageningen

Smith, S & Read, D (1997) *Mycorrhizal Symbiosis*. 2nd edn., London

Schulze Pals, L (1994) *Ökonomische Analyse der Umstellung auf ökologischen Landbau.* Schriftenreihe des BMELF, Reihe A, Angewandte Wissenschaft, Heft 436, Münster

Stolze, M, Piorr, A, Häring, A and Dabbert, S (2000) *The environmental impacts of organic farming in Europe*. Organic farming in Europe, Volume 6, University of Stuttgart-Hohenheim, Stuttgart

Umweltbundesamt(1997) *Daten zur Umwelt*. Berlin.

United Nations Environment Programme (1999) *Global Environment Outlook 2000*, UNEP, Nairobi, Kenia 1999, Available from http://www.unep.org/Geo2000/index.htm

Verejken, P (1990) Integrierte Nährstoffversorgung im Ackerbau. *Schweiz. Landw. Forschung* 29 (4): 359-365.

Weiger, H (1997) Naturschutz durch ökologischen Landbau. In: Weiger, H and Willer, H (eds) (1997) *Naturschutz durch ökologischen Landbau*. Ökologische Konzepte 95, Bad Dürkheim

Zarea, A, Koocheki, A and Nasiri, M (2000) Energy efficiency of conventional and ecological cropping systems in different rotations. In: Alföldi, T, Lockeretz, W and Niggli, U (eds) (2000) *Proceedings 13th International IFOAM scientific conference*. Vdf Hochschulverlag, Zürich.

8.3 References section 3: Organic farming and biodiversity

Alger, K (1998)The Reproduction of the Cocoa Industry and Biodiversity in Southern Bahia, Brazil, paper presented at Cacao Workshop in Panama (March 30-April 2 1998); Smithsonian Migratory Bird Center, Available at http://natzoo.si.ed/SMBC/Research/Cacao/cacao.htm

Altieri, Miguel A (1999) The ecological role of biodiversity in agriecosystems*. Agriculture, Ecosystems and Environment* 74, 19-31

Ammer, U, Utschick, U and Anton, H (1988) Die Auswirkungen von biologischem und konventionellem Landbau auf Flora und Fauna. *Forstw. Cbl*. 107: 274-291.

Bio Suisse (2001) Richtlinien für die Erzeugung, Verarbeitung und den Handel von Erzeugnissen aus biologischer (ökologischer) Produktion. Fassung vom 1. Januar 2001. Basel.

British Trust for Ornithology (1995) The Effects of Organic Farming Regimes on Breeding and Winter Bird Populations: Part 1. Summary Report and Conclusions. *BTO Research report, No. 154.* BTO; Thetford.

Bugg, R L and Hoenisch R W (2000) Cover Cropping in California Vineyards: Part of a Biologically Integrated Farming System In: Willer, H and Meier, U (eds.) (2000) *Proceedings 6th International Congress on Organic Viticulture - 25 to 26 August 2000 Convention Center Basel*. Stiftung Ökologie & Landbau, Bad Dürkheim SÖL-Sonderausgabe No. 77, Available at http://www.soel.de/inhalte/publikationen/s_77.pdf

Burn, A J (1989) Long-term effects of pesticides on natural enemies of cereal crops pests. In: Jepson, P C (ed.) *Pesticides and Non-target Invertebrates*, Intercept, Andover, p. 177-193.

Christensen, D K, Jacobsen, E M and Nohr, H (1996) A comparative study of bird faunas in conventionally and organically farmed areas. Dansk. Orn. Foren. Tidsskr 90: 21-28.

