Organic Crop Production – Ambitions and Limitations

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Editors

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Preface

Organic agriculture is being promoted against a background of intensive discussions about production methods, food and feed quality and renewable resources, with the overall aim of long-term sustainability. Organic agriculture is a subject that triggers many different responses in people. Some are convinced that it is the way forward, while others question its benefits and the wisdom of its large-scale implementation. Even among the scientific community, different views have developed over recent decades.

Organic agriculture is promoted in a number of popular and scientific books and is often described as being superior, the solution to common agricultural problems and a means of producing better food. Organic agriculture is often viewed as being environmentally sound and superior to conventional agriculture through the exclusion of synthetic fertilisers and pesticides. As a result, any questioning of organic practices is unpopular and criticism is often interpreted as impeding the development of sustainable systems. In addition, scientifically-based information contradicting the claims made for organic agriculture can be difficult to communicate and can be regarded as a step backwards and against political mainstream opinion.

The topic was discussed at a Symposium at the 18th World Congress of Soil Science in Philadelphia in 2006, where benefits and problems relating to organic crop production were presented. Some of the key findings from that symposium are presented in this book, together with other central aspects of organic crop production. The aim of this book is to provide the readers with a clear, scientifically-based overview of a number of relevant subjects relating to organic crop production so that they can form a balanced picture of this food production approach.

We are very thankful to all the contributing authors for providing their in-depth views in the various chapters. We would also like to acknowledge all the anonymous reviewers who helped to improve the quality of the different chapters and Dr Mary McAfee for excellent linguistic advice. Finally, we would like to thank Springer for publishing the book, which we hope will provide a better understanding of true long-term sustainability in future crop production.

Uppsala, Sweden — Holger Kirchmann
July 2008 — Lars Bergström

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Chapter 1
Widespread Opinions About Organic Agriculture – Are They Supported by Scientific Evidence?

Lars Bergström, Holger Kirchmann and Gudni Thorvaldsson

Abstract Organic agriculture ostensibly offers a concept of sustainable practices based on environmental responsibility. It is widely believed that organic principles based on natural means and methods are environmentally sound and thus superior to systems based on artificial inputs. This overview summarises the main results on organic agriculture and highlights relevant facts in order to provide scientific information about the potential and limitations of organic agriculture. The topics of food security and safety, environmental quality, system sustainability and energy consumption are addressed. Some of the main conclusions are that organic agriculture has consistently lower yields than conventional production and is thereby a less efficient method of land use; that environmental problems caused by processes such as nutrient leaching are not reduced by conversion to organic crop production; and that soil fertility status and microbial biodiversity are not improved a priori by organic cropping. The energy investment for production of artificial N fertilisers results in a five- to ten-fold energy return in the form of biomass and this highly positive energy balance needs to be fully acknowledged. The future challenge of developing sustainable forms of agriculture to provide sufficient food for a growing world population with minimal environmental disturbance deserves our wholehearted and unbiased attention.

Keywords Carbon sequestration · Energy issues · Food production · Natural toxins · Nutrient leaching · Pesticide residues · Soil fertility

1.1 Introduction

During the past two decades, organic agriculture has often been presented as being superior to conventional production in many respects. This has led to a widespread belief among the general public that organic crop production is better and in an ambition to satisfy this opinion, politicians and legislators have strongly promoted

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this type of agriculture. For example, in Sweden the political goal has been to increase the area used for organic production to 20% of all arable soils. In addition, organically produced food should constitute 25% of the food used in state schools, hospitals and residential homes for the elderly. The main driving forces have been to generate benefits for the environment and to improve food quality. More recently, impacts on energy consumption, climate change and long-term sustainability have also been in focus.

Buying organically produced food, and thereby supporting all these benefits, creates a feelgood factor for consumers of organically produced food. For many people, organically produced food is always better even if it requires long-distance transport. However, the question is whether these common opinions circulating in society are supported by the scientific evidence.

The principles of organic practices derive from natural philosophies and not natural sciences. A deeper scientifically-based analysis of long-term organic field experiments – which is the main focus of this book – gives a different picture of the benefits generated. However, scientific comparisons of organic and conventional farming are unappealing to society since they provide evidence that man-made inventions, such as artificial fertilisers, often lead to production of crops in larger quantities and of good quality. This is in contrast to the common belief that we should always follow rules determined by nature.

In this introductory chapter, we present some common opinions about organic agriculture and discuss them briefly in the context of the results presented in the other chapters of this book. The following topics relating to organic agriculture are addressed:

- Food security and safety
- Environmental quality
- System sustainability
- Energy consumption.

1.2 Widespread Opinions Versus Scientific Evidence

1.2.1 Food Issues

Since the introduction of organic agriculture in the 1920s, food quality issues have been a particular focus. One of the founders of organic agriculture, Rudolf Steiner (1924), believed that artificial fertilisers would degenerate agricultural produce to such an extent that they would not be fit for human consumption by the end of the 20th century. Concern about levels of yield only entered the agenda much later.

