Ecosystem Health and Sustainable Agriculture

Sustainable Agriculture

Editor: Christine Jakobsson
Origin and History

Organic agriculture movements in the major industrial countries, e.g. Germany, Britain, Japan, USA, emerged in the 1930s and 40s as an alternative to the increasing intensification of agriculture, particularly the use of synthetic nitrogen fertilisers. Synthetic nitrogen became available after World War I, when the infrastructure for the manufacture of explosives was converted to nitrogen fertiliser production. A consequence of this process was that organic carbon was decoupled from nitrogen and, along with the soil microbe community dependent on its energy, was essentially left out of the science of crop and soil fertility management for the next 50 years (Lotter, 2003).

In spite of that, the scientific basis for crop and soil management based on organic inputs as an alternative was developed quite early. In the 1920s, Rudolf Steiner outlined the principles of ‘biodynamic farming’. This farming system was founded in June 1924, when Steiner met around 60 farmers in Koberwitz near Wroclaw (Poland) and gave eight lectures about modern agriculture based on spiritual science. The concepts underlying biodynamic agriculture relate to the spiritual radiance of all earthly phenomena, including that of the inorganic pedosphere and the cosmos. The physical-sensory reality is seen as an expression of the diversely structured spiritual world, the development of which takes place through the processes in the physical world. This idea of development regards human beings as active creators of future development, both in the positive and in the negative sense. These views are based on anthroposophy, inspired by Steiner, with the core opinion that any thing, any occurrence in the world has its cause in a spiritual world that is actually present and can fundamentally be an object of human awareness. Anthroposophy, as it concerns the perception of nature, understands itself as giving an additional dimension – the spiritual one – which in no case would replace or deny any basic natural law (Leiber et al., 2006). Central to biodynamics is the concept that a farm is healthy only as much as it becomes an organism in itself – an individualised, diverse ecosystem guided by the farmer, standing in living interaction with the larger ecological, social, economic and spiritual realities of which it is a part.

A farm becomes an ‘individuality’ in which the various factors, like organs, have specific functions and are interlinked through feedback relationships. The prime objective is to encourage healthy conditions for life. Soil fertility, plant and animal health, product quality are to
be maintained and continuously improved in a largely closed system. For farms producing under the Demeter trademark, the following principles are compulsory:

- mixed holdings
- site-appropriate crop rotations
- intensive organic fertilisation
- biodynamic preparations
- animal welfare
- breeding locally adapted crop varieties
- maintaining plant health
- cosmic rhythms consideration
- low-impact soil management
- food quality
- including the landscape (Lieber et al., 2006).

In India, Robert McCarrison researched the vitality of soldiers and the reason why they lacked diseases common in the West, and promoted health as a positive concept of vitality rather than a negative form viewed as an absence of disease. Good health was based on a diet of wholesome food – mostly fresh plants and grains with modest amounts of meat, grown on land to which all manures were returned. McCarrison followed up his observations with dietary experiments on rats, feeding one group on the diet of the Indians and the other on the diet of the British poor. The rats on the Indian diet flourished, while the others suffered a range of diseases and negative sociological effects. This led McCarrison to expound the importance of a wholesome diet grown on soil fertilised with manures and other organic matter.

Sir Albert Howard also worked in India in the 1920s on an experimental research institute. He was a keen observer of the local peasant farmers and said that he learnt far more from them than from his scientific training. He undertook a wide range of activities including a highly successful plant breeding programme and observed the effects of how forage was grown on the health of farm animals. This led him to believe in links between the health of the soil and the health of the plants and animals fed by that soil. Howard adapted oriental methods of composting to Indian conditions, which resulted in the ‘Indore process’ of composting now linked inextricably to his name. These experiences were documented in his book *The Waste Products of Agriculture* (Howard, 1931), which spread his message across many continents (Kristiansen and Merfield, 2006).

The work and publications of Howard, McCarrison and Steiner influenced further development of organic movements. The first use of the term ‘organic farming’ was in 1940 by Lord Northbourne in his book *Look to the Land*. Northbourne used the term not only in reference to the use of organic materials for soil fertility, but also to the concept of designing and managing the farm as an organic or whole system, integrating soil, crops, animals and society. This systemic approach is still at the core of organic agriculture today.

The social and practical groundwork for the modern organic agriculture movement was laid in the 1940s in publications by Howard (1940) and Balfour (1943) in the UK, and Rodale (1945) in the USA, and centred on the importance of organic matter in agriculture. By the late 1940s, organisations such as the Soil Association in the UK, Rodale’s publishing house in the USA and the Bioland organic label in Germany were established as the first OA organisations (Lotter, 2003).

In the UK, Lady Eve Balfour was setting up the ‘Haughley experiment’ which compared organic and non-organic production over the long term. She also wrote the highly influential book *The Living Soil* (Balfour, 1943), which was partly informed by the Haughley experiment. She was the first president and founding member of the Soil Association, in 1946 (Kristiansen and Merfield, 2006).

Sir Howard and Lady Balfour developed the ‘organic farming’ method with more or less closely prescribed guidelines based on the ideas of Sir Howard regarding composting, and Lady Balfour regarding the utilisation of the mineral reserve in the subsoil by means of deep-rooting clovers and herbs, and the important role that the symbiotic mycorrhizae play in the maintenance of crop health (Boeringa, 1980).

In France, the pioneering work of Lemaire and Boucher led to the development of the ‘biological farming’ method based upon the notion that mineral fertilisers, chemical pesticides and large amounts of uncomposted organic fertilisers disturb the ‘balance’ of the soil and thus induce diseases and pests. Through administration of composted organic fertilisers, leguminous plants and Calmagol (a product characterised as unique and consisting of coral
algae, *Lithothamnium calcareum*), they claimed that balance is restored and maintained. Calmagol was also claimed to be the catalyst of the so-called biological transmutations by which, under the influence of primarily microbiological processes, elements change into other elements, in ideal circumstances according to the requirements of the crop. Biological transmutation, a theory developed by C.L. Kervran, plays an essential role not only in Lemaite-Boucher agriculture, but also in the macrobiotic dietetics of Ohsawa. However, Kervran’s research has not confirmed the existence of biological transmutation (Boeringa, 1980).

