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International Federation of
Organic Agriculture Movements EU Group

ORGANIC FOOD AND FARMING

A system approach to meet the sustainability challenge

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EXECUTIVE SUMMARY

Organic farming support is an effective and cost-efficient measure to reach sustainability objectives in agriculture policies. Organic standards consist of strict and European-wide certifiable rules that require knowledge and ecosystem-based management responses from farmers, resulting in farm practices that contribute to an array of sustainability aspects.

This dossier collects articles from different researchers, analysing available scientific results, approaching organic farming from different angles. The first article, written by Susanne Padel and Nic Lampkin, explains the **origin of the organic farming concept**, organic agriculture as a holistic approach to sustainable food production, the development of organic standards and the role science plays in progressing organic practices.

Climate change is the issue of the second article, provided by Andreas Gattinger, highlighting the adaptation and mitigation potential of organic farming resulting from improved humus management, increased carbon sequestration in soil and the ban of chemical fertiliser use.

The inter-linkage between **biodiversity** and organic farming has been investigated by Sylvaine Simon. This third article explicates that longer crop sequences, spatial design and in general a higher tolerance level for wild plants and pests under organic farming result in increased biodiversity compared to conventional farm systems.

Soil and water quality are the focus of Christine Watson's and Elizabeth Stockdale's article; they analyse the connection between organic farming practices such as crop rotation, nutrient recycling, restricted use of external inputs and crop mixtures with enhanced soil structure, long-term soil fertility and improved groundwater quality.

Myles Oelofse and Andreas de Neergaard further determine the efficiency of nutrient and energy use in organic farming, regarding the pressing need to make **efficient use of natural resources**. Nutrient recycling, the use of adapted plant varieties and energy-saving through the ban of synthetic nitrogen fertiliser are organic farming practices that enhance resource efficiency.

The last, concluding article has been provided by Urs Niggli, Christian Schader and Matthias Stolze. It delivers arguments why **policy support for organic farming is an effective and cost-efficient measure** to meet several sustainability goals, highlighting the combination of many different rules that may induce synergetic environmental effects, possibly lower transaction costs and enhanced consumer support through premium prices.

1 I INTRODUCTION TO THE CONCEPTS AND PRINCIPLES OF ORGANIC FARMING

Susanne Padel and Nicolas H. Lampkin, Organic Research Centre - Elm Farm, Hamstead Marshall, Newbury, Berkshire RG20 0HR, UK.

- **The ideas and principles underpinning organic farming go back almost 100 years.**
- **The term "organic" refers to the concept of the farm as an organism.**
- **Organic farming puts an emphasis on self-regulatory processes rather than external inputs.**
- **Science plays an important role in the development of organic farming concepts and its validation.**

If consumers are asked about organic farming most will characterise it by what organic farmers do not use. Answers will almost certainly include "no pesticides", "no fertilisers" and "natural" (Zanoli, 2004). Whilst it is not wrong to describe organic farming in this way, this does not help to understand what principles organic farming is based on and what practices organic farmers do use (Lampkin, 2003).

Organic farming in Europe has a long history and a variety of roots. The ideas and principles underpinning organic farming as a coherent concept go back almost 100 years (e.g. to King, 1911; see also Lockeretz, 2007). The various pioneers shared a passion for farming/growing and analysed and interpreted the main problems of mainstream agriculture, including the need for recycling nutrients and seeing the farm as an interconnected whole. The term 'organic', was first used in this context in the 1940s, and refers not to the type of inputs used, but to the concept of the farm as an organism (or system in more modern terminology), in which all the component parts - the soil minerals, organic matter, microorganisms, insects, plants, animals and humans - interact to create a coherent and stable whole. Central to the concept is the closing of nutrient cycles and the preference for local resources. Since then, different issues have come to the fore at different times, from soil conservation and the dustbowls in the 1930s (Howard, 1940; Balfour, 1943), to pesticides following Silent Spring (Carson, 1962), energy following the 1973 oil crisis (Lockeretz, 1977), and subsequently to concerns about animal welfare, biodiversity loss, climate change, peak oil, peak phosphate and food security today. These are reflected in the terms 'biological' or 'ecological' agriculture under which organic agriculture is known in many European countries. This reflects the emphasis of stimulating and enhancing self-regulatory processes and intensification of agricultural systems through 'biological' (living organisms) and 'ecological' tools (agricultural management of the ecosystem, habitat diversity) rather than external inputs (Vogt, 2000). These ideas are expressed in the four fundamental principles of organic farming – health, ecology, fairness and care (IFOAM, 2005). The formulation of these principles by IFOAM involved a process of stakeholder consultation and democratic acceptance by the membership.

