Health Benefits of Organic Food:

Effects of the Environment

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Edited by

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Preface

The last two decades have seen a marked increase in demand for organic produce and a substantial growth of this niche market. This is attributable to public concern regarding the impact of chemical herbicides, pesticides, fertilizers, growth-promoting agents and feed additives in plant and animal production on the integrity and safety of the products. In addition, public concern about the environment is likely to have played a part. Organic food is usually promoted as containing fewer contaminants, more nutrients and as being less likely to cause food poisoning as well as having a positive effect on the environment. Some of these attributes are difficult to quantify and there are also suggestions of potentially harmful consequences of organic production such as increased mycotoxin contamination in products from plants not treated with fungicides. These positions to some extent reflect the views of specific interest groups and need to be presented as part of a wider analysis. Moreover, although the ways in which organic food is produced is largely prescribed by the regulatory authorities, the impact that a wide range of environmental factors might have on any differences between organic and conventional food has not been examined to any extent.

This book is the result of a Workshop. The Workshop brought together a multidisciplinary group of experts from fields including nutrition, animal science, soil science, environmental microbiology, toxicology, consumer science and medicine. The objective of this Workshop was to address three key questions:

1. Are there quantifiable effects of organic rather than conventionally produced food on human health?
2. How might the environment impact on these possible health benefits?
3. How do the public perceive these benefits?

To address these questions, the Workshop examined such factors as the role of certain nutrients (e.g. nitrate and long-chain *n*-3 polyunsaturated fatty acids) in the prevention and promotion of chronic disease, the potential health benefits of bioactive compounds in plants (e.g. flavonoids), the prevalence of food-borne pesticides and pathogens and how both local and global environmental factors may affect any differences between organic and conventionally produced foods.

Clearly there is much more to learn but we think that this book sheds new and often very revealing light on this complex and sometimes contentious subject.

University of Reading, Reading, UK
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1 Organic Farming and Food Systems: Definitions and Key Characteristics

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Introduction

At the point of sale, apart from its labelling, organic food is largely indistinguishable from other foods in many respects. Certification is therefore not of the product, but of the whole production system from soil, via plant and animal, to the consumer. The existence of production and processing standards, certification procedures and, in many countries, a legislative basis gives a clear dividing line between organic and other farming systems, primarily to provide market integrity for the products. The organic farming movement has developed principles and recommendations for farm management from an underpinning recognition of the biological, ecological conception of nature and the importance of the relationships and interactions between organisms – plant and animals, both above ground and within the soil. This comprehensive, integrated view of nature and ethics within organic agriculture is evident in one of the original precepts of organic farming (here in the words of Lady Eve Balfour, 1943): '[T]he health of soil, plant, animal and man is one and indivisible.' In contrast, intensification of conventional agricultural production since the 1940s has been marked by increased use of mechanical and manufactured inputs and increased specialization of production; these changes mean that regulation of the agroecosystem through biological processes is consequently displaced in conventional farming systems (Giller *et al.*, 1997) and conventional farmers have become dissociated from food production and sales. In many cases, food is now an industrial product, e.g. dependent upon industrial inputs. None the less 'it is also a socio-cultural symbol and a link between the human being and Nature' (Tozlani, 1998).

In its most developed form, organic farming is both a philosophy and a system of food production. Efforts to ensure short-term viability are tested against long-term environmental sustainability, and attention to the uniqueness of every operation is considered in relation to ecological, economic and ethical imperatives, with an awareness of local and global implications. Four strong basic unifying principles defined by the International Federation of Organic Agriculture Movements (IFOAM) link the wide range of farming systems and management practices within the organic food system:

- Principle of health should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible.
- Principle of ecology should be based upon living ecological systems and cycles work with them, emulate them and help sustain them.
- Principle of fairness should build upon relationships that ensure fairness with regard to the common environment and life opportunities.
- Principle of care should be based on a precautionary and responsible manner to protect the health and well-being of the current and future generations and the environment (IFOAM, 2005).

None the less the implementation of these principles across the world in diverse climates leads to a great variety in the types of farming systems which produce organic food products of all types imaginable from vegetables, meat, bread and milk to organic cola and ready meals.