1.2.1.1 Food Security

A general opinion in society is that conversion to organic crop production is followed by little or no yield reduction and that organic crop production is therefore *capable of feeding the world. In fact, some researchers claim that the solution for famine in Africa is large-scale organic agriculture* (Pretty et al., 2003).

Our conclusion is that organic agriculture cannot feed the world, because there is substantial scientific evidence that crop yields are considerably lower in organic systems. The long-term yield reduction could be as much as 40–50% compared with the corresponding conventional crops. Therefore, to obtain equivalent yields in organic systems, significantly more land would be needed for agricultural crops. However, according to recent assessments, such land is not available in the world. It is worthwhile mentioning that most good agricultural soils are already under cultivation and that additional crop production would have to use soils of low fertility or with a high risk of erosion or other degradation processes when cropped.

A 40% yield reduction in developed countries would require 67% more agricultural land to produce the same amount of crops (Chapter 3; Kirchmann et al., 2008a). This does not take into account future population growth, which will primarily occur in developing countries where the situation regarding crop production is already critical in many cases. In a world perspective, population growth is expected to be 50% within the next couple of decades. Crop production in developing countries is largely limited by the lack of artificial fertilisers, water and crop protection strategies. In those systems, crop yields can only be increased by providing such inputs and methods. In this context, it is worth mentioning that a key conclusion presented at the FAO meeting in Rome 2008 by the Secretary General of the UN was that one of the most important ways out of starvation in developing countries is increased use of artificial fertilisers. Chapter 3 (Kirchmann et al., 2008a) presents several arguments concerning the need for increasing yields in developing countries.

Irrespective of the different situations prevailing in developed and developing countries, there is no doubt that when considering the population growth aspect and applying only organic production methods, land demand for crop production would increase considerably.

1.2.1.2 Food Safety

The current opinion is that organic food is healthier since it does not contain toxins and is free from artificial pesticide residues.

The use of pesticides is strictly regulated in developed countries, including pesticide residue levels in food. In fact, almost all pesticides with documented negative side-effects have been taken off the market and cannot be used for agricultural crops. Nevertheless, the low pesticide residue levels that are still detectable in food must be evaluated from a toxicological and potential health risk perspective, which must include appropriate safety margins.

The risks involved with pesticide levels in food products must be put into perspective and related to the risks of being exposed to other toxic substances in food products. Crop products generally contain natural toxins, compounds that in many cases are more toxic than pesticides. As shown in Chapter 11 (Winter, 2008), there is still insufficient conclusive scientific evidence that any form of production can reduce the levels of natural toxins. Nevertheless, it is important to stress that the levels of natural toxins are commonly several orders of magnitude higher in food products than pesticide residues. It is also worth mentioning that exposure, especially over the long-term, to low levels of toxic substances is difficult to evaluate. For example, lifetime exposure to pesticide residues by drinking 2 litres per day of water with levels at the EU drinking water criterion ($0.1\ \mu g\ L^{-1}$) would be less than the exposure to chemicals through ingesting one of most common medical pills. This stresses the importance of proper assessment when evaluating health risks. Furthermore, a recent scientific opinion is that substances that are toxic at higher concentrations can in fact be good for human health at low levels, since they trigger the immune system. This phenomenon is called the hormesis effect (Trewavas and Stewart, 2003).

Pesticides are used to protect the crop from infestation by fungi, insects and other pests in a similar way to humans taking medicine when they have a health problem. The crop itself also produces substances that prevent plant tissues from pest damage. Several such examples that are of possible concern to human health are mentioned in Chapter 11 (Winter, 2008). When a crop is not protected from diseases by appropriate pesticides, there is risk of the production of natural plant defence compounds (secondary metabolites) being increased.

It is noteworthy that some pesticides such as pyrethroids and copper sulphate are used in organic farming although they carry documented environmental and health risks (Felsot and Racke, 2006).

1.2.2 Environmental Issues

As pointed out in Chapter 2 (Kirchmann et al., 2008b), environmental concern was not addressed by the founders of organic agriculture. It was first during the 1960s that organic methods were presented as a solution to the emerging environmental problems caused by agriculture. For example, in the book ‘Silent Spring’ Carson (1962) provided evidence that the pesticides in use at that time were having a detrimental effect on nature. Since then, environmental issues have been used frequently as the main argument for the superiority of organic agriculture. Issues relating to climatic change and biodiversity are currently also on the list.

1.2.2.1 Nutrient Leaching

A common opinion is that widespread use of artificial nitrogen fertilisers causes water quality disturbance such as eutrophication of lakes and coastal waters. By exclusively using organic manures in organic agriculture, this problem is automatically solved since organic manures are adapted to nature and cause less leaching of nutrients.