The Swiss biologist Dr. Hans Müller and his wife Maria, in cooperation with Hans-Peter Rusch, a medical doctor, first demonstrated the practical possibilities of organic-biological agriculture. What they did was in fact to carry out an agricultural experiment on an ever-increasing scale, the consequences of which are of world-wide significance. The task of this ‘biological holistic experiment’ can be briefly summarised in the following points:

• Only a closed cycle of completely biological materials, a system comprising soil, plants, animals and man, can be the object of research for the determination of the functional quality of the life processes.

• The only valid criterion is the health and fertility of every separate link in the cycle, and the only organism worthy of testing is one that is demonstrably in relation to all the other links in the cycle.

• The attempt must be made to observe simultaneously as many as possible of the objects (of research) so as to distinguish the generally valid conditions from the particular ones and thus to arrive at generally applicable statements.

• Disturbing environmental influences and the effects of mutagenic foreign substance ought to be excluded. Only in this way can a model of the intact spontaneous biological cycle be realised which can lead to valid conclusions.

• Sufficient time must be allowed for the study of each member of the biocoenose, which will be determined by the biological regenerative capacity of the individual, and will in general be at least three generations.

As a link in the food chain, in their nutrition crops need inorganic salts and cell particles containing nucleic acids. Organic fertilisation is an absolute necessity for this. Because plants are unable to split up the cells from animal or vegetable manure themselves, this must be done by soil organisms. The soil is thus not only a substrate for the plant to grow in and, if its structure is good, a regulator of water and air supply, but also the ‘digestive’ organ for the plants. The optimal conditions for the ‘digestive’ processes were established by Rusch on the basis of his observations and experiments. His guide was undisturbed nature.

The working hypothesis of Rusch, which lies at the basis of organic-biological agriculture, was a cycle of lactic-acid forming bacteria of the forms: soil → plant → animal → soil and soil → plant → man → soil; and the possibility of gene induction by lactic acid-forming bacteria in plants. In light of current knowledge, this working hypothesis is plausible to only a limited extent (Boeringa, 1980).

In the late 1930s in rural Pennsylvania, USA, J.I. Rodale was keen to learn about and practise organic agriculture. He quickly came to realise the importance of restoring and protecting the natural health of the soil to preserve and improve human health. In 1947 he founded the Soil and Health Foundation, which later became the Rodale Institute. He was also responsible for a wide range of publications on health and farming and gardening organically, with a central message and philosophy of ‘healthy soil equals healthy food, equals healthy people’.

Independent developments were occurring in Japan. In 1936, Mokichi Okada began practising ‘nature farming’. Nature farming includes spiritual as well as agronomic aspects, with a view to improving humanity. It therefore has strong similarities to the biodynamic agriculture and anthroposophy of Rudolph Steiner. The Sekai Kyusei Kyo organisation was formed and continues to promote ‘Kyusei nature farming’ with experimental farms and offices located throughout South-East Asia.

Masanobu Fukuoka initiated a different approach to natural farming in Japan. With a background in microbiology and soil science, Fukuoka aimed to practise a simple form of agriculture, sometimes known as ‘do nothing farming’. Like Okada, Fukuoka’s farming approach also had a spiritual underpinning. The continuation and spread of these movements highlights the importance of seeing...
organic agriculture as a global phenomenon, not simply a European one.

While many of the ideas of these organic pioneers are still relevant to modern organic agriculture, there were a considerable number of pioneers whose political and religious views would be anathema to today’s environmentally minded, socially concerned, politically left-of-centre, organic supporters (Kristiansen and Merfield, 2006).

Modern Organic Movement

The ideas of some organic pioneers are now foreign to the modern organic movement, which underwent significant change and upheaval in the 1960s. While there is a continuum of thought and membership from the earliest days to the present, the modern organic movement is radically different from its original forms. The environmental sustainability is its core, in addition to the founders’ concerns for healthy soil, healthy food and healthy people. The publication *Silent Spring* by Rachel Carson (1962) was a key turning point and the start of the modern organic and environmental movements. Its publication brought new arguments against industrial farming in addition to those that the organic movement had been pushing for many decades.

In the 1970s, organic agriculture re-emerged and there was a strengthening of existing organic organisations and the founding of new ones. Many of these focused on the process of certification of farmers and growers. In spite of growing interest in organic agriculture, it was still outside mainstream agriculture and national politics.

The formation of a formal global network is one of the landmarks by which social and political movements can say they have come of age. For the organic movement this was the founding of the International Federation of Organic Agriculture Movements (IFOAM) in 1972, which to this day remains the only global organic non-governmental organisation (NGO) (Kristiansen and Merfield, 2006).

IFOAM has grown from a body that national governments ignored or argued against to one that now is respected by governments and intergovernmental organisations. The IFOAM mission is ‘leading, uniting and assisting the organic movement in its full diversity’ (IFOAM, 2005).

The main aims of the organisation are to:

- Provide authoritative information about organic agriculture, promote its worldwide application and exchange knowledge.
- Represent the organic movement at international policy-making forums.
- Make an agreed international guarantee of organic quality a reality.
- Maintain the Organic Guarantee System, setting international organic standards and certification procedures and auditing member certification organisations to these standards.
- Build a common agenda for all stakeholders in the organic sector.

Trends that began in the 1970s and accelerated through the 1980s continued to grow during the 1990s and into the new millennium. Demand and production continued to grow exponentially around the world. Formal political and legislative recognition was achieved.

Definitions of Organic Farming

Definitions of organic agriculture are similar world-wide and focus on ecological principles as the basis for crop production and animal husbandry. In current definitions of organic farming, the connections between health of the soil, health of people and health of society are recognised. According to the National Organic Standards Board, organic agriculture is:

> ‘An ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. It is based on minimal use of off-farm inputs and on management practices that restore, maintain and enhance ecological harmony’ (ATTRA, 1995).

The IFOAM goes further in defining organic agriculture (IFOAM, 2004):
Organic agriculture (OA) ‘is an agricultural production system that promotes environmentally, socially and economically sound production of food and fibres, and excludes the use of synthetically compounded fertilisers, pesticides, growth regulators, livestock feed, additives and genetically modified organisms. The purpose of organic agriculture is to optimise the health and productivity of interdependent communities of soil life, plants, animals and people’.

The international food standards, Codex Alimentarius (FAO 1999) state:

‘Organic agriculture is a holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. It emphasises the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using, where possible, agronomic, biological and mechanical methods, as opposed to using synthetic materials, to fulfil any specific function within the system’.