Compagnoni, A (2000); Organic agriculture and agroecology in regional parks. In: Stolton, S, Geier, B and McNeely, J A, (eds.) (2000) *The Relationship Between Nature Conservation, Biodiversity and Organic Agriculture,* *Proceedings of an International Workshop*, Vignola, Italy, 1999. IFOAM, Tholey-Theley, Germany, p. 52-66Convention on Biological Diversity (2001) Agricultural Biodiversity : Dimensions of Agricultural Biodiversity. Homepage of the Convention on Biological Diversity, http://www.biodiv.org, Updated on 3 August 2001, Available at http://www.biodiv.org/programmes/areas/agro/dimensions.asp

Convention on Biological Diversity (2001) Agricultural Biodiversity. Homepage of the Convention on Biological Diversity, http://www.biodiv.org, Updated on 3 August 2001; available at http://www.biodiv.org/programmes/areas/agro/default.asp

Crabb, Charlene (1997) Sting in the tale for bees, *New Scientist*, 16. August 1997.

European Environmental Agency (EEA) (2002) **EEA multilingual glossaries. EEA Glossary. Homepage of the** European Environmental Agency. Available at http://glossary.eea.eu.int/EEAGlossary/B/biodiversity. Last Modified 30.1.2002

Feber, R E, Firbank, L G, Johnson, P J, Macdonald D W (1997) The effects of organic farming on pest and non-pest butterfly abundance. *Agriculture Ecosystems and Environment*, 1997, 64, p. 133-139

Feber, R E, Bell, J, Johnson, P J, Firbank, L G and Macdonald, D W, (1998). The Effects of Organic Farming on Surface-Active Spider (Araneae) Assemblages in Wheat in Southern England, UK. *The Journal of Arachnology,* (1998), 26, 190-202.

Fliessbach, A and Mäder, P (2000) Microbial biomass and size-density fractions differ between soils of organic and conventional agricultural systems. *Soil Biology & Biochemistry*, 32 (6) 757-768.

Flores-Escuerdo, P (2000) Conservation of a forest sanctuary in Peru by implementing an organic agriculture and sustainable development programme for small farmers in the buffer zone. In: Alföldi, T, Lockeretz, W and Niggli, U (eds.) (2000) *Proceedings 13th International IFOAM scientific conference*. Vdf Hochschulverlag, Zürich.

Freyer, B (1997) Kennziffern der Nachhaltigkeit von 317 ackerbaubetonten Betrieben des biologischen Landbaus in der Schweiz, ausgewertet auf der Basis von Betriebskontrolldaten. In: Köpke, U and Eisele, J A (eds.) (1997) *Beiträge zur 4. Wissenschaftstagung zum ökologischen Landbau*; Bonn, 103-108.

Frieben, B (1997) Arten- und Biotopschutz durch Organischen Landbau. In: Weiger, H and Willer, H (eds.) (1997) *Naturschutz durch ökologischen Landbau*. Ökologische Konzepte 95, D-Bad Dürkheim, 73-92.

Frieben, B and Köpke, U (1996) Effects of farming systems on biodiversity. In: Isart, J and Llerena J J (eds.) (1996) *Biodiversity and Land Use: The role of Organic Farming. Proceedings of the First ENOF Workshop, 8-9 December 1995*, Bonn.

Gardner, SM and Brown. R W (1998) Review of the Comparative Effects of Organic Farming on Biodiversity. ADAS Wolverhampton, MAFF Contract OFO 149.

Hald, B (1999) Weed vegetation (wild flora) of long established organic versus conventional cereal fields in Denmark. *Ann. Appl. Biol* (1999), 134: 307-314

Hausheer, J, Rogger, C, Schaffner, D, Keller, L, Freyer, B, Mulhauser, G, Hilfiker, J and Zimmermann, A (1998) Ökologische und produktionstechnische Entwicklung landwirtschaftlicher Pilotbetriebe 1991 bis 1996. *Schlussbericht der Nationalen Projektgruppe Öko-Pilotbetriebe. Nationale Projektgruppe Öko-Pilotbetriebe und FAT*; Tänikon, 169.

Isart, J and Llerena J J (eds.) (1996) *Biodiversity and Land Use: The role of Organic Farming*. Proceedings of the First ENOF Workshop, 8-9 December 1995, Bonn.