The objectives of environmental, social and economic sustainability lie at the heart of the organic food system and are among the major factors determining the acceptability or otherwise of specific production practices. The term 'organic' is not directly related to the type of inputs used, but refers to the concept of the farm as an organism, first proposed by Steiner (1924), in which all the component parts – soil minerals, organic matter, microorganisms, insects, plants, animals and humans – interact to create a coherent whole. In other European languages terms such as 'biological' and 'ecological' are used for the farming systems described in English as 'organic', reflecting the reliance on ecosystem management rather than external inputs: chemical, organic, biological or otherwise. Detailed descriptions of the principles and practices of organic farming are available (e.g. Lampkin, 1990; Siebeneicher, 1993) and we will not repeat those here. In this chapter, we attempt to draw together information on the key distinguishing features of organic food systems and the extent of organic farming in a European context. We aim to provide a framework for the consideration of how a range of environmental variables affect the composition of organic foods and their differences from foods produced in other systems.

Development of Organic Farming and Food Systems

The roots of organic farming can be traced in the European literature back to the late 19th/early 20th century. The early organic movement focused strongly on issues of human diet, nutrition and health, as well as the promotion of soil fertility through the use of composts and other organic fertilizers. Pesticides did not become a major issue in organic agriculture until the publication of *Silent Spring* generated widespread public concern (Carson, 1963).

Modern organic farming represents a merging of a number of different streams of thought and the history is told differently in different places (Boeringa, 1980; Merrill, 1983; Conford, 1988; Harwood, 1990; Tate, 1994; Heckman, 2006). Of particular interest is the fact that those engaged in developing organic agriculture provided great breadth of vision from a wide variety of backgrounds including philosophers, ecologists and consumers groups, alongside agriculturalists (Michelsen, 2001).

In the English-speaking world, Sir Robert McCarrison's work linking human health and nutrition (McCarrison, 1926), Sir George Stapledon's work with alternate husbandry systems (Stapledon, 1939) and Sir Albert Howard's work on the role of organic matter in soils and composting (Howard, 1943) provided a powerful stimulus to Lady Eve Balfour (Balfour, 1943). In 1939, she began the Haughley Experiment to investigate the links between the way food is produced, food quality and human health; this experiment continued until 1969 (Balfour, 1975). Howard and Balfour's ideas emphasizing the role of a healthy, fertile soil in the production of healthy crops and livestock and the link with human health and nutrition were also pursued in the USA by the Rodale family, who founded the Soil and Health Foundation in 1947 (Merrill, 1983; Harwood, 1990). The Limits to Growth report of the Club of Rome and the energy crisis of 1973 drew attention to the sustainability of resource use (Lockeretz, 1990). During the 1980s and 1990s, other issues increased in importance, in particular nature and biodiversity conservation, animal welfare, social justice issues relating to fair trade with developing countries, and most recently the potential of organic agriculture to contribute to rural development (Anon, 1999). It is inevitable given the historical development of organic farming that it has taken some time for the ideas to fuse into a coherent concept, which is now practised worldwide. The formation of the IFOAM in 1972 gave an international framework for the discussion and codification of internationally recognized principles for organic farming. However, this framework is not fixed; the development of organic agriculture is not complete. The formulation of the principles has changed and will continue to evolve as understanding of the interlocking roles of soil, crops, livestock and natural ecosystems and their link with human health and well-being increases and new technologies, which may be used in agriculture, emerge.

As organic farming has developed, acceptable production practices have been recorded in technical guides and handbooks (Lampkin, 1990; Blake, 1994). Where marketing of produce was locally based and small-scale, production standards might be guaranteed by word of mouth. However, as the market for organic produce expanded, it was necessary to codify commonly accepted production practices. Since the early 1970s, considerable efforts have been put into the development of production standards for organic production in order to create a differentiated market for organic products. Production standards are based on the overarching principles of organic farming but may be expressed in great detail, may be related to local conditions and may indicate recommended, restricted and prohibited practices and inputs (e.g. Soil Association, 2007). Production standards therefore represent a blend of ethics, tradition, experience, scientific knowledge and

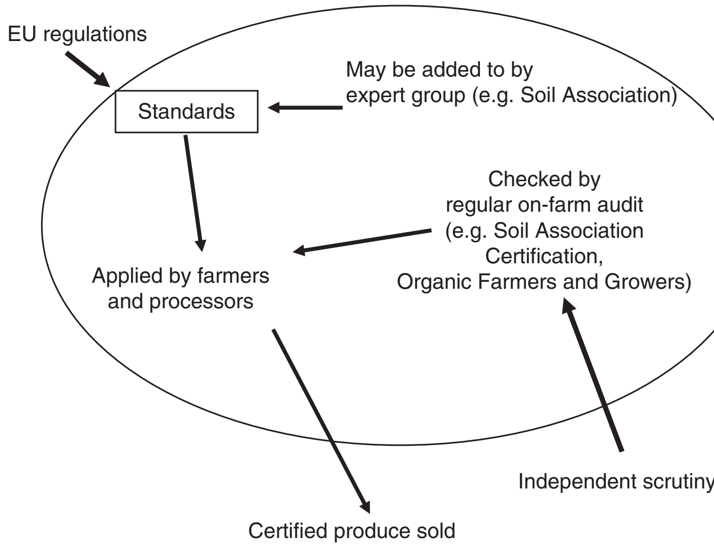

Fig. 1.1. Schematic diagram showing steps in the certification process governing organic food production in the UK.