EU Council Regulation (EC) No 834/2007 on organic production and labelling of organic products, applied from January 1, 2009 states:

‘Organic production is an overall system of farm management and food production that combines best environmental practices, a high level of biodiversity, the preservation of natural resources, the application of high animal welfare standards and a production method in line with the preference of certain consumers for products produced using natural substances and processes. The organic production method thus plays a dual societal role, where it on the one hand provides for a specific market responding to a consumer demand for organic products, and on the other hand delivers public goods contributing to the protection of the environment and animal welfare, as well as to rural development’.

The principles of organic agriculture have changed with the evolution and development of the movement. At the beginning, the principles were unwritten, because they were inherent in the philosophy and practice of the farmers. IFOAM has been the key organisation defining the principles of organic agriculture. The original principles defined in 1980 are as follows (Woodward and Vogtmann, 2004):

- To work as much as possible within a closed system, and draw upon local resources.
- To maintain the long-term fertility of soils.
- To avoid all forms of pollution that may result from agricultural techniques.
- To produce foodstuffs of high nutritional quality and sufficient quantity.
- To reduce the use of fossil energy in agricultural practices to a minimum.
- To give livestock conditions of life that conform to their physiological needs and to humanitarian principles.
- To make it possible for agricultural producers to earn a living through their work and develop their potentialities as human beings.

The principles have been published as an introduction to the IFOAM ‘basic standards’ of the organic guarantee system. They clarify the aims of organic agriculture. The original seven principles have frequently been amended and added in a process carried out at the biennial General Assembly, where the changes are debated and voted on by members.

This process has led to the formulation of ‘principle aims of organic agriculture for production and processing’ in 2002 (IFOAM).

- To produce sufficient quantities of high quality food, fibre and other products.
- To work compatibly with natural cycles and living systems through the soil, plants and animals in the entire production system.
- To recognise the wider social and ecological impact of and within the organic production and processing system.
• To maintain and increase long-term fertility and biological activity of soils using locally adapted cultural, biological and mechanical methods as opposed to reliance on inputs.
• To maintain and encourage agricultural and natural biodiversity on the farm and its surroundings through the use of sustainable production systems and the protection of plant and wildlife habitats.
• To maintain and conserve genetic diversity through attention to on-farm management of genetic resources.
• To promote the responsible use and conservation of water and all life therein.
• To use, as far as possible, renewable resources in production and processing systems and avoid pollution and waste.
• To foster local and regional production and distribution.
• To create a harmonious balance between crop production and animal husbandry.
• To provide living conditions that allow animals to express the basic aspects of their innate behaviour.
• To utilise biodegradable, recyclable and recycled packaging materials.
• To provide everyone involved in organic farming and processing with a quality of life that satisfies their basic needs, within a safe, secure and healthy working environment.
• To support the establishment of an entire production, processing and distribution chain which is both socially just and ecologically responsible.
• To recognise the importance of, and protect and learn from, indigenous knowledge and traditional farming systems.

In recent years there has been an increasing feeling that these principle aims lack consistency and have been weakened. Therefore in 2005, revised principles of organic agriculture were accepted. These revised principles differ notably from the principal aims and are closer in philosophy and structure to the original from 1980.

Principle of Health
Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible. This means that the health of individuals depends on the health of ecosystems – healthy soil produces healthy crops that foster the health of animals and people. Immunity, resilience and regeneration are key characteristics of health. Organic farming is intended to produce high quality, nutritious food that contributes to preventive health care and well-being. In view of this it should avoid the use of fertilisers, pesticides, animal drugs and food additives that may have adverse health effects. This principle is holistic in its outlook and applies to the whole agricultural sphere from ecosystems as a whole to the individual parts such as soil, plants, animals and people.

Principle of Ecology
Organic Agriculture should be based on living ecological systems and cycles, should work with them, sustain them and keep ecological balances in nature. Production must be based on ecological processes, and recycling. Nourishment and wellbeing are achieved through the ecology of the specific production environment. For example, in the case of crops this is the living soil; for animals it is the farm ecosystem; for fish and marine organisms, the aquatic environment.

Organic management must be adapted to local conditions, ecology, culture and scale and it should attain ecological balance through the design of farming systems, establishment of habitats and maintenance of genetic and agricultural diversity. Those who produce, process, trade, or consume organic products should protect and benefit the common environment including landscapes, climate, habitats, biodiversity, air and water. Inputs should be reduced by reuse, recycling and efficient management of materials and energy in order to maintain and improve environmental quality and conserve resources.

Principle of Fairness
Fairness is characterised by equity, respect, justice and stewardship of the shared world, both among people and in their relations to other living beings. There must be fairness at all levels and for all groups of people – farmers, workers, processors, distributors, traders and consumers. This principle insists that animals should be provided with the conditions and opportunities of life that accord with their physiology, natural behaviour and well-being.
Principle of Care
This principle states that precaution and responsibility are the key concerns in management, development and technology choices in organic agriculture. Science is necessary to ensure that organic agriculture is healthy, safe and ecologically sound. However scientific knowledge alone is not sufficient. Practical experience, accumulated wisdom and traditional and indigenous knowledge offer valid solutions, tested by time. Organic agriculture should prevent significant risks by adopting appropriate technologies and rejecting unpredictable ones, such as genetic engineering. Decisions should reflect the values and needs of all who might be affected, through transparent and participatory processes (IFOAM 2005).

A key policy role for many governments is defining organic agriculture in law and creating enforcement mechanisms. In order to keep differing national organic regulations from becoming trade barriers, there is a need to adopt one set of internationally recognised organic guarantee tools, including production standards, certification procedures and accreditation requirements. One example of this is EU Council Regulation (EC) No 834/2007 on organic production and labelling of organic products.

Laws and Regulations are often as much for the protection of consumers as for the advancement of organic agriculture. Policy formulation based on local food needs, rural development imperatives and environmental conservation can greatly influence producers’ decisions through accurately targeted subsidies, fiscal measures and other policy instruments for multiple societal goals such as employment, environmental services and health (El-Hage Scialabba, 2007).