The development of organic farming and the debate surrounding it has also been influenced by the seeking of close contacts and alliances with consumers, initially mainly through direct sales from the farms. In order to maintain the financial viability of organic systems producers have looked to consumer willingness to pay higher prices for the perceived benefits of organic food. In some cases, this reflected more altruistic environmental, animal welfare and social concerns, but in many cases this reflects more 'self-interested' concerns relating to food quality and safety, in particular issues relating to pesticide residues and personal health (for example Aertsens et al., 2009; Hughner et al., 2007).

The ideas and principles of organic farming have also formed the basis for the development of organic standards. To protect consumers and bona fide producers, the first organic standards were developed by the private sector in the form of recommendations; producers would be visited regularly and would receive feedback from other organic farmers and/or advisors. With the growth of the sector and longer supply chains, the relationship between consumer and producer became less personal, resulting in the need for a more rigorous independent quality assurance system to protect both the producer and the consumer (Schmid, 2007). However, in the long history of organic farming since the early 20th century, the development of a distinct market for certified organic food since the 1970s is a relatively recent development (Lockeretz, 2007).

Since the late 1980s the development of the sector has also been influenced by policy support. The legal definition of organic farming in 1991 through the first European Regulation on organic food EEC 2092/91 provided the basis for introducing organic policy support options as part of the agri-environmental programme EEC 2078/92. European policy-makers became interested in supporting organic agriculture for two main reasons: it was seen as a public good, delivering environmental, social, and other benefits to society that are not, or only partially, paid for through the normal price of food; and it was an infant industry, support for which could be justified in terms of expanding consumers' choices and allowing the industry to develop to a point at which it could independently compete in established markets and make a positive contribution to rural development (Dabbert et al., 2004; Padel and Lampkin, 2007).

In the European Union today, organic food is produced according to the European Council Regulations (EC/834/2007) and implementing rules. Any producer using the term "organic" or the terms protected in different languages has to follow these clearly defined rules and this is verified through inspection, certification and the accreditation of control bodies.

The Regulation recognises the dual role of organic farming in delivering public goods as well as producing for a specific market with growing consumer demand.

"Organic production plays a dual societal role, where it on the one hand provides for a specific market responding to a consumer demand for organic products, and on the other hand delivers public goods contributing to the protection of the environment and animal welfare, as well as to rural development" (Recital 1 of EC/834/2007).

Organic farming is sometimes challenged as being unscientific, or worse 'anti-science'. This is far from the case. Science has a fundamental role to play in understanding how agricultural systems work and can be improved, and in understanding how ecosystems work and can be managed to help sustain food production and the production of other ecosystem services on which our existence depends. As such, science has played, and still does play, a particularly important role in the development of organic farming concepts and its validation, and is central to research on organic farming (e.g. Niggli et al., 2008). The scientific method that has delivered so much to the development of human knowledge and understanding is central to that process, although we may still struggle at the frontiers of methodology, particularly with respect to the understanding of complex systems – something which much conventional research has failed to address.