The use of artificial fertilisers dramatically intensified during the 1950s and 1960s and resulted in large yield increases in agricultural crops. However, increasing levels of nitrate were simultaneously observed in surface waters and groundwaters and it was logical to couple this to the intensive use of fertilisers. In many cases, fertiliser use during these early days was excessive since fertilisers were relatively inexpensive and much more nutrients were applied than the crop needed.

From the mid-1980s onwards, leaching of nitrogen has levelled out and in many cases decreased due to better fertiliser management and introduction of a number of efficient countermeasures such as no autumn application of nitrogen fertilisers, inclusion of cover crops and reduced tillage practices. If fertilisers are applied at rates matching crop demand, significant leaching of nitrogen normally does not occur (Bergström and Brink, 1986; Lord and Mitchell, 1998).

One of the main reasons cited by advocates of organic farming for the superiority of organic manures is that nutrients are organically bound and delivered in synchrony with crop demand, thus reducing leaching losses. However, as described in Chapter 7 (Bergström et al., 2008), a number of long-term field experiments have shown that leaching losses of N are in fact increased when solely organic manures are used. The reason is that crop demand and delivery of nutrients from organic manures are not synchronised over a whole year (Chapter 5; Kirchmann et al., 2008c). A large amount of nitrogen is released after the cropping season and this nitrogen is very exposed to leaching in cold and humid regions.

Far less conclusive results have been published regarding leaching losses of phosphorus from organic and conventional cropping systems. However, the use of green manure and cover crops has the potential to increase P losses due to release of soluble phosphorus from the biomass during autumn and winter (Miller et al., 1994).

1.2.2.2 Carbon Sequestration

A widespread opinion is that organic farming sequesters more carbon in soil and can thereby reduce CO_2 levels in the atmosphere.

As stressed in Chapter 3 (Kirchmann et al., 2008a) and pointed out above, organic yields are significantly lower than conventional. Consequently, less soil organic matter can be formed from the biomass produced, which means that less carbon is sequestered, as outlined in Chapter 8 (Andrén et al., 2008). Furthermore, lower yields in organic production mean less water uptake by crops and thereby higher moisture content in soil, which speeds up decomposition of soil organic matter. An additional factor speeding up decomposition of soil organic matter is the intensive mechanical weed control that commonly occurs in organic crop production. In fact, if for example all cereals in Sweden would be grown organically, this would cause a substantial loss of soil carbon. The associated CO_2 emission will be equivalent to the yearly amount of CO_2 emitted by 675,000 average Swedish cars.

1.2.2.3 Pesticides

A common opinion is that pesticides kill useful organisms and pollute the environment.

Even though the occurrence of pesticide residues in the environment is not specifically discussed in this book, there is certainly a clear difference between organic and conventional agriculture, which is probably the cause of most concern among people. When pesticides are used, they are likely to be found at low levels in surface waters, groundwater and other environmental compartments, something that has to be taken seriously. However, analytical techniques have improved dramatically during the past couple of decades and today residues can be detected at parts per trillion (ppt) levels. This stresses the importance of conducting relevant risk assessments with appropriate safety margins.

In a similar way to those in food products, pesticide residue levels in the environment are controlled by various regulations. Within the European Union (EU), some are common for all EU countries, whereas others are specific for individual countries. The overall goal is to avoid unacceptable environmental disturbances. However, in a similar way as regards pesticide residues in food, the question is what is an acceptable level. Furthermore, the risks arising from pesticide residues in the environment must be related to possible disturbances by other chemical substances, which are also regulated.

To guarantee minimal negative side-effects in natural ecosystems, pesticides, whether natural or artificial, should have no or low toxicity except towards the target organism. There appears to be great potential to develop pesticides that are effective, reliable and have a low environmental risk. In addition, new and more precise application techniques can reduce the dose substantially. The trend today is to develop pesticides that inhibit specific process mechanisms in the target organism, such as enzyme reactions in photosynthesis, rendering them effective with a minimum of environmental side-effects. This development will likely continue and make the use of pesticides less controversial in the future.

1.2.3 Sustainability Issues

Achieving sustainable agricultural production is one of the major goals in organic agriculture. This is assumed to be possible through use of a set of pre-determined rules and methods mimicking nature, as discussed in Chapter 2 (Kirchmann et al., 2008b). According to these rules, sustainable agricultural production is achieved by maintaining/improving soil fertility, recycling of nutrients and imitating natural processes. However, irrespective of system, agricultural crop production is mainly a man-made single-crop cultivation with little resemblance to natural ecosystems.

There are other forms of agriculture for which sustainability is a key goal, commonly grouped under the term 'sustainable agriculture' (Bergström et al., 2005; Bergström and Goulding, 2005; Kirchmann and Thorvaldsson, 2000). However, these forms of agriculture have established goals to reach long-term sustainability without postulating rules and methods. In this type of agriculture, artificial fertilisers and pesticides are applied when needed.