pragmatism. They are constantly evolving, reflecting the need to respond to the appearance of new technologies (e.g. genetic modification) and new evidence of environmental impact (e.g. the aim to remove Bordeaux mixture as a restricted pesticide for organic farming). Of key importance is that the definition of agriculture is in terms of standards for production and processing, not the certification of the products themselves. It is the way food and fibre is produced, not the end product, which is the focus of organic standards.

The introduction of clear production standards has also required the introduction of processes of farm certification and inspection, to ensure that the standards are adhered to (Fig. 1.1). Increasing consumer demand has often forced the attention of regional and national governments towards organic farming systems, with the enactment of legislation to regulate the use of the word 'organic' in marketing. In some cases, this may have come to the attention of the departments concerned with consumer affairs or trading standards before a department of agriculture (Hill and Macrae, 1992). This has often led to the legislation of production standards often drawing on those previously developed by organic farming organizations themselves.

Legislation of Organic Food Systems

International agreements (e.g. Codex, 1999) have also been agreed to define organic production and ensure a differentiated market for organic products. In the European Union (EU), Regulation 2092/91 was largely established as a labelling regulation, meant to regulate the internal market for organic products (Commission of the European Communities, 2004). It defines in detail the requirements for agricultural products or foodstuffs describing the organic production standards and the inspection and supervision requirements. While the original regulation covered only plant production and processing, in 1999 (Regulation 1804/99), it was extended substantially to cover animal production. The detailed approach in this regulation was needed as a result of the great diversity of animal production systems throughout the EU and the lack of consensus in the existing rules relating to livestock management developed by organic farming organizations in each country. In addition, Regulation 2092/91 provides for an equivalency regime for organic products imported from third countries, which must adequately demonstrate that they are produced in accordance with production standards and are subject to inspection arrangements equivalent to those applied to organic production in the EU. In March 2000, the European Commission introduced a logo bearing the words 'Organic Farming – EC Control System' (Regulation 331/2000). Since that date, this logo can be used on a voluntary basis by producers whose systems and products have been found to satisfy Regulation 2092/91. Genetically modified (GM) organisms and/or any product derived from such organisms must not be used in organic farming (with the exception of veterinary medicinal products). The presence of GM crops in non-GM farming systems cannot be completely excluded during cultivation, harvest, transport, storage and processing. The main sources of GM admixture are seed impurities, cross-pollination, volunteers and harvesting–storage–processing practices.

Denmark was the first country to introduce public economic support for organic agriculture in 1987 as compensation for economic loss during conversion (Michelsen, 2001). The increasing role of policy support during the 1990s has arisen because of a gradual convergence of policy goals with the underlying objectives of organic agriculture, including environmental protection, animal welfare, resource use sustainability, food quality and safety, financial viability and social justice. Organic farming is also perceived to contribute to reducing problems of overproduction and to rural development. Organic farming offers three potential advantages over other, more targeted policy measures: it addresses all (or most) of these goals simultaneously; it utilizes the market mechanism to support these goals; and it is recognized globally. Increasing consumer demand for organic produce has generated interest within governments of meeting demand for organic food self-sufficiently. In the EU, the agri-environmental measures introduced by Council Regulation 2078/92 included approval for aid for farmers who converted to, or continued with, organic farming measures. Financial support during the conversion period to organic agriculture was therefore provided in some states and countries to provide financial compensation to farmers for any losses incurred during conversion (Hill and Macrae, 1992; Padel and Lampkin, 1994). Within the EU, agri-environment schemes have been applied differently at the country level; where more direct support has been given to organic farming systems, the area under certified organic production has expanded more rapidly (Padel *et al.*, 1999). By 2001, organic farming support made up around 15% of the EU expenditure on agri-environment measures (Haring *et al.*, 2004). One of the objectives in the 2003 reform of the Common Agricultural Policy was to promote production that supports environment-friendly, quality products; organic farming is considered to be an important device towards the attainment of this objective (Commission of the European Communities, 2004). Consequently, there is now greater scope for Member States to implement measures to provide support for organic farmers. However, there are still large differences between Member States, for example:

- In Germany, the Federal Organic Farming Scheme (Federal Ministry of Consumer Protection Food and Agriculture, 2003) contains a number of measures targeted at eliminating obstacles to growth of supply and demand in the market for organic food including information, training and advisory activities for organic farmers and those planning conversion, providing suggestions and ideas to foster innovation and competition in food processing, providing consumer information and supporting research and development.
- The devolved administrations of the UK all provide support to organic farming but have slightly different rules in their schemes. In England, the organic entry-level scheme is now a distinct tier in the package of environment stewardship schemes available to all farmers (Defra, 2008). This scheme provides support for those in conversion and those continuing to farm organically in recognition of the role of organic management requirements in delivering effective environmental benefits.
- In autumn 2006, the Spanish Ministry of Agriculture launched a Campaign for Organic Farming with the slogan 'Cultura-Lógica, Agricultura Ecológica, es cultura, es de lógica' co-financed by the EU. The campaign aims to stimulate consumption of organic products, to enhance the knowledge of consumers about organic farming and its products, to promote the EU logo for organic products and to provide information about the EU standards and their monitoring.
- Currently in Greece there is no government support for organic farming.

Governments around the world also provide a range of support measures for organic agriculture. In addition, the FAO provides assistance in establishing appropriate legislative frameworks: tapping market opportunities, improving quality and performance of low-input production systems; and improving value chains.

In many aspects the development of the regulation has followed an evolutionary approach, including several transitional rules within the legislation which facilitated a step-by-step development of organic farming as the number of organic farmers increased (Commission of the European Communities, 2004). A major revision process of the EU regulations governing organic food systems began in 2005; the aim was to replace the current rules by simpler, more transparent ones but which are no less stringent in their requirements for farmers, processors and the certification process. Regulation 834/2007 on organic production and labelling of organic products will come into force on 1 January 2009. The new regulation lays down more explicitly the objectives, principles and production rules for organic farming while providing flexibility to account for local conditions and stages of development, and it will not prohibit stricter private standards such as those of biodynamic farming from coexisting with organic standards. The regulation will have an extended scope and include both aquaculture and viticulture. The EU logo will become compulsory – along with further certification logos, if appropriate, and an indication of the place of production. IFOAM have expressed their approval of the clearer and more appropriate objectives and principles; however,

> much will now depend on the Implementing Rules, in particular to ensure the criteria for evaluating inputs and for allowing flexibility are sufficiently restrictive. It is vital that the Implementing Rules are adequate both to protect the integrity of organic food and farming, and to ensure a vibrant and successful organic sector.
>
> (IFOAM, 2007)

Land area

Recent years have seen very rapid growth in organic farming and food production, particularly in Europe (until 2002, Fig. 1.2) and the USA, but also in many other regions of the world including China, Latin America and Africa. Worldwide, organic agriculture occupies 31 Mha of certified crop and pasture lands and more than 62 Mha of certified wild-harvested areas (FAO, 2007). In the EU, certified and policy-supported organic production accounted for just 100,000 ha on 6300 holdings in 1995, or less than 0.1% of the total utilizable agricultural area (UAA). In 2005, the organic area within the EU (EU-25) was *c*.4% of the UAA, equivalent to 1.6% of the registered agricultural holdings; both are still increasing slightly (Llorens Abando and Rohner-Thielen, 2007). The land area under organic cultivation in the EU increased at a rate of about 21% per year between 1998 and 2002 (Romer-Thielen, 2005). Geographic trends in organic livestock largely reflect the patterns seen in land area (Llorens Abando and Rohner-Thielen, 2007). Nearly all the expansion in the organically registered land area in Western Europe has taken place since the implementation in 1993 of Regulation 2092/91 defining organic crop production, and the widespread application of policies to support conversion to, and the maintenance of, organic farming as part of the EU's agri-environment programme (Lampkin *et al.*, 1999). The former has provided a secure basis for the agri-food sector to respond to the rapidly increasing demand for organic food across Europe. The latter has provided the financial basis to overcome perceived and real barriers to conversion. Similar responses to the development of supportive legislation are seen worldwide.