In Europe, such incentives have been used for several years to encourage farmers to convert to organic agriculture. More recent government policies have actively assisted and promoted organic agriculture as a means of addressing the problems of agriculture (e.g. development of ‘action plans’ to ensure stable and strategic growth of organic food production). Organic agriculture is now widely recognised by the public and governments as a valid alternative to conventional agriculture and is a source of ideas and approaches that conventional agriculture can also adopt to make it more sustainable (Kristiansen and Merfield, 2006).
The Growth of Organic Farming

Recent years have seen very rapid growth in organic farming. In 1985, certified organic production accounted for 103,000 ha in Europe, approximately 0.1% of the total agricultural area. By the end of 2000, this area increased to 4.3 million ha, in 2006 representing 7.4 million ha in Europe (1.65% of European agricultural area) and 6.8 million ha in EU 27 (4.0% of agricultural area). Worldwide, 30.4 million ha are certified according to organic standards (0.65% of global agricultural land). Australia, with its vast grazing lands, continues to account for the largest certified organic surface area, 12 million hectares, followed by Argentina (2.8 million ha) and Brazil (1.8 million ha). In terms of certified land as a share of national agricultural area, the Alpine countries, such as Austria (13.4%) and Switzerland (11%) top the statistics. The global market for organic products reached a value of over 46 billion US Dollars in 2007, with the vast majority of products being consumed in North America and Europe (IFOAM, 2009; Willer et al., 2008). Although difficult to quantify, non-certified organic systems of several million small farmers may represent at least an equivalent share in the subsistence agriculture of developing countries (El-Hage Scialabba, 2007).

Environmental Impacts of Organic Agriculture

Organic agriculture has become an important aspect of European environmental policy. Since the implementation of EC Reg. 2078/92, the EU promotes organic farming explicitly due to its positive effects on the environment. EU supports organic agriculture through agri-environment programmes. In most EU countries OA is growing in importance or plays a central role in national agri-environment policy.

The most advanced indicator concept in the area of environment and resource use has been presented by OECD. The OECD also provides a set of environmental indicators adapted for the agricultural sector (OECD, 1997). This concept is based on the Driving Force – State – Response framework (DSR). ‘Driving forces’ are those elements that cause changes in the state of the environment. Driving force sub-categories are: Environment, Economic and social framework, Farm inputs and outputs. ‘State’, or condition, refers to changes in environmental conditions that may arise from various driving forces. State sub-categories are: Ecosystem, Natural resources, Health and welfare. ‘Responses’ refer to the reaction by groups in society or policy-makers to the actual and perceived changes in the state. Response sub-categories are: Consumer reaction, Agro-food chain responses, Farmer behaviour, Government policies.

In a study by Stolze et al. (2000), the environmental and resource use effects of organic farming relative to conventional farming in a European context were assessed. The original set of OECD indicators was adapted with the aim of evaluating and analysing the system effects rather than evaluating policies. The results of the comparison of organic and conventional farming systems are shown in Table 37.1 in the form of indicators according to the Stolze et al. (2000) assessment and absolute and relative environmental impacts according to Kasperczyk and Knickel (2006).

Ecosystem Indicators: Floral, Faunal, Habitat Diversity and Landscape Conservation

Organic farming performs better than conventional farming in respect to floral and faunal diversity due to the ban on synthetic pesticides and N fertilisers, with secondary beneficial effects on wildlife conservation and landscape. Diverse crop rotations in organic farming provide more habitats for wildlife due to the resulting diversity of housing, breeding and nutritional supply. However, direct measures for wildlife and biotope conservation depend on the individual activities of the farmers. With respect to habitat and landscape diversity, research deficits have been identified. As with any other form of agriculture, organic farming cannot contribute directly to wildlife conservation goals. Nevertheless, in productive areas, organic farming is currently the least detrimental farming system with respect to wildlife conservation and landscape (Stolze et al., 2000).

Genetic diversity of crops within conventional farms is very low, usually one variety per planting. Organic farms have a greater diversity due to mandatory crop rotation. One pillar of organic plant protection and animal health
Table 37.1. Assessment of the environmental impact of organic farming (Stolze et al., 2000; Kasperczyk and Knickel, 2006).

<table>
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<tr>
<th>Indicators</th>
<th>Environmental impact A</th>
<th>Environmental impact B</th>
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<tr>
<td><strong>Ecosystem</strong></td>
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<tr>
<td>Floral diversity</td>
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<td>Faunal diversity</td>
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<td>Habitat diversity</td>
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<td>+?</td>
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<td>Landscape</td>
<td>X</td>
<td>+?</td>
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<td><strong>Soil</strong></td>
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<td>Soil organic matter</td>
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<tr>
<td>Biological activity</td>
<td>X</td>
<td>+?</td>
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<tr>
<td>Soil structure</td>
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<tr>
<td>Erosion</td>
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<td><strong>Ground and surface water</strong></td>
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<tr>
<td>Nitrate leaching</td>
<td>X</td>
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<tr>
<td>Pesticides</td>
<td>X</td>
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<tr>
<td><strong>Climate and air</strong></td>
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<tr>
<td>CO₂</td>
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<td>+?</td>
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<td>N₂O</td>
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<td>CH₄</td>
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<tr>
<td>NH₃</td>
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<tr>
<td>Pesticides</td>
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<tr>
<td><strong>Farm input and output</strong></td>
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<tr>
<td>Nutrient use</td>
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<td>Water use</td>
<td>X</td>
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<tr>
<td>Energy use</td>
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<tr>
<td><strong>Animal health and welfare</strong></td>
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<tr>
<td>Husbandry</td>
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<tr>
<td>Health</td>
<td>X</td>
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<tr>
<td>Genetic diversity</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Desertification</td>
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<td>+</td>
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<tr>
<td>Nutrient use and balance</td>
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<td>–</td>
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<tr>
<td>Pathogens</td>
<td></td>
<td>–</td>
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<tr>
<td>Intensity of energy use</td>
<td>na</td>
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</table>

Legend A: Organic farming performs: ++ much better; + better; 0 the same; - worse; -- much worse, than conventional farming. When no data were available, the rating was ‘0’. X – subjective confidence interval of final assessment.

Legend B: ‘Absolute’ refers to the impact of organic farming on the environment, ‘relative’ refers to the relative impact in comparison with conventional system. + slightly better; ++ better; +++ substantially better; +/- better with some aspects that are negative; +? better with some uncertainties; +/-? partly better and partly worse with some uncertainties; ? unclear; - worse; 0 no impact or change; ‘na’ not applicable.
is the use of a more diverse range of diseases, pest and parasite tolerant or resistant varieties and breeding lines. The potential of genetic diversity on crop level for stabilisation of low-input farming systems and for adaptation to environmental changes is theoretically well understood in organic farming, but cultivar or race choice is still strongly based on immediate market needs (Niggli et al., 2007). Since 1995, organic agriculture has indirectly established a rescue process for species, varieties and breeds threatened by underuse or extinction. Organic agriculture is providing an important contribution to the in situ conservation, restoration and maintenance of agricultural biodiversity (El-Hage Scialabba et al., 2002). As resistance and robustness to environmental stress are multigenetic characteristics, in situ conservation and on-farm breeding are likely to be more successful than genetic engineering (Niggli et al., 2007).