Two major conditions determine the sustainability of farming systems, namely that plant nutrients removed or lost must be replaced or returned to the system to avoid depletion and that plant availability of nutrients in soil must be maintained (Chapter 5; Kirchmann et al., 2008c).

1.2.3.1 Soil Fertility and Nutrient Use

A widespread opinion is that yields increase over time if organic management practices are used. In contrast, artificial fertilisers, which are seen as unnatural and *unnecessary chemicals, reduce yields over the long-term. A common opinion is that natural cycling of nutrients in organic agriculture is a guarantee for maintenance of good soil fertility.*

Any agricultural system requires nutrient support and crop protection strategies to survive and maintain high crop yields. In conventional systems this is achieved by recycling manures and adding artificial fertilisers and pesticides, whereas in organic agriculture manures, feedstuffs, bedding materials, food wastes and untreated minerals are applied to compensate for export of nutrients through various products and losses (Chapter 5; Kirchmann et al., 2008c). Although the ‘law of nutrient replacement’ can also be followed in organic agriculture, addition of nutrients in the form of less soluble materials than nutrients present in soil results in lower plant availability (Chapter 4; Goulding et al., 2008), and in less efficient utilization and lower yields (Chapter 3; Kirchmann et al., 2008b). Regarding the argument that yields are reduced by the use of artificial fertilisers, one need only look at the historical trends in crop yield. From the time when artificial fertilisers were first introduced there has been a steady increase in yields, which to a large extent is attributed to use of the fertilisers.

A complicating issue when comparing organic and conventional management is that field experiments are often placed on fertile soils, for example on a soil with a high organic matter content such as newly converted grassland or soils previously enriched with P and K through decades of inorganic fertiliser additions (Chapter 4; Goulding et al., 2008). This results in smaller relative yield differences between organic and conventional systems due to the fact that more nutrients are released at such sites than at sites with normal soil fertility. Over the long-term, this results in a depletion of nutrients and/or soil organic matter. Few, if any, organic cropping experiments have been carried out on arable soils that have never received any artificial fertilisers. The general belief that soil organic matter increases in organically managed soils is not valid for most arable systems (Chapters 6 and 8; Korsaeth and Eltun, 2008; Andrén et al., 2008). Another complicating issue is that crop rotations are often designed to favour environmental status of organic production. For example, the arable crop rotation in the Apelsvoll experiment (Chapter 6; Korsaeth and Eltun, 2008) had insown clover/grass during two years, which most likely had a decreasing effect on N leaching whereas no clover/grass was grown in the conventional rotation. Furthermore, potatoes were grown more frequently in the conventional rotation which presumably increased N leaching. Such differences will also favour the soil fertility situation in the organic rotation.

1.2.3.2 Life in Soil

A common principle in organic production is to fertilise the soil but not to feed the crop directly. The underlying concept is that life in soil is promoted by organic farming practices, which are the key to sustainable crop production. One example is the increased colonisation of roots with mycorrhizas, which is considered beneficial for nutrient uptake by crops. Artificial fertilisers are assumed to have a negative impact on life in soil.

A rich microflora in soil is positive primarily due to its potential to release nutrients from soil constituents and added organic material. Life in soil, i.e. biological activity and the occurrence of microbes, is increased by the addition of any nutrient-rich organic material. A benefit from high abundance of microbes in soil and their degradation of organic material is stabilisation of the soil structure.

There are indications that organically managed soils can develop a mycorrhizal community with an increased capacity for P uptake by plants (Chapter 10; Ryan and Tibbett, 2008). However, mycorrhizas cannot substitute for fertiliser inputs as phosphorus taken up by the fungi primarily originate from the finite pool of soil phosphorus and its removal in farm products must be matched by inputs of off-farm sources. Indeed, high mycorrhizal colonisation may be considered an indicator of low plant-available P and in fact under certain conditions may reduce plant growth due to consumption of photosynthate from the host plant. Therefore, enhanced mycorrhizal activity does not compensate for low plant availability of P.

It is important to stress that organic manures are added in conventional systems too and that the beneficial effects are also present in such systems. Furthermore, there is no negative effect on life in soil of adding artificial fertilisers at normal rates. As stated above, organically bound nutrients are released in poor synchrony with crop demand and thereby used less efficiently than artificial fertilisers.

1.2.4 Energy Issues

1.2.4.1 Energy Requirement in the Perspective of Fertiliser Production and Land Demand

The general opinion is that production of artificial fertilisers is energy-demanding and means careless use of valuable resources. In organic systems, no energy for production of artificial fertilisers is needed as nitrogen can be supplied through nitrogen fixing crops. It is also common among organic advocates to look at energy consumption per unit food produced, which favours organic crop production.