The growth of the organically farmed area in the EU (Fig. 1.2) hides great variability within and between countries. Italy, Germany and Spain have the largest areas of organically certified land in the EU, representing between them 46% of organically certified land (Llorens Abando and Rohner-Thielen, 2007), while Austria has the highest proportion of its agricultural area under organic production (11%). These differences are in part a reflection of the

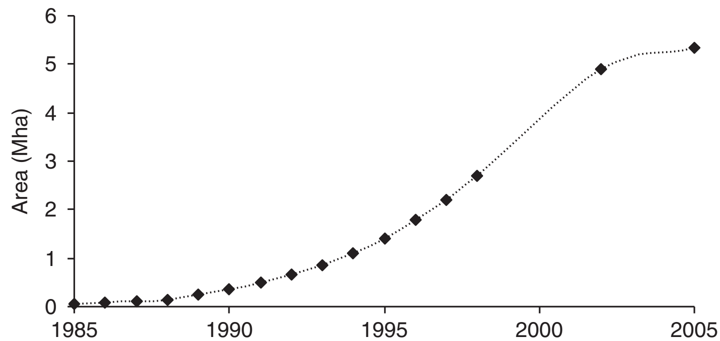

Fig. 1.2. Certified and policy-supported organic and in-conversion land area (Mha) in the European Union (EU-15) 1985–2005. Total UAA in the European Union (EU-15) is approximately 93.3 Mha. (Data taken from Lampkin, 1999; Rohner-Thielen, 2005; Llorens Abando and Rohner-Thielen, 2007.)

intensity of the farming systems previously operating. For example, much of the utilizable agriculture area in Austria is based on upland pastures, which can be relatively easily converted to organic production. The cropping patterns across the EU reflect the dominant locally adapted farming systems so that in 2002 only five Member States (Greece, France, Italy, Cyprus and Portugal) had significant areas under perennial organic crops – mainly fruit trees, olive groves and vineyards (Romer-Thielen, 2005). In general, a larger proportion of mixed farms are managed organically than specialized dairy or arable units. Consequently, long-term pastures and meadows (>5 years duration) used to support livestock are a feature of organic farming systems in all Member States and green forages are also an important component of the area used for annual cropping. The balance between long-term pastures and annual cropping varies, e.g. Italy has 23% of the area of organically certified land under long-term pasture, whereas the UK has more than 70% (Llorens Abando and Rohner-Thielen, 2007). Vegetable production represents only a small proportion of organic cultivation – but the relative share of production does not reflect the proportions of total UAA farmed organically. For example, in 2002, Denmark had the highest share in organic cultivation of fresh vegetables (nearly 14% of the total vegetable cultivation area), closely followed by the UK and Luxembourg; conversely, in Belgium, Greece and Spain, the organic area of fresh vegetables has a share of less than 1% (Romer-Thielen, 2005).

Features of organic food systems in practice

While food production systems involve engagement with both social and ecological systems, only the technical aspects of the differences between organic and conventional food systems are considered briefly below. Organic processing standards prohibit the use of a number of processing aids and additives routinely used in conventional food processing, such as artificial colours and many preservatives. In several standards, guidelines and publications organic food processing is strongly associated with 'minimal processing' (Beck *et al.*, 2006). However, there are frequent discussions regarding the underlying rationales and criteria used to allow some but not other processing methods and additives, especially when new processing technologies or additives have to be assessed for conformity with organic processing standards (Gallmann, 2000). Regulation 2092/91 also requires 'sufficient separation during the harvesting, transportation, processing and packaging of organic food' and traceability to be maintained throughout the processing stages. Hence, organic foods have to be produced on processing lines which are clearly separated in space or time from conventional food processing. There is a lack of detailed consideration of the impacts of organic processing standards on the consequent food processing methods and products, e.g. prohibition of certain flavourings will require redesign of the entire process to enable consumer acceptability to be maintained. The organic food sector is therefore considered to be highly innovative in developing approaches which use natural substances with appropriate technological properties or less critical additives than are used normally, or technologies based on additive-free processes (Beck *et al.*, 2006). The focus of this book (and much of the existing literature) is on the differences in organic food arising directly as a result of organic and conventional farming systems rather than food systems taken as a whole; consequently, the distinguishing features of organic food processing will not be discussed further.

Increasing awareness of the environmental impact of conventional farming practice (e.g. Stoate *et al.*, 2001) has led to a move towards alternative systems, which explicitly acknowledge the externalities of farming systems (e.g. the impact of pesticides on wildlife or fertilizers on water supplies) and seek to minimize them by changes within the farming system. The organic (biological/ecological) approach is not the only alternative to conventional production systems currently practised or advocated. Lower-input and organic systems are both covered under the headings 'sustainable' and 'alternative' (NRC, 1989; Edwards *et al.*, 1990; Francis *et al.*, 1990). Conventional agricultural systems often rely on targeted short-term treatments to tackle problems such as application of a soluble fertilizer nutrient or use of herbicides. Reduced use, but not elimination, of these chemical inputs is a key factor distinguishing 'low-input sustainable agriculture' (USA) and 'integrated farming systems' (Europe) from organic farming (e.g. Grubinger, 1992; El Titi, 1995). Organic farming systems use a strategically different approach, which relies on a network of partial longer-term solutions (preventative rather than reactive) operating at the system level (Watson *et al.*, 2002). The majority of organic farming in Europe is on mixed farms or livestock units. In these areas crop rotations based on the use of forage legumes offer an important mechanism for nitrogen management in organic farming systems, because they have the potential to support both animal production during the ley phase and a subsequent, exploitative, cropping phase. However, specialized arable, horticultural and livestock organic farming systems also occur. The key characteristics of organic farming include:

- Protecting the long-term fertility of soils by maintaining organic matter levels, fostering soil biological activity and careful mechanical intervention;
- Nitrogen self-sufficiency through the use of legumes and biological nitrogen fixation, as well as effective recycling of organic materials including crop residues and livestock wastes;
- Weed, disease and pest control relying primarily on crop rotations, natural predators, diversity, organic manuring, resistant varieties and limited (preferably minimal) thermal, biological and chemical intervention;
- Supplementing crop nutrients, where necessary, by using nutrient sources which are made available to the plant indirectly by the action of soil microorganisms and chemical reactions in the soil;
- The extensive management of livestock, paying full regard to their evolutionary adaptations, behavioural needs and animal welfare issues with respect to nutrition, housing, health, breeding and rearing;
- Careful attention to the impact of the farming system on the wider environment and the conservation of wildlife and natural habitats (Padel and Lampkin, 1994).

A period of several years, known as the conversion or transition period, is needed to change a farm from conventional to organic management. The length of the conversion period depends on the certification scheme, but under many schemes a period of 2 years in conversion is required before a farm, or part thereof, is certified as organic (Regulation 2092/91). However, there is wide agreement that the development of a fully functioning organic farm takes much longer than 2 years (Voss and Shrader, 1984; Liebhardt *et al.*, 1989) and is dependent on the previous management of the farm and the soil and environmental conditions. Martini *et al.* (2004) highlighted the fact that yield changes following conversion to organic farming were as much a result of the farmer's development of skills and understanding as changing processes/systems on the land farmed.

Approaches in cropping

Crop diversification can deliver many agronomic and ecological benefits simultaneously, while maintaining or enhancing the scale and efficiency of production. Such complex systems can have a major influence in limiting diseases, pests and weeds and ensuring a balanced nutrient supply for crops. However, to achieve even some of these benefits requires great attention to management: diversity simply as an end in itself may lead to losses in production and productivity (Altieri, 1999); what is needed is functional diversity. Consequently, in organic farming systems, rotation design is critically important for nutrient cycling and conservation as well as weed, pest and disease control; crop diversity in space and in time is at the heart of a well-designed organic cropping system (Stockdale *et al.*, 2001). This is also true for many low-input systems, where legumes are also integrated into rotations to reduce the demand for nitrogen fertilizer (Crews and

Peoples, 2005). Where fixation is the major external source of nitrogen, the balance between nitrogen-fixing and exploitative arable cropping periods is critical in determining not only productivity but also environmental impact. Nitrogen budgets are generally positive for organic systems (Halberg *et al.*, 1995), indicating that there is surplus nitrogen, which may be lost by leaching or denitrification, particularly following cultivation and handling of animal manures (Köpke, 1995; Stopes *et al.*, 2002). Management of residual nitrogen from legumes, particularly the timing of incorporation and the nitrogen demand of subsequent crops, is critical to minimize crop nitrogen deficiency and nitrate losses (Watson and Philipps, 1997). Organic farming systems rely on the effective recycling of nutrients within the farm system in crop residues and animal manures together with management practices to maintain or improve soil organic matter status; a limited range of external amendments are available to supply nutrients for crops (Watson *et al.*, 2002).

Crop health is maintained through complex interactions and feedback among soil, crops, pests and inputs. Crop diversity is also used to maintain crop health, for example, by separating crop hosts so that soil-borne pathogen inoculum is diminished. Crop rotation and soil management have been identified by farmers as a key disease control strategy in organic farming systems (Brenner, 1993). Pest control strategies are largely preventative, rather than reactive. The balance of cropped and uncropped areas, crop species and variety choice and the temporal and spatial pattern of the crop rotation seek to maintain a diverse population of pests and their natural enemies and disrupt the life cycle of pest species. Some external inputs are also permitted to be used as supplementary tools in the control of pests, disease and recalcitrant, particularly perennial, weeds. Weed management strategies involve the whole cropping system with cultural measures providing a form of residual control (Rasmussen and Ascard, 1995; Bond and Grundy, 1998; Bond and Lennartsson, 1999). The aim is to maintain weeds at a manageable level by cultural means to ensure that direct control measures can succeed in preventing crop losses. An integrated approach using a combination of cultural and direct techniques is necessary. Consequently, a higher level of plant diversity is maintained throughout the crops even in monocultures than in their conventional equivalents, where biodiversity is only encouraged at the edges.