Specific management practices that are part of the organic systems can be adopted by any farmer, whether certified organic or not. It is the combination of these different components/practices with the aim to deliver broad sustainability, health and quality objectives that defines the organic system approach and that delivers a variety of public good benefits (Lampkin, 2010).

The Principles of Organic Agriculture.

The principles are to be used as a whole. They are composed as ethical principles to inspire action.

(Source: IFOAM, 2005)

Principle of **HEALTH**	Principle of **ECOLOGY**
Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible.	Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.
Principle of **FAIRNESS**	Principle of **CARE**
Organic Agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities.	Organic Agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.

2 I THE ROLE OF ORGANIC AGRICULTURE IN MEETING THE CLIMATE CHALLENGE

Andreas Gattinger, Forschungsinstitut für biologischen Landbau (FiBL, Research Institute of Organic Agriculture), Ackerstrasse, CH-5070 Frick.

- **Humus accumulation as practised in organic farming has a significant climate benefit as it goes hand in hand with carbon sequestration, and is also one of the most effective strategies to adapt to the consequences of climate change.**
- **Ideal organic farming systems are capable of storing on average 590 kg CO_2 per ha and year extra carbon compared to conventional systems.**
- **Livestock breeding on lifetime elongation and robustness of the animals is simultaneously a climate change mitigation and adaptation strategy.**

Nitrous oxide emissions from extensive nitrogen fertilisation practices, methane emissions from cattle husbandry: Intensive agriculture is responsible for large amounts of greenhouse gases (GHG) and contributes by ca. 14 per cent to the total climate relevant emissions. However, agriculture and in particular organic agriculture can also be part of the solution.

Mitigation

Improving and maintaining soil organic matter is a core principle in organic agriculture. Humus management is not only essential for plant nutrition and to maintain the long term built-up soil fertility, it also has a significant climate benefit as humus accumulation goes hand in hand with sequestration of GHG CO_2 in soil. CO_2 emissions are also spared through the avoidance of synthetic nitrogen fertiliser. By cultivation of perennial clover grass in organic crop rotation systems and application of organic fertiliser like manure and compost a potential humus loss caused by soil cultivation and removal of crop residues is not only balanced out but even overcompensated.

Comparing different long term field studies from Switzerland, Germany and the USA revealed that ideal organic farming systems are capable of storing on average 590 kg per ha and year extra carbon compared to conventional systems (Niggli et al., 2009) (Table 1). In a recent study, the carbon storage potential in soil of organic and conventional agriculture systems in Switzerland and nearby countries was investigated (Häni, 2010). On a dataset covering 1,789 samples of 9 studies a so-called meta-analysis was undertaken. While soil carbon amounts (relative amounts expressed in per cent) under organic farming conditions were significantly higher than those of conventional systems, comparing the carbon stock (= absolute amount of soil carbon in t/ha) no statistically significant differences between these systems could be detected. The latter is due to the fact that only few studies are based on pairwise system comparisons, and data on soil bulk density to evaluate the carbon stock are rarely available.

It has to be mentioned that various factors have an impact on soil organic matter and thus affect soil carbon storage potential. A comprehensive study on humus contents in Bavarian fields concluded that local factors (soil texture, i.e. clay, silt, sand; precipitation) and the integration of livestock have a higher impact on soil organic matter than the farming system itself (organic, conventional) (Capriel, 2006). In this respect, further system comparisons concerning carbon storage in soil under equal site conditions should be carried out. The data availability for organically-managed soils regarding nitrous oxide emissions is even poorer.

Organic farming systems are likely to bear advantages because of a lower nitrogen input and an improved soil constitution. On the other hand they produce a major amount of readily-available organic residues which provide favourable conditions for N_2O Emissions. N_2O has a 300 times higher impact on climate change than CO_2; studies on this issue are therefore of high relevance. A preliminary review (Table 2) showed that in nearly all of the published studies available so far, organically-managed soils emit less N_2O than conventional. When GHG emissions are related to yield units, organic farming did not show an advantage over conventional due to often lower grain yields. However, far more research is needed to assess the climate impact of organic cropping systems and show ways for further improvements. This requires outdoor measurements of greenhouse gas emissions over a few vegetation periods, ideally over a whole crop rotation cycle at various site conditions.