The Haber-Bosch process, which is used in the fertiliser industry to convert atmospheric nitrogen into ammonia, requires considerable amounts of energy. A rule of thumb is that one litre of oil is consumed for each kilogram of nitrogen produced. This means that about 100 litres of oil are used annually per hectare of cultivated soil for N fertiliser production in order to produce about six tons of cereals. However, the net result is that for agricultural crops, between 5 and 10 times more energy in form of carbohydrates is produced than is consumed in fertiliser manufacture. In other words, with the help of artificial fertilisers, a very positive energy balance is obtained (Chapter 9; Bertilsson et al., 2008). Therefore, expressing energy requirement per unit yield is misleading as the total yield (food per energy input) and the total areal demand for crop production are not considered. Disregarding such conditions would lead to the conclusion that the most energy-efficient system would actually be a manual cultivation system without tractors or horses.

In a global perspective, there is a certain (and increasing) food demand and this food can either be produced as efficiently as possible on the available arable land or can be produced by considerably increasing the area for food production. In Chapter 9 (Bertilsson et al., 2008), the authors point out that the surplus land released due to higher productivity in conventional crop production compared with organic can be used for bio-fuel production and thereby replace fossil fuel energy. Instead of saving energy through low-input organic farming, modern conventional agriculture increases energy productivity by land being made available for bio-energy. Conventional methods thereby allow 2–4 times more food/energy to be produced on the total available area.

It is also important to note that legume N is not a source without a cost. As pointed out in Chapter 3 (Kirchmann et al., 2008a), growth of green manure legumes for N supply is often only possible by not using the land for saleable food crops, which must be considered as a reduction factor in any food production system.

1.3 Incorporating Scientific Evidence into Decisions Made in Society

As shown above, there are a number of widespread public opinions about organic agriculture that are not supported by scientific evidence. This is a major problem since scientific views have traditionally been a major and successful driving force for development in society in terms of technical improvements, medical treatments, democratic structures and agriculture. It is worrying that something so fundamental for life and survival as food production has become an issue highly influenced by a philosophical view on nature (Chapter 2; Kirchmann et al., 2008b), without considering long-term sustainability and sufficient food supply.

In other disciplines such as medicine, all treatments and methods have to be evidence-based to prove that they are safe and efficient. This is a widely accepted basis and has long been shown to be the best way of obtaining good results. This way of thinking should also be fully applied in food production. We need to produce sufficient, nutritious and wholesome food with as little environmental disturbance as possible. This goal can only be reached by modern, scientifically-based agriculture, not excluding certain inputs and methods due to philosophically-based views. Problems caused by agriculture are inevitable but solutions can be found through thorough analysis, wise planning and innovative thinking not biased by predetermined organic methods.

Overlooking the scientific evidence in decision-making has implications for a democratic society. Science itself is not democratic, but it can only flourish and survive in an open democratic society. Practices based on the ‘Back-to-Nature’ movement undermine the development of food production and ultimately the survival of society.

It is quite obvious that scientific results need to be communicated to politicians and legislators, but the question is how this can be achieved. Political views are a reflection of public opinion and if politicians are to be re-elected they must satisfy the wishes of the electorate. As indicated in this chapter, there is strong public opinion in favour of organic food production. To attract political attention, the general public must first be educated about sustainable food production without dogmatic limitations. Success in this will eventually change the political views in favour of the idea that a science-based approach typically solves more problems than it creates. In terms of food production, the bottom line is whether further yield declines and increased starvation must be tolerated before political decisions are based on scientific results instead of nature-based opinions.

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Chapter 2
Fundamentals of Organic Agriculture – Past and Present

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Abstract Organic agriculture can be traced back to the early 20th century, initiated by the Austrian spiritual philosopher Rudolf Steiner. It was later diversified by a number of key people, and more recent versions are guided by principles issued by the International Federation of Organic Agricultural Movements (IFOAM), founded in 1972. Organic practices were built upon the life philosophies and convictions of the founders regarding how to perceive nature. Today, those original views and ideas are considered as history. However, to understand the principles and opinions of modern organic agriculture, such as the exclusion of water-soluble inorganic fertilisers, we analysed the original ideas and arguments of the founders, who shared the common principle of relying on natural processes and methods, seen as a prerequisite for human health. For example, the British agriculturalist Sir Albert Howard, who together with Lady Eve Balfour founded the British Soil Association, claimed that healthy soils are the basis for human health on earth. In their view, healthy soils could only be obtained if the organic matter content was increased or at least maintained. Later, the German physician and microbiologist Hans-Peter Rusch together with the Swiss biologists Hans and Maria Müller, focused on applying natural principles in agriculture, driven by the conviction that nature is our master and always superior. Even though these early ideas have been abandoned or modified in modern organic agriculture, the principle of the founders regarding exclusion of synthetic compounds (fertilisers and pesticides) is still the main driver for choosing crops and pest control methods.