Soil Indicators: SOM, Biological Activity, Structure and Erosion
Organic farming tends to conserve soil fertility better than conventional farming. This is mainly due to higher organic matter content and higher biological activity. Therefore, organic farming systems control erosion more effectively. The more continuous soil cover due to close crop rotations also assists in this. In contrast, no differences between the farming systems have been identified for soil structure (Stolze et al., 2000).

Groundwater and Surface Water Indicators: Nitrate Leaching and Pesticides
As a result of fertiliser or manure application and N fixation by leguminous crops, N accumulates in the soil. Nitrate leaching occurs when the amount of nitrate in the soil exceeds plant requirements and when water from rain, irrigation or snowmelt moves through the soil into the groundwater. Nitrate in water can lead to toxic contamination of drinking water for humans and animals, as well as surface water eutrophication with excessive algal growth.

Organic farming results in lower or similar nitrate leaching rates to other systems. Leaching rates per hectare are up to 57% lower. However, the leaching rates per tonne of output produced are similar or slightly higher. Ploughing legumes at the wrong time, unfavourable crop rotations and composting farmyard manure on unpaved surfaces increase the risk of nitrate leaching in organic farming. However, awareness of the problem and alternative measures have been developed and introduced in practice (Stolze et al., 2000).

The other nutrient that can occur as a major pollutant is phosphorus (P). However, for P the literature shows substantially and systematically less leaching from organically fertilised soils than from soils treated with synthetic fertiliser, probably due to formation of complexes with organic molecules that facilitate immobilisation by binding to soil particles (Hart et al., 2004). The risk of groundwater and surface water contamination with synthetic pesticides is zero.

Persistent pesticides (such as DDT) have damaged wildlife globally and are still being used in many developing countries. Organic agriculture has the potential to benefit the global situation if the proportion of land under organic management becomes large enough to reduce the total use. Recent data indicate that organically managed soil may be more efficient at denitrification, releasing most of the nitrate into the atmosphere as harmless \( \text{N}_2 \). If this is a general trend, the benefits of organic farming are much larger than previously estimated (Brandt, 2007).

Climate and Air Indicators: \( \text{CO}_2 \), \( \text{N}_2\text{O} \), \( \text{CH}_4 \), \( \text{NH}_3 \), Pesticides
Research on \( \text{CO}_2 \) emissions shows varying results. On a per hectare scale, the \( \text{CO}_2 \) emissions are 40-60% lower in organic farming systems than in conventional, whereas on a per unit output scale \( \text{CO}_2 \) emissions tend to be higher in organic farming systems. Similar results are expected by experts for \( \text{N}_2\text{O} \) and \( \text{CH}_4 \) emissions, although to date no research results exist. Calculations of \( \text{NH}_3 \) emissions in organic and conventional farming systems have concluded that organic farming has a lower \( \text{NH}_3 \) emission potential than conventional farming. Nevertheless, housing systems and manure treatment in organic farming should be improved to reduce \( \text{NH}_3 \) emissions further (Stolze et al., 2000).

The carbon sequestration efficiency (tonnes \( \text{CO}_2 \)-C per ha) of organic systems in temperate climates is almost double that of conventional systems, when the total of above- and below-ground biomass of cash and catch crops and weeds is calculated (Haas and Köpke, 1994,
Air contamination with synthetic pesticides is significantly lower due to their ban under organic standards.

**Farm Input and Output indicators: Nutrient, Water, and Energy Use**

Nutrient balances of organic farms are generally close to zero because organic farms rely heavily on internal nutrient cycling: N surpluses of organic farms are significantly lower than on conventional farms, but P and K deficits can arise. These deficits are related to the relatively infrequent use of P and K (potassium) fertilisers in organic farming, with some authors reporting a decline in the concentration of extractable P and K in soil after conversion to organic management (Nguyen et al., 1995). The energy efficiency of annual and permanent crops seems to be higher in organic farming than in conventional, mainly due to lower inputs of elements requiring a high energy input, i.e. N. Research results comparing water use in organic and conventional farming systems are not available (Stolze et al., 2000).

**Animal Health and Welfare Indicators: Husbandry, Health**

Husbandry, healthy housing conditions and health status depend highly on farm-specific conditions. Thus, housing conditions do not differ significantly between organic and conventional farms. Preventive use of synthetic, allopathic medicines is restricted by some national standards and recently also by EU rules. Although the application of homeopathic medicines is preferred, conventional veterinary measures are permitted and used in acute cases of disease. Health status seems to be closely related to the economic relevance of animal husbandry on the farm: significantly fewer incidences of metabolic disorders, under diseases and injuries are found when dairy production is properly managed. Organic dairy cows tend to have a longer average productive life than conventional dairy cows (Stolze et al., 2000).

With a view to future developments, it seems to be important to keep in mind that the relative economic and environmental performance of organic farming compared with conventional might change. There might be changes in relative yields through technological progress. Technological development will also influence relative environmental performance, e.g. by using precision farming methods more widely in conventional farming, but possibly also in organic systems. If legal restrictions on conventional agriculture lead to a ‘greener’ conventional system, it will be interesting to see whether the organic sector reacts by tightening its own standards in order to keep a clear distinction. The magnitude and the resulting net effect of these developments is an interesting area of speculation. For practical policy, two lessons emerge from such discussion: First, technological development within the organic sector is a key question for its future development. Second, policies geared at conventional agriculture might heavily influence the future development of organic farming (Dabbert, 2003).

**Soil Fertility**

Soil is one of the most important natural resources because it is the central basis for all agricultural activity. Soil quality can be defined as the capacity of a soil to function, whilst maintaining environmental quality and promoting plant and animal health. It also refers to the capability of soil to function at present and in the future for an indefinite period of time. Soil quality is a basic concept in the sustainable management of any agricultural system aimed at producing, avoiding or reducing negative effects on the environment, preserving resources and saving energy on a medium or long-term basis (Canali, 2003).

The effective management of soil fertility is based on understanding processes associated with its chemical, physical and biological components, with greater emphasis having traditionally been given to soil chemical fertility. Organic farming is based on the maintenance and enhancement of soil life and natural soil fertility, soil stability and soil biodiversity preventing and combating soil compaction and soil erosion, and the nourishment of plants primarily through the soil ecosystem.