Isart, J and Llerena J J (eds.) (1997) *Resource Use in Organic Farming. Proceedings of the Third ENOF Workshop*, 5-6 June 1997, Ancona

IUCN (2000) 2000 IUCN Red List of Threatened Species, IUCN, Gland, Switzerland. Available at: http://www.redlist.org

Kabourakis, E (1996) Prototyping and dissemiantion of ecological olive production systems: a methodology for designing and a first step towards validation and dissemination of prototype ecological olive production systems (EOPS) in Crete. Landbouw University Wageningen

Kennel, W (1990) The role of the earthworm *Lumbricus terrestris* in integrated fruit production*. Acta Horticulturae*, 285, p. 149-156.

Köpke, U (1999) Welchen Beitrag kann der Ökologische Landbau für eine Landbewirtschaftung der Zukunft leisten? Öffentliches Hearing der Bundestagsfraktion von Bündnis 90 / Die Grünen am 19.5.1999 in Bonn. Eigenverlag des Instituts für Organischen Landbau, Bonn 1999

Kromp, B (1989) Carabid beetle communities (*Col. Carabidae*) in biologically and conventionally farmed agroecosystems. *Agriculture, Ecosystems and Environment*, 27, p. 241-251.

Lampkin, N (1990) *Organic Farming*. Farming Press; Ipswich

Letourneau, D K and Goldstein, B (2001) Pest damage and arthropod community structure in organic vs. conventional tomato production in California. Journal of Applied Ecology, 38 (3), June 2001, 557-570

Luff, M L (1983) The potential of predators for pest control. *Agriculture, Ecosystems and Environment*, 10, p. 159-181.

Mäder, P, Pfiffner, L, Fliessbach, A, von Lützow, M and Munch J C (1996) Soil ecology – The impact of organic and conventional agriculture on soil biota and its significances for soil fertility; In: Østergaard, T V (ed.) *Fundamentals of Organic Agriculture. Proceedings of the 11th IFOAM Scientific Conference, 11-15 August 1996, Copenhagen*, IFOAM; Tholey-Theley, 24-

46.

Mansvelt, J D van and Van der Lubbe, M J (eds.) (1999) Checklist for Sustainable Landscape Management. Final report of the EU concerted action AIR3-CT93-1210: The Landscape and Nature Production Capacity of Organic/Sustainable Types of Agriculture. Elsevier, Amsterdam

Mattsson E and Kvarnbäch, O (2000) A Swedish project for co-operation between nature conservation and organic agriculture organisations. In: Stolton, S, Geier, B and McNeely, J A, (eds.) (2000) *The Relationship Between Nature Conservation, Biodiversity and Organic Agriculture, Proceedings of an International Workshop*, Vignola, Italy, 1999. IFOAM, Tholey-Theley, Germany, p. 52-66

McNeely, J A and Scherr S J (2001) *Future Harvest*. IUCN, Gland

Miller, K, Chang, E and Johnson, N (2001) Defining Common Ground for the MesoAmerican Biological Corridor, World Resources Institute, Washington DC, USA. Available at http://www.wri.org/pdf/mesoamerica_english.pdf

Nabhan, G P (1998) Pollinator Redbook. Volume One. Global List of threatened vertebrate wildlife species serving as pollinators for crops and wild plants. Homepage of the Arizona-Sonora Desert Museum. Available at http://www.desertmuseum.org/conservation/fp/redbook.html

Nyffeler, M and Benz, G (1987) Spiders in natural pest control: A review. *J. Appl. Entomol*., 103, p. 321-339.

Östmann, Ö, Ekbom, B and Bengtsson, J (2001) Landscape heterogeneity and farming practice influence biological control. *Basic Appl. Ecol*., 2, pp 365-371

Pfiffner, L (1997) Welchen Beitrag leistet der ökologische Landbau zur Förderung der Kleintierfauna. In: Weiger, H and Willer, H (eds) (1997) *Naturschutz durch ökologischen Landbau*. Ökologische Konzepte 95. Bad Dürkheim, Germany

Pfiffner, L (2000) Significance of organic farming for invertebrate diversity - enhancing beneficial organisms with field margins in combination with organic farming. In: Stolton, S, Geier, B and McNeely, J A, (eds.) (2000) *The Relationship Between Nature Conservation, Biodiversity and Organic Agriculture, Proceedings of an International Workshop*, Vignola, Italy, 1999. IFOAM, Tholey-Theley, Germany, p. 52-66

Pfiffner, L and Luka, H (1999) Overwintering of arthropods in soils of arable fields and adjacent seminatural habitats. *Agriculture, Ecosystems and Environment*, 1529 p.1-8.