Keywords Ethics · Founders · History · Life philosophy · Nature philosophy · Theories · E. Balfour · A. Howard · H.-P. Rusch · R. Steiner

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2.1 Introduction

In this chapter, the thinking and arguments of the founders of organic agriculture are analysed. The origins and characteristics of the different schools of organic agriculture are described and the theories and statements of the founders are discussed and evaluated. Furthermore, to get an in-depth picture of the principles of organic agriculture, it is useful to be familiar with the philosophies of life in which the founders were interested, as these influenced their perception of nature and their views on human activities. Only a few scientifically-based analyses of organic agriculture theories have been performed (Jansson, 1948; Kirchmann, 1994).

We want to emphasise that we acknowledge the sincerity and well-minded intentions of the founders and their followers. Many organic farmers are highly skilled and successful experts. Our analysis is solely focused on the roots of organic agriculture and our perspective is limited to methods developed in Europe. Asian forms of organic agriculture such as natural farming according to Buddhism by the Japanese Masanobu Fukuoka (1978, 1989, 1991) or Zen macrobiotic farming based on the diet of George Oshawa (Oshawa and Dufty, 2002) are not considered in this overview.

2.2 Brief History of the Development of Organic Agriculture

The development of organic agriculture dates back to the beginning of the 20th century summarised in Table 2.1. It started as a reaction against industrialization of agriculture and was a response to concerns over the use of mineral fertilisers and pesticides (Merrill, 1983; Conford, 2001). Critics pointed out the unnaturalness of these compounds and regarded their use as a wrong way to produce food. The message was that organic practices have been around for a several thousand years and that maintenance of these practices is a reliable way to achieve healthy food

Table 2.1 Brief overview of the development of European organic agriculture

Movements	Focus
Early 1900s–1960: Reform movement	
1924 Introduction of bio-dynamic farming	Spiritual food production
1946 Foundation of the Soil Association	Health food production
1960–1990: Environmental movement	
1962 Publication of "Silent Spring" by Carson	Against pesticides and pro-environment
1968 Introduction of bio-organic farming	Holistic food production
1972 Foundation of International Federation of Organic Agriculture Movements (IFOAM)	Standardisation, lobbying for world-wide adaption
1980s Definition as "eco-agriculture"	Marketing environmental superiority
Since 1990: Political movement	
Governmental support	Promotion, subsidies, funding of research, etc.

products. One of the forerunners of organic agriculture was the “life reform movement” (Lebensreform Bewegung) in Germany in the 1920s, which acted against urbanisation and industrialisation, idealising vegetarian food, self-sufficiency, natural medicine, allotment gardens, physical outdoor work and all kinds of nature conservation (Vogt, 2001). In 1927/1928, the first “organic” organisation – Arbeitsgemeinschaft Natürlicher Landbau und Siedlung (Community of Natural Farming and Settlement) – was founded with the focus on fruit and vegetable production without artificial fertilisers and pesticides.

The first distinct form of organic agriculture was introduced in 1924 by the Austrian Rudolf Steiner, forming the basis for bio-dynamic farming (Steiner, 1924). Steiner gave a series of lectures entitled “Geisteswissenschaftliche Grundlagen zum Gedeihen der Landwirtschaft” (Spiritual foundations for the renewal of agriculture), with instructions on how to produce organic food supplying spiritual forces to mankind.

The 1940s brought the next wave of organic pioneers, with Lady Eve Balfour (widow of the British Prime Minister Arthur James Balfour) and Sir Albert Howard as prominent figures in the United Kingdom (Howard, 1940, 1947). In 1943, Lady Balfour published a highly influential book called “The Living Soil” in which she pointed out the importance of a healthy soil and the nutritional superiority of organically grown food. In 1946, Balfour and Howard founded the British Soil Association.

In the 1950s, the Swiss couple Hans and Maria Müller developed biological-organic farming methods, encouraged by the bio-dynamic agriculture of Steiner. In 1968, the German physician Hans-Peter Rusch provided the basis for biological organic agriculture in his book entitled “Bodenfruchtbarkeit” (Soil fertility), stressing the recognition of biological wholeness and a holistic view on food production and nature (Rusch, 1978).

In 1972, during an organic agriculture congress in Versailles (France), five organic organisations founded a global organisation called the International Federation of Organic Agriculture Movements (IFOAM), which since then has promoted its worldwide adoption, set standards, drawn up certification procedures etc.