**Soil Organic Matter**

The soil’s supply of organic matter plays a central role in the maintenance of soil fertility. Ewel (1986) describes soil organic matter (SOM) as ‘the warehouse of most of the nitrogen, phosphorus and sulphur potentially avail-
able to plants, is the main energy source for microorganisms and is a key determinant of soil structure.

Various comparison trials and on-farm investigations show that organically managed soils tend to have higher total soil organic carbon contents ($% C_t$) than conventionally farmed arable land. This is indicated by a higher ratio of soil microbial biomass to total soil organic carbon and lower metabolic quotient, characterising biomass specific soil respiration (Mäder et al., 1995).

In a long-term DOC (bio-Dynamic, bio-Organic, Conventional) experiment (Mäder et al., 2002), the organic system accumulated 12% more carbon in the soil and the bio-dynamic 15%. The carbon sequestration rate was 575-700 kg carbon per ha per year. Pimentel et al. (2005) in the Rodale experiment, USA, reported an annual soil carbon increase of 981 kg per ha in the manure-based organic system and an increase of 574 kg per ha in the legume-based organic system.

In a study by Marriott and Wander (2006), soil organic carbon concentrations were 14% higher in the organic system compared with the conventional. The labile fraction of the soil organic matter, a source of mineralisable C and N with important implications for plant nutrition, showed 30-40% higher values in organic soils.

Soil organic matter contributes significantly to soil quality and health. SOM enhances and drives numerous chemical, biological processes and soil physical properties. Higher levels of soil organic matter have been observed regularly in organically managed soils compared with conventional. Foereid and Hogh-Jensen (2004) estimated that conversion of Northern Europe from conventional arable crops to organic crops would result in an increase in SOM during the first 50 years of about 10 to 40 g C per m² per year. Steady state (stable level of SOM) would be reached after 100 years. The main factors for the increase in SOM were use of grass-clover leys for feed and cover crops in organic rotations.

Soil physical fertility contributes to the sustainability of organic farming systems by creating the framework in which biological and chemical processes supply nutrients to plants and protect soil from erosion. The environmental significance of favourable soil structure lies in an improved resistance to structural soil damage, such as compaction and erosion. Soil physical fertility can be measured by diverse parameters, such as the stability of aggregates, air capacity, water-holding capacity, bulk density.

A long-term Swiss field experiment on loess soil that began in 1978 found the aggregate and percolation stability of bio-dynamic and organic plots to be significantly higher (10-60%) than that of conventionally farmed plots. This also affected the water retention potential of these

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soils in a positive way and reduced their susceptibility to erosion. Soil aggregate stability was strongly correlated to earthworm and microbial biomass, important indicators of soil fertility (Mäder et al., 2002). Compared with stockless conventional farming, values of aggregate stability on plots in livestock-based integrated production were 29.4% higher, while in organic and bio-dynamic plots they were 70% higher (Siegrist et al., 1998). The percentage of water-stable macro-aggregates on organically farmed sites was 72% higher than on conventional. The higher physical stability was linked to significantly increased soil organic matter content and to a larger volume of worm-worked soil (organic 28%, conventional 8%). The investigation was carried out on farms that had been under organic management for 70 years (Niggli et al., 2007). In many other experiments, a positive effect of organic farming on soil structure could not be confirmed or, if at all, only for topsoil. An improvement in soil structure can only be observed after decades of farming organically (Stolze et al., 2000).

Water is becoming increasingly scarce in certain regions of the world, so it will be important to increase water efficiency in both rain-fed and irrigated agriculture. The soil fertility building techniques of OA that lead to higher organic matter content, better aggregate stability and biologically more active soils in turn increase water retention in soils and improve water use efficiency. Soils retain significantly more rainwater thanks to the ‘sponge properties’ of organic matter. In heavy loess soils in a temperate climate, the water-holding capacity is 20 to 40% higher in organically managed soils (Mäder et al., 2002).

Organic management of soils leads to improved soil stability and resistance to water erosion compared with conventionally managed soils, due to higher soil C content and improved soil aggregation and permeability. Lotter et al. (2003) presented evidence that organic systems perform better than conventional during climate extremes, in this case for both drought and excessive rainfall. In the 21-year Rodale trial, in which two organic and a conventional crop rotation were compared, the organic crop systems performed significantly better in 4 of 5 years of moderate drought. In the severe drought year of 1999, three out of the four crop comparisons resulted in significantly better yields in the organic systems than the conventional. The evidence indicates that the better water-holding capacity of organically managed soils is a likely mechanism for better yields during water deficits. Water harvest, important for groundwater recharge, was significantly better in the organic systems in both the severe drought year and...
over a 5-year period. Organic crop management techniques will be a valuable resource in an era of climatic variability, providing soil and crop characteristics that can better buffer environmental extremes.

**Soil chemical fertility** reflects the capacity of soil to provide a suitable chemical and nutritional environment to the plants and support biological and physical processes. The maintenance of soil chemical fertility depends strongly on processes that govern transformations from fixed to soluble forms of nutrients, such as mineralisation of organic matter and dissolution of minerals.

- Nutrient sources in organic systems are predominantly organic or poorly soluble and therefore slow to become available.
- Nutrient availability is more dependent on dynamic soil biological processes.
- Release and uptake of nutrients occurs without demonstrable changes in soil chemistry, because nutrients are rapidly taken up by the plants or soil microorganisms without accumulating in the soil solution (Davis & Abbott, 2006).

Soil biological fertility can be quantified by measuring the size, activity, diversity and function of communities. Central to organic farming is the aim of optimising plant production by maintaining a rich biological diversity in the soil. High biological activity promotes metabolism between soil and plants, worms and other beneficial soil biota that help process nutrients from residues for plant uptake, while also creating stable organic matter. Earthworms, as a key species for soil macro-fauna, are an appropriate indicator of soil biological activities due to their sensitivity to any kind of disturbance. A high supply of organic matter and manure provides favourable living conditions for worms and other fauna in soils (Stolze et al., 2000).

Relevant scientific results as summarised by Pfiffner and Mäder (1997) resulted in these general conclusions:

- A significantly higher biomass and abundance of earthworms.
- A significantly higher diversity of earthworm species.
- Changes in population composition, indicated by the presence of more anecic and juvenile earthworms in organically farmed soils.

Organic farming may alter the function of the soil microbial community, increasing its ability to release nutrients from organic and poorly soluble sources, thereby compensating for the absence of soluble nutrients inputs (Ryan, 1999).