Pfiffner, L and Luka, H (2002) Effects of low-input farming systems on carabids and epigeal spiders in cereal crops – a paired farm approach in NW-Switzerland. Paper Submitted August 2001 for Publication in Basic and Applied Ecology

Pfiffner, L and Mäder, P (1997) Effects of Biodynamic, Organic, and Conventional Production Systems on Earthworm Populations. Entomological Research in Organic Agriculture*. Biological Agriculture and Horticulture,* 15:3-10.

Pfiffner, L and Niggli, U (1996) Effects of Bio-dynamic, Organic and Conventional Farming on Ground Beetles (Col. Carabidae) and Other Epigaeic Arthropods in Winter Wheat. In*: Biological Agriculture and Horticulture*, 1996, Vol 12, pp. 353-364

Pfiffner, L, Häring, A, Dabbert, S, Stolze, M and Piorr, A (2001) Contributions of Organic Farming to a sustainable environment. In: Ministry of Food, Agriculture and Fisheries (2001) *European Conference: Organic Food and Farming - Towards Partnership and Action in Europe,* 10.-11.5.2001, Copenhagen. Proceedings [online]. Document available at: http://www.fvm.dk/kundeupload/konferencer/organic_food_farming/proceedings.pdf

Parrott, N and Marsden, T (2002) *Organic and agro-ecological farming in the developing world. A scoping report for Greenpeace Environmental Trust.* Cardiff

Pryor, A W (2000) Organic certified products as a basis for sustainable management of biological reserves: "Case study of Guayaki biological reserve in Paraguay". In: Alfoeldi, T, Lockeretz, W and Niggli, U (eds.) (2000) *IFOAM 2000 – The World Grows Organic. Proceedings 13th IFOAM Scientific Conference*. Zuerich: 465

Rhône-Poulenc (1997) Rhône-Poulenc Agriculture. Farm Management Study. 7th Annual Report. Ongar. Rhône-Poulenc

Rice, R and Ward, J (1996) Coffee, conservation and commerce in the Western Hemisphere, Smithsonian Migratory Bird Center and Natural Resources Defence Council, Washington DC, USA. Available at: http://www.nrdc.org/health/farming/ccc/cptinx.asp

Rösler, S and Weins, C (1997) Situation der Vogelwelt in der Agrarlandschaft und der Einfluß des ökologischen Landbaus auf ihre Bestände. In: Weiger, H and Willer, H (1997) *Naturschutz durch ökologischen Landbau*. Ökologische Konzepte 95. Stiftung Ökologie und Landbau. Bad Dürkheim, Germany

Rydberg, N T and Milberg, P (2000) A Survey of Weeds in Organic Farming in Sweden. In: *Biological Agriculture and Horticulure* Vol. 18, pp. 175-185

Shiva, V (2001): *Tomorrow's Biodiversity (Prospects for Tomorrow).* Thames & Hudson, London

Soil Association (2000) *The biodiversity benefits of organic farming*. Soil Association; Bristol.

Soil Association (2001) Briefing paper Biodiversity and genetic engineering. The Soil Association homepage. Available via http://www.soilassociation.org

Sotherton, N W (1998) Land use changes and the decline of farmland wildlife: an appraisal of the set-aside approach. *Biological Conservation* 83: 259-268.