Although some environmental problems as a result of the industrialisation of societies had already been identified, the breakthrough in broad environmental consciousness in the 1960s enabled advocates of organic agriculture to advance their argumentation. Organic agriculture methods were now also presented as a solution to the environmental problems caused by modern agriculture. The book “Silent Spring” by Carson in 1962 was a keystone pointing out the detrimental effects of widespread pesticide use poisoning nature. Later, the “Club of Rome” book “Limits to Growth” by Meadows et al. (1972) focused on population growth and resource depletion, including the environmental consequences of modern agriculture. The exclusion of pesticides and the additional elimination of limited resources such as phosphates and fossil fuels for fertiliser production, respectively, were now used as arguments for the superiority of organic agriculture.

Water pollution by agriculture through nutrient leaching followed by algal blooms was observed during the 1970s (e.g. Ahl and Odén, 1972). Earlier emphasis by organic agriculture organisations on the better quality of organic food and the benefits of organic agriculture for soil (Koepf et al., 1976; Dloughý, 1981) was now complemented by reports pointing out the benefit of this type of agriculture for the environment (e.g. Koepf, 1973). In the early 1980s, eutrophication of lakes and rivers was intensively reported in Europe and nutrient leaching from agriculture was identified as being a main cause. Somewhat later, the advocates of organic agriculture used this opportunity to claim that organic agriculture would be able to reduce N leaching (Granstedt, 1990; Kristensen et al., (1995).

The period between 1980 and 1990 saw a great revival in organic agriculture, initiated by environmental problems caused by modern agricultural practices. Organic agriculture was attributed to be sustainable and environmentally friendly and was redefined as "ecological" agriculture or "eco-agriculture". The image of organic agriculture as a problem-solver attracted much larger groups of "green" supporters, who made a political case for public support.

Since 1990, "green" and other political parties have initiated a number of activities promoting organic agriculture, such as ear-marked research grants, creation of research foundations and funding of university departments of organic agriculture. Furthermore, subsidies for organic production, educational programmes and extension services for organic agriculture were established. In several countries in Europe, organic agriculture has grown in the past 20 years to be a significant sector within agricultural production, whereas in other countries it has remained at a relatively low level. In Austria, for example, 200 farms were managed according to organic principles in 1980 and 18,360 in 2001, the latter accounting for approximately 25% of Austrian arable land (Freyer et al., 2001). In Sweden, a political programme with the aim of increasing organic production to cover 20% of farmland and to encourage the consumption of organically grown food in schools, hospitals, residential care homes etc. has recently been proposed. Today, organic agriculture is a mainstream interest in Western societies, although it has been criticised for not taking into account contradictory evidence regarding some of its claims (Avery, 2000; Tinker, 2000; Trewavas, 2004; Taverne, 2005; Avery, 2006).

2.3 The Schools of Organic Agriculture

2.3.1 Biological Dynamic Agriculture (Rudolf Steiner)

The Austrian Dr Phil Rudolf Steiner (1861–1925), who taught mysticism and esoteric wisdom, created a spiritual system called anthroposophy, a variant of theosophy. He applied his teachings to a wide range of areas in society, e.g. arts and architecture, medicine, religion, pedagogics and also agriculture. Biological dynamic (biodynamic) agriculture builds upon Steiner's lectures during a one-week agricultural course in 1924 in Koberwitz (now Wroclaw), Poland (Steiner, 1924), when he taught a group of followers on considerations of spiritual matters in agriculture.

Steiner wanted to change agriculture and introduced new practices in accordance with his supernatural insights. He gave detailed instructions on non-visible matter, how it acts in soil, crops and animals and how to affect and control the "forces" related to such matter. The text of his lectures provides the core information for current biodynamic farming and can be seen as the basis for the first distinct form of organic agriculture.

Steiner was worried about food quality and the effect of inorganic fertilisers in decreasing crop quality. For example, he taught that agricultural products would degenerate so that they could not be used as food for humans by the end of the century ". . . .die Produkte so degeneriert sein werden, dass sie noch im Laufe dieses Jahrhunderts nicht mehr zur Nahrung der Menschen dienen können" (Steiner, 1924 p. 12). Furthermore, he stated that nobody could know whether mineral fertilisers would lead to a significant degeneration in the quality of agricultural products "Es weiss zum Beispiel kein Mensch heute, dass alle die mineralischen Dungarten gerade diejeningen sind, die zu dieser Degenerierung, von der ich gesprochen habe, zu diesem Schlechterwerden der landwirtschaftlichen Produkte das Wesentliche beitragen" (ibid. p. 20). He claimed that plants are stimulated by wateriness through inorganic fertilisers; they are not stimulated by the living soil "Daher werden Ihnen Pflanzen, welche unter dem Einfluss irgendwelchen mineralischen Düngern stehen, ein solches Wachstum zeigen, das verrät, wie es nur unterstützt wird von angeregter Wässrigkeit, nicht von lebendiger Erdigkeit" (ibid. p. 94). Furthermore, Steiner pointed out that this is a general law "Denn jeder mineralische Dünger bewirkt, dass nach einiger Zeit dasjeninge, was auf den Feldern erzeugt wird, die mit ihm gedüngt werden, an Nährwert verlieren. Das ist ein ganz allgemeines Gesetz" (ibid. p. 176).