Adaptation

Humus accumulation is also one of the most effective adaptation strategies to climate change, as soils rich in organic matter absorb more water during extreme rainfall, reduce surface run-off and erosion and persistently supply water during dry periods. Zeiger and Fohrer (2009) determined a higher aggregate stability and water infiltration in organically as compared to conventionally-managed soils during simulated rainfall experiments.

In general it can be said that single measures are less effective for climate change adaptation of farming, but coordinated sets of measures concerning the whole animal-plant system are needed to result in adaptability and resilience of these systems. These include a consistent risk distribution: Cultivation of various species and varieties, spacious crop rotations, crop combination for improved resource efficiency, erosion protection using land cover, reduced tillage, measures to enhance biodiversity (e.g. flower-strips attracting beneficial organisms). Hole et al. (2005) found higher biodiversity on organic than on conventional farms and Thies and Tscharntke (1999) were able to link the parasitism of eggs of the rape beetle to increased presence of beneficial insects as a result of field margins and flower- strips. Additionally, integration of livestock husbandry supports risk distribution. An essential measure for organic farmers to mitigate greenhouse gas emissions and to simultaneously adapt to climate change is livestock breeding on lifetime elongation and stabilisation of animal health by promoting robustness of the animals. An increase in the number of lactation periods in organic dairy cow herds in Switzerland from 3.3 to 4.3 lactations per cow was obtained by consequent prophylactic health management (Ivemeyer et al., 2008). This leads to a reduction of unproductive days in the rearing phase (mitigation potential) of dairy cows and went along with a better overall health status of the animals and thus is a contribution to make livestock systems more resilient to climate change.

Photographs: (Andreas Fliessbach, Nov. 2002): Accumulation of organic soil matter as adaptability to extreme rainfall using the example of DOK long-term field experiment in Therwil/CH; *Above*: parcel of bio-dynamic cultivation system (only organic fertiliser); *Below*: parcel of integrated cultivation system (only mineral fertiliser).

Table 1: **Comparison of carbon gains and losses in soils under various management systems (from Niggli et al., 2009)**

Trial	System comparison	Carbon gains (+) or losses (-) kg C/ha and year
DOK-Trial[1], FiBL and Agroscope ART (Switzerland); Mäder et al., 2002, Fliessbach, et al., 2007 Start of the trial 1977	Organic, composted farmyard manure	+42
	Organic, fresh farmyard manure	-123
	Integrated, fresh farmyard manure	-84
	Integrated, stockless with mineral fertiliser	-207
SADP Trial, USDA-ARS, Beltsville, Maryland (USA); (Teasdale et al., 2007) Duration of the trial: 1994 - 2002	Organic, reduced tillage	+ 810 up to + 1,738
	Conventional, direct seeding	0
Rodale Farming Systems Trial, Rodale Institute, Kutztown, Pennsylvania (USA); Hepperly et al., 2006; Pimentel et al., 2005 Start of the trial 1981	Organic, farmyard manure	+ 1,218
	Organic, green fallow based on legumes.	+ 857
	Conventional	+ 217
Soil tillage trial Frick[2], FiBL (Switzerland); Berner et al., 2008 Start of the trial 2002	Organic, with plough	0
	Organic, reduced tillage	+ 879
Research Farm Scheyern[3], Helmholtz-Centre Munich (Germany); Rühling et al. 2005 Start of the trial 1990	Organic	+ 180
	Integrated	-120

1 In the DOK trial all plots showed the same humus content at beginning. In the treatment “Organic, composted farmyard manure“ a slight increase in carbon content was found whereas a slight decline was observed in the farmyard manure variants of organic and integrated farming. A significant humus loss was determined in the treatment “integrated, mineral fertiliser”.