Spears, T (2001) Superweeds Invade Farm Fields; Canola Plants Are Almost Pesticide-Proof, Experts Say. *The Ottawa Citizen* of 6.2. 2001. Quoted in

Gen-Lex-News of October 2001, Available at http://www.blauen-institut.ch/Pg/pM/pm0/pm403.html

Stanners, D and Bourdeau, P: Europe's Environment: The Dobris Assessment - An Overview. Chapter 22. Agriculture, European Environmental Agency, Copenhagen, 1995, Available at http://reports.eea.eu.int/92-827-5122-8/en

Steinborn, H and Heydemann, B (1990) Indikatoren und Kriterien zur Beurteilung der ökologischen Qualität von Agrarflächen am Beispiel der Carabidae Laufkäfer. *Schriftenreihe Landschaftspflege und Naturschutz*, 32, p. 165-174.

Stolton, S (2002) Biodiversity and Organic Agriculture. Draft; to be published as IFOAM Dossier No. 2, spring 2002. Available from the International Federation of Organic Agriculture Movements (IFOAM), D-Tholey-Theley, Germany

Stolton, S and Nigel, Dudley, N (2000a) The Use of Certification of sustainable management Systems and their possible application to protected area management. Homepage of the Conference Beyond the Trees (http://www.panda.org/forests4life/spotlights/trees/index.htm), 8.-11.May 2000 in Bangkok, Thailand. Paper available at http://www.panda.org/forests4life/spotlights/trees/bt_sdpaper.htm

Stolton, S and Dudley, N (2000b) Organic agriculture in protected areas – creating partnerships for development. In: Alföldi, T, Lockeretz, W and Niggli, U (eds.) (2000) *Proceedings 13th International IFOAM scientific conference*. Zürich.

Stolton, S and Geier, B (2002): The relationship between Biodiversity and Organic Agriculture. Defining Appropriate Policies and Approaches for Sustainable Agriculture. Paper commissioned by the European Council, unpublished. Available from the International Federation of Organic Agriculture Movements (IFOAM), Tholey-Theley, Germany

Stolton, S, Geier, B and McNeely, J A (eds.) (2000) *The Relationship Between Nature Conservation, Biodiversity and Organic Agriculture, Proceedings of an International Workshop,* Vignola, Italy, 1999. IFOAM, Tholey-Theley,Germany

Stolze, M, Piorr, A, Häring A and Dabbert, S (2000) *The Environmental Impacts of Organic Farming in Europe*. University of Hohenheim, Stuttgart.

Thies, C and Tscharntke, T (1999) Landscape structure and Biological Control in Agroecosystems. In: *Science*, Vol. 285

Van Elsen, T (2000) Species diversity as a task for organic agriculture in Europe. *Agriculture, Ecosystems & Environment*, 77: 101-109.

Weiger, H and Willer, H (1997) *Naturschutz durch ökologischen Landbau*. Ökologische Konzepte 95. Stiftung Ökologie und Landbau. Bad Dürkheim, Germany

World Resources Institute (WRI (2001) Biodiversity Glossary of Terms. The WRI homepage, last updated 18.10.2001, Available at http://www.wri.org/wri/biodiv/gbs-glos.html

Wyss, E (1994) The effects of weed strips on aphids and aphidophagous predators in and apple orchard, *Entomologia Experimentalis et Applicata* 75; 43-49, 1995, p 43-49.

Wyss, E, Niggli, U and Nentwig, W (1995) The impact of spiders on aphid populations in a strip-managed apple orchard. *J. Appl. Ent.* 119, 473-478 (1995)

Yardim, E N and Edwards C A (2000) The effects of weed control practices on surface-dwelling arthropod predators in tomato agroecosystems. In: Alföldi, T, Lockeretz, Wand Niggli, U (Ed.) (2000) *Proceedings 13th International IFOAM scientific conference*. Zürich.

Znaor, D and Kieft, H (2000): Environmental impact and macro-economic feasibility of organic agriculture in the Danube River Basin. In: Alföldi, T, Lockeretz, W and Niggli, U (eds.) (2000) *Proceedings 13th International IFOAM scientific conference*. Zürich, 161-163

8.4 References Section 4: Organic agriculture and climate change

Bockisch, F J (ed.) (2000) *Bewertung von Verfahren der ökologischen und konventionellen Produktion im Hinblick auf den Energieeinsatz und bestimmte Schadgasemissionen* Landbauforschung Völkenrode, Sonderheft 211. Bundesforschungsanstalt für Landwirtschaft, Braunschweig.