Absolute yield levels under organic management are lower than those of conventional systems; most studies have been carried out with temperate crops where arable crops yields around 60–80% of those of conventional systems (Stockdale *et al.*, 2001). Yields of forage crops are often similar with no difference in feed quality (Stockdale *et al.*, 2001). In developing countries, the UNDP (1992) concluded that organic farming methods seem able to provide similar outputs, with less external resources, supplying a similar income per labour day as high-input conventional approaches. Studies commonly show large increases where local farmers adopt organic farming systems reaching levels similar to those of high-input systems (FAO, 2007). Direct comparisons of yields are difficult because of the differences in the farming systems adopted under high-input or organic management. Absolute yields are, however, subject to considerable variability due to a number of factors, including variety selection and plant breeding, soil type, climate, rotation design and nutrient management, length of time under organic management, as well as management ability and developments in scientific knowledge and technology. A significant number of critical voices raise concerns that organic agriculture is not capable of meeting the world's growing food needs due to lower productivity per unit area (e.g. Borlaug, 2000; Trewavas, 2002). However, recent work using the International Food Policy Research Institute's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) and extensive farming systems data showed that even at high levels of conversion to organic agriculture (up to 50%) in Europe and North America, there would be relatively little impact on the availability of food, and price changes would be limited. In the case of sub-Saharan Africa, a conversion of up to 50% would likely increase food availability and decrease food import dependency, with negligible changes in prices and no changes in current malnutrition rates (FAO, 2007).

Approaches for livestock management

Regulation 1804/99 effectively ruled out landless livestock production systems emphasizing that 'organic stockfarming is a land-related activity', with livestock as the intermediary between the utilization of home-grown feed and the return of nutrients as manure. This consequently leads to the greatest distinction between livestock conventionally reared very intensively, such as pigs and poultry, and their organic counterparts (e.g. Millet *et al.*, 2005). Within organic systems partnerships between poultry producers and arable farmers are increasingly common, solving a waste disposal problem for one and a nutrient deficiency for the other. A comprehensive review of organic dairy production was recently completed by Nicholas *et al.* (2004) and it is clear that uptake of organic farming systems in most European countries has been greater in regions with less intensive grazing livestock systems, such as dairy, beef and sheep production.

The emphasis of organic livestock production is to optimize production systems to avoid animal health problems and to guarantee species-specific animal welfare standards. Organic systems achieve higher animal welfare standards than conventional systems, mainly due to reduced tethering and/or caging of animals and the use of bedding (Hörning, 1998; Sundrum *et al.*, 1999). The requirement to retain as closed a herd/flock as possible reduces the risk of buying in disease, and encourages selection on the basis of farm needs as well as the development of greater resistance to the spectrum of disease present. Reviews of animal health and welfare in organic livestock systems have recently been completed (Lund and Algers, 2003; Kijlstra and Eijick, 2006); consequently, these aspects will not be considered further here.

Organic farming aims to apply species-specific husbandry with consideration for the animal's ability to express its natural behaviour, by preventing intentional and unintentional mutilation of animals and by applying species-specific feeding regimes. Sound nutrition, taking account of the physiological adaptations of livestock to different types of feedstuffs, underpins health, vitality and productivity. The basic features of organic livestock feeding have been described by Kamphues (1998), emphasizing the integrated nature of feed production and manure use. Ruminant diets must be forage-based with organically produced feed; zero grazing is not permitted. Due to a prohibition of solvent-extracted feeds, there is greater reliance on home-produced forage legumes, such as peas and beans. For monogastric animals transitional rules still apply, allowing a small proportion of non-organic feeds while the supply chain develops. The use of pure nutrients and feed additives is limited by organic production standards to 'natural' ingredients and levels are determined by an animal's minimum needs rather than maximum production levels (e.g. antibiotic production enhancers are not acceptable). Maximum stocking densities are set both in housing and grazing situations (Regulation 2092/91); these are lower than conventional stocking rates and are now related to the return of nitrogen (<170 kg N/ha) to the land. Organic systems also promote the use of appropriate breeds, suited to the system of production, which ideally are locally adapted. The judicious use of breed is seen as an important strategy to improve disease resistance, reduce metabolic problems and retain genetic diversity. In addition, opportunities may be presented to exploit possibilities to market specialist breeds and meats in order to improve producer returns (Marchini and Santucci, 1998).