A synthesis of comparative studies conducted to observe soil microbial activity found:

- Improvement of soil microbial activity, 20-30% higher microbial biomass in organic systems.
- Higher microbial diversity, higher efficiency in organic carbon turnover.
- More efficient use of available resources by soil organisms, indicated by a lower metabolic quotient for CO₂.
- Higher mycorrhization in soil under organic winter wheat, cover crops and clover-grass.
- Higher numbers and abundance of saprophytic soil fungi with higher potential to decompose organic material (Stolze et al., 2000).

In parallel to the changes in organic matter in soils, soil microbial biomass and the physiological functions of soils are enhanced by organic agriculture. Important soil enzyme activities such as dehydrogenase, protease and phosphatase are higher in organic field plots, leading e.g.
to faster phosphorus flux through the microbial biomass and contributing to plant phosphorus supply (Mäder et al., 2002). Some of the changes in soil biological and chemical fertility upon conversion to OA can take many years, such as increases in SOM and microbial community structure, while others can change almost immediately, as with aggregate microbial biomass and activity (Gunapala et al., 1998, cit. Lotter, 2003).

**Productivity and Yields**

There have been several reviews of comparative studies of organic agriculture (OA) and conventional agriculture (CA) crop yields. The productivity of OA compared with CA depends strongly on environmental factors such as soil, water resources and climate conditions, as well as on the crops being compared. Padel and Lampkin (1994) reviewed comparative studies of crop yields in OA versus CA. Organic yields in the UK were on average 11% lower, while in the US differences were highly variable, ranging from 50% higher in the Midwest (oats) to 60% lower in California (rice). In intensive production areas of Europe, OA yields are on average 30-40% lower than CA yields.

Organic crop systems in North America have been shown to produce on average approximately 90-95% of the yields in conventional crop systems. Where organic crop systems excel, however, is in water and climate stress situations. A number of studies have shown that under drought conditions, crops in organically managed systems produce higher yields than comparable conventional crops (Lotter, 2003). Mechanisms that may increase the drought tolerance of organic cropping systems are discussed within soil physics.

Discussions of yield comparisons need to take into consideration the type of crops being compared. For maize and soybeans, Pimentel et al. (2005) reported equal yields for OA and CA under less favourable soil conditions. The importance of fertility-building crops in rotations and crop sequences on grain yields is stressed by Younie et al. (2000) and Olesen et al. (2000). Grain yield of spring barley decreased in rotations without manure or catch crops. Differences in oat grain yield were caused by its place in the crop rotation. In long-term trials established on fertile soil in Central Europe, organic winter wheat yield was 82% of that in an integrated system and organic pea yield 92%, but organic maize outyielded integrated maize by 19.6% and spring barley yields were equal in both farming systems (L.-Bartošová, 2006).

Extensive and rigorous research with regard to the productivity of the organic agriculture system has been carried out in developed countries, but scientific evidence from developing countries is still rare. In developing tropical countries in which organic practices were introduced, a survey of more than 200 projects showed an average yield increase of 5-10% for irrigated crops and 50-100% for rain-fed crops (Pretty and Hine, 2001).
A report by Zundel and Kilcher (2007) summarised the information available on the productivity of OA by considering four different agro-ecological zones in terms of their productivity when converting from conventional to organic management. In all four, yield reductions were usually low (or sometimes nonexistent) in the first two to three years if conversion was from a low-input system but after the conversion period, organic yields could reach levels even higher than conventional yields. Yield reductions were generally higher if the system had been run on a high-input level. Yields recovered after the conversion period, but usually not to the level of the previous conventional yields.

Agriculture in temperate and irrigated areas is generally characterised by favourable soils, high levels of mechanisation and functioning markets for farm supplies. In these areas, high external inputs make it possible to obtain high production levels but productivity may be pushed beyond the actual ecosystem capacity. Soils receive a high level of inputs and the crop varieties and hybrids used are often designed to perform well under intensive conditions. Conversion to organic management from these conditions usually means a considerable drop in yields, during two to three years of conversion. The estimated yield reductions during conversion are 20-30% for cereals, 10-20% for maize, 30-40% for potatoes, 10-40% for vegetables and around 30% for fruits. In the medium and long term, when soil fertility recovers, yields are slightly lower or comparable to the pre-conversion yields. Studies in several short and long-term field trials with field crops found no difference between organic and conventional crop yields. Other field trials reported crop yields to be 5 to 35% lower than conventional. Lower yields are often a result of lower availability of nitrogen and higher weed pressure, generally due to inexperienced management of the system. If conventional farm management was on a low-input level prior to conversion, organic farmers can expect to maintain similar yields. If the farm was previously managed at a high-input level, yields will drop initially, recover as soil fertility recovers and then stabilise at a level corresponding to the carrying capacity of the ecosystem.

In semi-arid environments, the main challenge in converting to organic agriculture is dealing with water scarcity and the disrupted dynamics of biomass decomposition during the long dry season. In Ethiopia, a case study reported double yields as the result of organic soil management. In tropical humid and peri-humid areas the main challenges are increased crop rotations, diversification, agroforestry and integration of livestock.

Considering the complexity and diversity of organic farms, participatory development of site-specific technologies is of immense importance for later adoption and positive impact on productivity. Many studies have shown that a technology can be successful at one site but not another, even with only slightly different agro-ecological conditions.

Going head-to-head in yield comparisons may be unfair until research and extension investment in OA catches up and allows OA systems to reach a mature stage comparable to CA systems (Lotter, 2003). The common claim that large-scale conversion to OA would result in drastic reductions in world food supplies or large-scale conversion of virgin land to agriculture has not been proven in modelling studies. Conversion of existing global agriculture to organic management, without converting virgin land to agriculture and or using artificial N fertilisers, would result in a global agricultural supply of 2640-4380 kcal/person/day. Sustainable intensification in developing countries through organic practices would increase production by 56%. Organic farms use 33-56% less energy per ha than conventional. Nutrient use is enhanced through recycling and minimising losses, but the availability of phosphorus can be a challenge (FAO, 2007).