However, Steiner did not teach common crop quality criteria such as mineral, protein, carbohydrate or vitamin content or taste. Instead, he instructed on how to manufacture eight different compounds consisting of mixtures of minerals, wild plants and animal organs. Two compounds are aimed at affecting supernatural crop qualities enabling the transfer of "forces" into soil (humus compound) and crops (silica compound). Six compounds are used for the preparation of animal manure (compost compounds) also transferring "forces" via manure into soils and crops. For example, cow manure and powered silica should be placed into cow horns (humus and silica compound) to accumulate "forces". Thereafter, these materials must be highly diluted with water through both clockwise and counter-clockwise spinning and then sprayed on crops and soil. The "forces" accumulated in the cow horns will thereby enable a balanced exchange of terrestrial and cosmic forces in fields. Steiner also stated that sowing or planting of crops should be carried out according to astrological principles.

Steiner's supernatural views on "radiation" and flows of "forces" were not derived from natural science but gained from views and inspiration received during mental exercises. The "forces" Steiner instructed on are unknown to science. However, this is not a proof of their non-existence. On the other hand, there are other strong indications that Steiner's scientific knowledge was limited, as exemplified by the following quotes. Steiner talked about a secret chemistry in organic processes.

For example, he claimed that potassium is transformed into nitrogen and even lime "Ich habe fortwährend davon gesprochen, . . . weil nämlich im organischen Process eine geheime Allchemie liegt, die zum Beispiel das Kali, wenn es nur in der richtigen Weise drin arbeitet, wirklich in Stickstoff umsetzt und sogar den Kalk, wenn der richtig arbeitet, wirklich in Stickstoff umsetzt" (Steiner, 1924 p. 136). According to current scientific knowledge, the energy in biological systems is too low to drive nuclear reactions and transmute elements. In addition, the following quote also reveals Steiner's poor knowledge in the field of chemistry, since he believed that silica is transformed into another element of the utmost importance in organisms "Das Silizium wiederum wird umgewandelt im Organismus in einen Stoff, der von ausserordentlicher Wichtigkeit ist, der gegenwärtig unter den chemischen Elementen überhaupt nicht aufgezählt wird" (ibid. p. 137). Even in 1924, it was common scientific knowledge that there is no element transmutation in biological systems.

The following quotes expose Steiner's lack of understanding of science. He lectured on the effect of wild plants that were used for the preparation of his biodynamic compounds. The stinging nettle (*Urtica dioica*) compound makes the soil reasonable "Es ist wirklich etwas wie eine Durchvernünftigung des Bodens, was man durch diesen Zusatz von Urtica dioica wird bewirken können" (ibid. p. 133). Dandelion (*Taraxacum vulgare*) is the intermediary between the homeopathically distributed silica in the cosmos and the silica really needed in the whole area "Der gelbe Löwenzahn, wo er in einer Gegend wächst, ist . . . . der Vermittler zwischen der im Kosmos fein homoöpathisch verteilten Kieselsäure und demjeningen, was als Kieselsäure eigentlich gebraucht wird über die ganze Gegend hin" (ibid. p. 137).

Steiner looked upon each farm as a closed entity and as a self-sustaining unit. He said that any import to the farm should be seen as a cure for a sick farm "Landwirtschaft . . . kann als eine wirklich geschlossene Individualität aufgefasst werden. Was in die Landwirtschaft hereingebracht wird an Düngemitteln und ählichem von auswärts, das müsste in einer ideal gestalteten Landwirtschaft angesehen werden schon als ein Heilmittel für eine erkrankte Landwirtschaft" (ibid. p. 42). The idea of self-sustaining farms is attractive in many ways as it excludes long-distance transport of animal feedstuffs, purchase of fertilisers, import of animals etc. and only presupposes sale of food products. However, in reality this is difficult to achieve. It is well-known that sale of products from a farm means a significant export of nutrients through food products, leaching and other losses, which will result in nutrient depletion in soil over time. It is impossible to maintain soil fertility and high yields over time through an internal recirculation of manure only. On the other hand, Steiner prohibited the return of nutrients present in toilet wastes. A more thorough analysis of biodynamic agriculture has been published earlier (Kirchmann, 1994).

In summary, Steiner stated that behind visible nature there is a supernatural, spiritual world. According to him, organisms have spiritual bodies (e.g. physical, ethereal and astral) interacting with each other in interwoven flows either emitting or absorbing "forces". Spiritual energies are regarded to fill and pervade all things. The specific biodynamic compounds introduced by Steiner should supply soil and plants with "forces" in order to control the absorbance or emanation of "terrestrial