2 In the soil tillage trial at Frick only organic treatments were compared.

3 The Research Farm Scheyern is divided into the two separate management systems “integrated” and “organic”.

Table 2: **Comparison of area related N_2O emissions from soils under conventional and organic management (“x” means that there is scientific proof by the relevant paper; CON > ORG means higher N_2O emissions per ha under conventional management)**

	Type of study	CON > ORG	CON = ORG	CON < ORG
Petersen et al., 2006/AT, DK, FIN, IT, GB	Field measurements	x		
Chirinda et al., 2010/DK	Field measurements		x	
Küstermann et al., 2008/D	Modelling	x		
Flessa et al., 2002/D	Field measurements	x*		
Sehy, 2003/D	Field measurements	x*		
Lynch, 2008/Canada	Field measurements	x		
Nemecek et al., 2005/CH	Life cycle assessment	x**		
Hansen, 2008/NO	Field measurements	x		

*** yield-related emissions did not show differences**

**** yield-related emissions showed lower emissions under ORG**

3 I BIODIVERSITY AND ORGANIC FARMING – STRENGTHENING THE INTERACTIONS BETWEEN AGRICULTURE AND ECOSYSTEMS

Sylvaine Simon, INRA (French National Institute for Agricultural Research), Gotheron Experimental Unit, F-26320 Saint-Marcel-lès-Valence.

- **In organic farming, crop sequences, field design and margins contribute to an increase in agro-biodiversity and biodiversity.**
- **The use of compost favours detritivore organisms and the permanency of foodwebs, which is favourable to biodiversity and functional biodiversity.**
- **Mechanical weeding in contrast to herbicide use allows a greater diversity of wild plants remaining in the field.**

Biodiversity loss is a major threat to mankind. As around 1.5 billion hectares of the globe's land surface are used for crop production (FAO, 2003), agroecosystems play an essential role in meeting this challenge. Conventional agriculture has largely contributed to the decrease in plant and animal biodiversity in agro-ecosystems through the loss of habitats and the heavy use of chemical inputs, namely pesticides and fertilisers (Krebs et al., 1999). Alternative agricultural systems such as organic farming have been proven to be more favourable to biodiversity than conventional ones (Bengtsson et al., 2005; Hole et al., 2005; Letourneau & Bothwell, 2008). Some specific and general properties of organic farming systems are discussed here for their contribution to the preservation and promotion of biodiversity within agricultural fields and landscapes.

Organic design and practices preserve and promote agro-biodiversity and biodiversity

Biodiversity covers the "variability among living organisms from all sources… and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems" (UN, 1992). Compositional, structural, and functional aspects of biodiversity are interdependent (Noss, 1990). The economic value of biodiversity (e.g. in the TEEB project (TEEB, 2010)) and its essential role as basis for all human actions are becoming increasingly known. Functional biodiversity supports for example the delivery of ecosystem services such as pest control and pollination that are highly valuable for farming. Agriculture is also a source of biodiversity ('agro-biodiversity') through the selection of various plant and animal species used to supply food and other products over millennia (FAO, 2005). Biodiversity, associated ecosystem services, and agriculture thus develop complex relationships (Le Roux et al., 2008).

Organic farmers have to develop holistic approaches to crop production. Because they do not rely on direct pest, disease and weed control through conventional pesticides, they have adopted various strategies to avoid crop damages or weed competition in re-designed cropping systems (Zehnder et al., 2007):

- Crop sequences in organic farming are longer and more complex than conventional ones, and include both annual and perennial crops, such as grass or legumes (e.g. alfalfa).
- Hardy cultivars and breeds are bases of organic cropping systems and thus contribute to the preservation of locally-adapted (and therefore diversified) breeds and cultivars; population varieties and plant mixtures are also used. This also presents an opportunity to develop participative plant breeding towards ideotypes or ideotype assemblages beside usual standards (Desclaux et al., 2009).
- The provision of food resources and habitat in fields and field margins (e.g. flower strips) to favour the natural enemies of pests and increase pest control (conserving biological control mechanisms of pests) is a practice which is applied in several organic farms. Ecological infrastructures such as hedgerows also contribute to diversify farm habitats.