Bossel, H, Meier-Ploeger, A, Vogtmann, H (1994) Landwirtschaft und Ernaehrung. Quantitative Analysen und Fallstudien (Teilbericht A) und ihre klimatische Relevanz (Teil B).Veraenderungstendenzen im Ernaehrungssystem. In: Enquete-Kommission Schutz der Erdatmosphaere des Deutschen Bundestages (Hrsg.) *Landwirtschaft. Studienprogramm, Teilband II*. S. 5-189, Bonn

Burdick, B (1994) *Klimaänderung und Landbau - Die Agrarwirtschaft als Täter und Opfer*. Ökologische Konzepte, Vol. 85, Bad Dürkheim

Busemann, C and Heusinger, E (1999) Ernährungssicherung durch ökologischen Landbau? *Ökologie und Landbau* 110, 28-31

Cole, C V, Duxbury, J, Freney, J, Heinemeyer, O, Minami, K, Mosier, A, Paustian, K, Rosenberg, N, Sampson, N, Sauerbeck, D and Zhao, Q (1997) Global estimates of potential mitigation of greenhouse gas emissions by agriculture. *Nutrient Cycling in Agroecosystems* 49, 221-228.

Drinkwater, L E, Wagoner, P and Sarrantonio, M (1998) Legume-based cropping systems have reduced carbon and nitrogen losses. *Nature* 396, 262-264.

Haas, G and Köpke, U (1994) Vergleich der Klimarelevanz ökologischer und konventioneller Landbewirtschaftung. In Enquète-Kommission Schutz der

Erdatmosphäre des Deutschen Bundestages (ed.) (1994) *Schutz der Grünen Erde Klimaschutz durch umeltgerechte Landwirtschaft und Erhalt der Wälder* (, Bonn, 92-196. Economica Verlag, Bonn.

Haas, G, Geier, U, Schulz, D G and Köpke, U (1995) Klimarelevanz des Agrarsektors der Bundesrepublik Deutschland: Reduzierung der Emission von Kohlendioxid. In *Berichte über Landwirtschaft*, Vol. 73, 387-400

IPCC (Intergovernmental Panel on Climate Change) (2001) Revised guidelines for national greenhouse gas inventories. Chapter 4, Agriculture, Nitrous oxide from agricultural soils and manure management, OECD, Paris, France

Reilly, J, Baethgen, W, Chege, F E, van de Geijn, S C, Erda, L, Iglesias, A, Kenny, G J, Patterson, D, Rogasik, J. Rotter, R, Rosenzweig, C, Sombroek, W, and Westbrook, J (1996) Agriculture in a changing climate: impacts and adaptation. In: Watson, R T, Zinyowera, M C and Moss, R H (eds.). Climate Change 1995, impacts adaptations and mitigation of climate change: Scientific-Technical and analyses. The Second Assessment Report of the Intergovernmental Panel on Climate Change: Contribution of Working Group II, Cambridge University Press, Cambridge, p 427-467. (CEARSPub-96-11-IPCC-3)

Sauerbeck, D (2001) CO_2-Emissionen und Kohlenstoffsenken im Landbau - Möglichkeiten und Grenzen ihrer Beeinflussung -. In Rosenkranz, D, Bachmann, G, König, W and Einsele, G (eds.) *Bodenschutz* Vol. 2, Kapitel 4130, 31 S. Verlag Erich Schmidt, Berlin.

Smith, P, Powlson, D S, Glendining, M J and Smith, J U (1997) Potential for carbon sequestration in European soils: Preliminary estimates for five scenarios using results from long-term experiments. *Global Change Biology* 3, 67-79.