With greater emphasis on management approaches, the performance of an organic livestock system will be highly dependent on the level of stockmanship applied. Value judgements may be difficult when dealing with complex biological systems, particularly at the limits of current knowledge. With less emphasis on a prescriptive, blueprint approach, observation of the farming system, and of the behavior and performance of the animals within that system, plays an important role in the development and refinement of an organic livestock system (Boehncke, 1998).

Impacts of organic farming systems

The Commission of the European Communities (2004) explicitly recognizes a dual role for organic food systems within society: first, providing food products in response to the demand of consumers – this role should therefore be constrained by market rules, rewarded by the market and hence be financed by consumers; and second, providing public goods, as a result of farm management practices, primarily environmental, but also rural development benefits and improved animal welfare – this role is external to the operation of markets and should be driven by society.

So far in this chapter we have largely focused on the first of these roles. However, much of the policy support for organic farming is predicated by its second role, i.e. the delivery of a range of public benefits not rewarded by the market. The recognition that agricultural systems must take a multifunctional role in support of the provision of a broad range of ecosystem goods and services is now well established in Europe. Organic food and farming systems provide a good example of such integration, but by no means the only one. A large number of studies have considered the relative importance and value of the benefits of organic farming systems for biodiversity (e.g. Bengtsson *et al.*, 2005; Hole *et al.*, 2005), animal welfare (Lund and Algers, 2003) and impacts on air, water and soil quality, especially in relation to mitigation of, and adaptation to, climate change (e.g. Shepherd *et al.*, 2003). The Commission of the European Communities (2004) considers that some of these are well established (Box 1.1); however, it does not currently accept that organic farming gives additional benefits with regard to food safety or nutritional quality. A number of reviews of food quality of organic and conventional products have been written (e.g. Woese *et al.*, 1997; Brandt and Molgaard, 2001; Bourn and Prescott, 2002). All highlight the technical difficulties associated with such comparisons (different methods of sampling variations in other factors not directly related to the production system) and the lack of robust information currently available to allow the hypotheses that enhance the nutritional value of plant foods to be tested.

Box 1.1. The main benefits of organic farming (Commission of the European Communities 2004, Annex).

- *Pesticides: research indicates that organic farming has, on average, a greater effect on the improvement of the landscape, wildlife conservation and faunal and floral diversity than non-organic farming systems. Restricting the use of pesticides, as is the case in organic farming, also improves water quality and fewer pesticide residues are found in food products.*
- *Plant nutrients: organic farming usually results in lower nitrate-leaching rates than those achieved on average in integrated or non-organic agriculture, as shown by studies on autumn nitrogen residues in the soil of almost all relevant crops.*
- *Soil protection: management practices broadly used by organic farmers, such as growing catch crops to reduce nitrate leaching, wider and more varied crop rotations, and mixed grazing to reduce mono-specific overgrazing, all help to protect the soil. Although the organic matter content of soil is highly site-specific, it is usually higher on organic compared to non-organic farms.*
- *Biodiversity and nature protection: organic farming contributes to the reservation of species and natural habitats by means of its reduced inputs, its high share of grassland within holdings and its greater use of indigenous breeds and plant varieties.*
- *Animal welfare: organic farming may have a positive impact on animal welfare since the standards for organic farming include several requirements in this area that go further than the statutory provisions.*

With regard to *food safety* it is, in general, not possible to claim that all organic food is more or less safe than non-organic food.

Comparison of organic and conventional farming and food systems are fraught with difficulties – there is no clear definition of what conventional is, and even within the legally defined organic systems there is significant variation in practices. Watson *et al*. (2008) provide a useful review of the research approaches applied in the study of organic farming systems; they highlight the need to ground all future comparative work in improved understanding of all farming systems and their environments. In fact, it can be argued that what is needed is not a narrow comparison of organic and conventional systems with regard to one or other aspect or outcome. Instead there is a need for a holistic view of food systems beyond productivity to include the integrated evaluation of environmental, social and health impacts; only when food systems are viewed in this way might we be able to move forward towards meeting the food-related Millennium Goals (FAO, 2007). More remains to be determined about the links between health and nutrition for both humans and animals. There is currently a lack of methodologies available which work across the whole food system and link production systems to product quality and onwards into livestock and human health and well-being (Watson *et al*., 2008). Science continues to advance and it is important that we continue to evaluate the importance of environmental and management factors in controlling the composition of our diet.

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