In organic farming, both temporal (crop sequences) and spatial (fields and margins) designs and management elements thus contribute to an increase in agro-biodiversity and biodiversity through higher plant richness and associated fauna. Moreover, most organic practices are favourable to the preservation and/or increase in plant and animal diversity:

- Because mechanical weeding leaves residues of wild flora on the field, in contrast to herbicides, a greater diversity of plants associated with crops (among which are segetal plants) are present and more abundant in organically-managed fields.
- Pesticide use is one of the most disruptive practices in agriculture. Organic cropping systems are designed differently and organic farmers in general

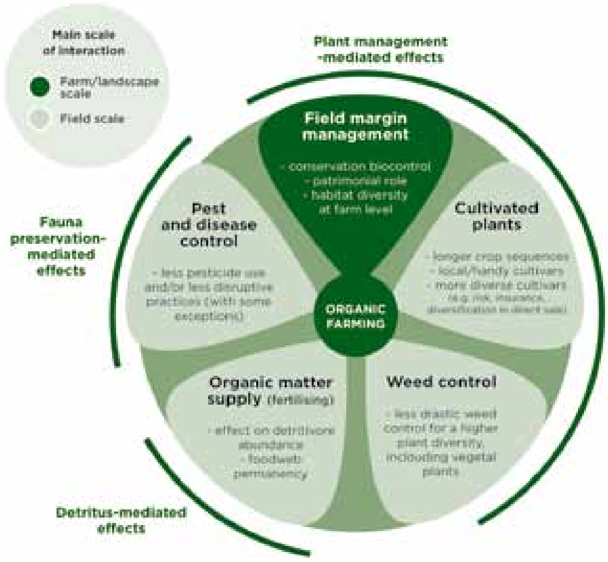
tolerate higher levels of pests before they apply measures. In addition, most organic crops are more robust and rely less on the use of pesticides than conventional ones. Moreover, most pesticides are prohibited for use in organic production, and only some are allowed with restrictions. Due to the different management system it can be said in general that pesticide-related impacts on biodiversity are lower in organic than in conventional farms. Only crops relying on the use of large amounts of copper fungicide can be an exception. Organic stakeholders are aware of this issue and alternatives to copper are currently being investigated (e.g. TP organics, 2009). A case study on fruit tree production – fruit trees are one of the most heavily treated crops to combat pests and diseases – found that organic orchards host a more abundant, although not always more diversified, fauna (Rösler, 2007), whereas functional biodiversity is less altered in organic than in conventional orchards (Simon et al., 2007).

- Organic fertilising inputs and the use of compost supply the soil with organic matter which increases soil organic content, thus favouring detritivore organisms and the permanency of foodwebs. Beside plant nutrition, such processes are highly favourable to biodiversity and functional biodiversity (Suckling et al., 1999; Mäder et al., 2002; Birkhofer et al., 2008). Tillage practices also contribute to soil aeration and are favourable to belowground living organisms (Birkhofer et al., 2008).

Depending on the taxonomic group, biodiversity is generally higher in organic farming than in conventional agricultural systems (Hole et al., 2005). Less direct mortality and sub-lethal effects of organic practices, together with higher opportunities to shelter, develop and/or multiply in organic than in conventional systems are likely to explain such differences.