Stolze, M, Piorr, A, Häring, A and Dabbert, S (2000) *The Environmental Impacts of Organic Farming in Europe*. University of Hohenheim; Stuttgart

Tilman, D (1998) The greening of the green revolution. *Nature* 396, 211-212.

Tilman, D (1999) Global environmental impacts of agricultural expansion: The need for sustainable and efficient practices. *Proceedings of the National Academy of Sciences, USA* 96, 5995-6000.

Watson, R T, Zinyowera, M C, Moss, R C (1996) Technologies, Policies and Measures for Mitigating Climate Change. **November 1996,** paper prepared under the auspices of IPCC Working Group II. Published at http://www.gcrio.org/ipcc/techrepI/toc.html, at the Homepage of the US Global Change Research Information Office (GCRIO) (http://www.gcrio.org), Columbia University, New York

8.5 References Section 5: Organic agriculture and desertification

Harris, P C, Lloyd, H D, Hofny-Collins, A H, Barrett, A R and Browne, A W (1998) Organic Agriculture in sub-Saharan Africa: Farmer demand and potential for development. Published by the Department of International Development and the Henry Doubleday Research Association. Ryton-on-Dunsmore

Forschungsinstitut fuer biologischen Landbau (FiBL) (1998) Proposal for 3 Test Plots on organic citrus production in collaboration FiBL-UNICA (Cuba) Unpublished Document. Frick, 1998

Kotschi, J (1985) Möglichkeiten für eine ökologische Agrarproduktion in der Dritten Welt. In: Vogtmann, H (ed.) *Oekologischer Landbau – Landwirtschaft mit Zukunft.* Stuttgart

Kotschi, J (ed.) (1986) *Towards control of desertification in African drylands: problems, experiences, guidelines.* Sonderpublikation der GTZ 168, published jointly by the Commission of the European Communities (CEC) and Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) Eschborn 1986

Djigma, A, Nikiema, E, Lairon, D and Ott, P (eds.) (1990) *Proceedings of the IFOAM Seventh International Scientific Conference, 2-5. January 1989*, Ouagadougou, Bukina Faso, IFOAM; Tholey-Theley.

Parrott, N and Marsden, T (2002) *Organic and Agro-ecological Farming in the developing world. A scoping report for Greenpeace Environmental Trust.* Cardiff

Scialabba, N (2000) Opportunities and constraints of organic agriculture. A socio-ecological analysis. Università degli studi della Tuscia. Faculty of Agriculture, Viterbo 17-28 July 2000. Food and Agriculture Organisation of the United Nations (FAO), Rome

United Nations Secretariat of the Convention to Combat Desertification (UNCCD) (2001) *Homepage of the United Nations Secretariat of the Convention to Combat Desertification*. United Nations Secretariat of the Convention to Combat Desertification, Bonn, Germany, Available at http://www.unccd.int

8.6 References Section 6: Organic agriculture and comprehensive evaluations

Haas, G, Wetterich, Fand Köpke, U (2001) Comparing intensive, extensified and organic grassland farming in southern Germany by process life cycle assessment. *Agriculture, Ecosystems & Environment* 83/1-2, 43-53

Pfiffner, L, Häring, A, Dabbert, S, Stolze, M and Piorr, A (2001) Contributions of Organic Farming to a sustainable environment. In: Ministry of Food, Agriculture and Fisheries (2001) *European Conference: Organic Food and Farming - Towards Partnership and Action in Europe, 10.-11.5.2001, Copenhagen. Proceedings* [online]. Document available at: http://www.fvm.dk/kundeupload/konferencer/organic_food_farming/proceedings.pdf

Reganold, J, Glover, J, Andrews, P and Hinman, H (2001) Sustainability of three apple production systems. *Nature*, 410, 926-929

Stolton, S (1997) Fighting Draught in Kenya. In: *Ecology & Farming*, No. 19

Stolze, M, Piorr, A, Häring, A and Dabbert, S (2000) *The environmental impacts of organic farming in Europe*. Organic farming in Europe, Volume 6, University of Stuttgart-Hohenheim, Stuttgart