Food Quality

In organic agriculture the term ‘quality’ has a larger scope and wider content than in conventional agriculture and aims at the holistic and not only the analytical perspective. Internal nutritional attributes of quality are highly valued. The technological quality is considered to be of less importance, with quality given priority over quantity. Among the factors determining quality there are also those that are more difficult to define, such as vitality, fertility, health, resistance, etc. The quality of the product is thus a result of the quality of the entire production system. The OA interpretation of quality leads to a
wider definition, where new dimensions and aspects are involved (Dlouhý, 1990; L.-Bartošová, 1995):

- Sensory quality – e.g. size, shape, taste, colour, appearance
- Technological quality – suitability for various food processing technologies, storage, transport
- Nutritional quality – e.g. desirable compounds, proteins, vitamins, essential amino acids
- Hygiene quality – contamination of food by non-natural substances, pesticide residues
- Social-psychological dimension – e.g. working conditions, trust of consumers, welfare of animals,
- Environmental dimension – e.g. effects on the environment, energy input, processing technologies
- Political dimension – e.g. import from developing countries, world prices, hunger

In OA, emphasis is placed not only on food quality in a narrow sense (directly measured by scientific methods), but also on aspects such as the links between the agricultural system and environment, agricultural system and product, and its influence on consumer health and welfare.

So far, only conventional chemical analyses of food quality have been reviewed. The potential deficiency of analyses that only consider food composition in describing food quality has been recognised by various scientists. The development of holistic methods can lead to better characterisation of product quality, while its dynamic aspects can be revealed in the behaviour and the effect of the product on other organisms. Several holistic/alternative methods of assessing food quality have been proposed, such as:

- Picture-developing methods, e.g. cupric crystallisation method according to Pfeiffer; capillary dynamolysis method according to Wala; circular chromatographic method according to Pfeiffer (Balzer-Graf, 1987; Pfeiffer, 1984; Balzer-Graf and Balzer, 1991).
- Food preference tests (Phochberger & Velimirov, 1992).
- Feeding experiments (Plochberger, 1989).
- Low level illuminescence (Popp, 1988).
- Self-decomposition tests, storage quality and others.

Promising results have been obtained with food preference tests that differentiate product quality on the basis of the instinctive feeding behaviour of the test animals. Animals were able to distinguish between the two foodstuffs and preferred the biologically cultivated option. Feeding experiments with animals have revealed positive effects on parameters such as fertility, susceptibility to infections, feed conversion, perinatal mortality, liveweight gain, egg weight, yolk fraction, litter weight and others.

With picture-developing methods attempts are made to visualise the vitality of foodstuffs and assess the physiological state of plant substances according to the pattern of crystallisation. Mäder et al. (1993) suggested that picture-developing methods should be standardised for a large number of crops and varieties in order to identify products from various cultivation systems.

In response to the greatly increased market share of organic food, there is an increasing interest in investigating whether there are any differences in the effects of organic and conventional food on health. There are ample examples that the methods used for food production make a difference for food composition or other quality aspects, and that these differences are large enough to make a difference to consumer health (Brandt and Molgaard, 2006).

Rembialkowska (2004) summarised the studies conducted in several countries regarding organic food quality. Positive attributes of organic plant and animal products compared with conventional include:

- Organic crops contain fewer nitrates, nitrites, pesticide residues; lower total protein content.
• More dry matter, vitamin C content, B-group vitamins, essential amino-acids, total sugars, plant secondary metabolites (phytochemicals).
• Higher content of some minerals (iron, magnesium, phosphorus, selenium, calcium, zinc and others).
• Better sensory quality, e.g. smell and taste, fruits sweeter and more compact because of higher dry matter content.
• Vegetables, potatoes, fruits have better storage quality during winter, lower mass losses caused by transpiration, decay and decomposition processes.
• Farm animals have fewer metabolic diseases, e.g. ketosis, lipidosis, mastitis, milk fever.
• Milk and meat have different lipid composition, with more unsaturated and conjugated fatty acids, more vitamin E.
• Animals have better health and fertility parameters, e.g. lower incidence of prenatal mortality, higher birth weight, better immunity to disease.
• Environmental contamination (heavy metals, PCB, dioxins, aromatic hydrocarbons) can be similar, because the impact of industrial, transport and communal sources is equal for organic and conventional farms located in the same area.

The organic preference for outdoor rearing, using manure as fertiliser and on-farm slaughtering often raises concerns about the potential risks of contamination by a range of zoonotic bacteria, parasites and viruses. Surveys have not found consistently higher levels of zoonotic disease in organic animals, which means that there are other factors in OA that protect animals against disease as efficiently as the use of medication and biosecurity. Possible explanations are that:

• A diet containing a variety of fresh herbs can support the immune system of animals.
• Early exposure to a variety of micro-organisms may improve immunity.
• A diet containing roughage inhibits the proliferation of pathogens in the gut of ruminants.
• Selection of resistant breeds, intensive monitoring for early signs of disease, and others.

Mycotoxins are toxic compounds produced by the secondary metabolism of toxic fungi in the Aspergillus, Penicillium and Fusarium genera occurring in foodstuffs and food commodities. The impact on human health includes carcinogenic and immunosuppressive activity. It has been suggested that organic food may be more susceptible to contamination by mycotoxins than conventional, because no fungicides are permitted (Rembialkowska, 2004). However, recent studies and reviews report 50% lower frequency of toxic levels of mycotoxins in organic food across a large range of climates (Benbrook, 2005).

Greater availability of nitrogen in conventional systems reduces the plant’s ability to fight against pathogens. If plants grow relatively slowly, they build up their chemical defences to a level that prevents most diseases and pests. However, if a plant is allowed to grow unusually fast by providing it with an abundance of nutrients, the accumulation of defence compounds (plant secondary metabolites) is reduced (Stamp, 2003, cit. Brandt and Molgaard, 2006).

There are many indications that secondary plant metabolites are responsible for beneficial effects of vegetables and fruits. Many scientists believe that the antioxidant effects of phenolics, carotenoids and related compounds are responsible for health benefits, but this hypothesis has not been proven. This indicates that the documented benefits of vegetables and fruits probably result from the properties of plant secondary metabolites other than their antioxidant capacity. The levels of plant secondary metabolites/plant toxicants are more strongly and systematically determined by the production system than the other factors on the list (Brandt and Molgaard, 2006).

Definitive benefits of organic foods on human health have not been confirmed, but several studies list important conclusions:

• It is possible to detect health impacts that are definitely due to the production methods.
• All of the five markers of health (accumulation of adipose tissue, content of IgA, protein oxidation, sleep, lymphocyte proliferative capacity) indicated as relevant for this purpose have not been tested in earlier studies (Brandt and Molgaard, 2006).
References


Chapter 37


References