Organic farm systems rely on principles and rules which are highly favourable to an increase in biodiversity in agro-ecosystems at field, farm and landscape level. Therefore, positive effects of organic farming on species richness and diversity are especially visible in intensively-managed agricultural landscapes (e.g. Bengtsson et al., 2005). Of course, as outlined by Hole et al. (2005), biodiversity is not an exclusivity of organic farming, and a few negative externalities related to the use of a few compounds can be reported. But organic farming is one agricultural system which contributes to agro-biodiversity and biodiversity through many different processes (Fig. 1). Cropping systems designed in organic farming (Zehnder et al., 2007) can therefore be considered as prototypes to preserve and promote biodiversity in agricultural areas.

Figure 1: Main Organic Farming design factors and practices likely to promote and preserve biodiversity in agroecosystems.



Organic cropping systems and biodiversity as win-win partnership

Benefits of organic farming on ecosystem services related to biodiversity are numerous (Sandhu et al., 2010). The supervised management of plant diversity and distribution of semi-natural and cultivated areas usually observed on organic farms increase habitat possibilities and resources for natural enemies of pests at field and farm level (conservation biological control of pests, farmscaping (Smukler et al., 2010)), thus contributing to pest control in crops (Landis et al., 2000; Bengtsson et al., 2005). Pollinators and pollination are also increased in organic systems (Gabriel & Tscharntke, 2007; Rundlöf et al., 2008). Organic soil management practices are highly favourable to belowground, detritivore and aboveground arthropods, including natural enemies of pests (Birkhofer et al., 2008). Of course some of the underlying processes in organic farming-biodiversity interactions are not completely disentangled (Crowder et al., 2010), most probably due to their complexity and the huge number of species involved in the system.

Empirical rather than scientific knowledge is still often the basis of plant diversity management devoted to conservation biocontrol (Letourneau & Bothwell, 2008; Simon et al., 2010). Moreover, since landscape effects highly constrain populations of pests, natural enemies, and birds (Bengtsson et al., 2005; Tscharntke et al., 2007), the scale at which these processes occur may also be different to that of the management scale (field or farm scale). This partly explains why measures of conservation biocontrol are not always effective at avoiding damages and sometimes produce disservices such as an increase in pest diversity or abundance (Zhang et al., 2007; Letourneau & Bothwell, 2008; Penvern et al., 2010).

Organic farming is the agricultural system which has largely been under focus at both scientific and technical levels to develop holistic approaches maximising ‘plant-mediated’ bottom-up processes and ‘natural enemies-mediated’ top-down processes which are both related to the preservation and promotion of biodiversity (Letourneau & Bothwell, 2008). This gives perspectives on the importance of the development of innovative agricultural systems and their intra-landscape distribution to optimise ecosystem services and more generally to contribute to biodiversity in agro-ecosystems. This brief overview of the interactions between organic farming and biodiversity shows that the organic approach can be proposed as an agricultural system that may best benefit but also provide biodiversity in the agro-ecosystem, thus minimising the trade-off between production aims and biodiversity preservation and restoration.

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4 I SOILS, WATER QUALITY AND ORGANIC FARMING

Christine Watson, Crop & Soil Systems Research Group, SAC, Craibstone Estate, Aberdeen AB21 9YA; and Elizabeth Stockdale, School of Agriculture, Food and Rural Development, Newcastle University, Newcastle upon Tyne NE1 7RU, UK.

- **Soils have a key role to play in mitigating climate change and improving food security.**
- **Organic farming emphasises soil management as an important determinant of system productivity and environmental impact.**
- **The combination of management practices encouraged in organic farming systems, e.g. lower stocking rates, use of green manures and cover crops, can result in enhanced water quality and soil protection.**
- **Maintaining or enhancing soil organic matter levels improves soil physical properties – so seedbeds can be formed more easily and water availability is maintained under drought conditions, as well as supporting the soil ecosystem and providing a carbon store.**
- **Organic farming encourages the use of renewable resources to maintain soil fertility and replace nutrients sold in produce. This provides a set of viable alternative management practices for agriculture as input costs increase.**

Soils are an integral part of our daily lives, they perform a range of important functions including acting as a platform for food and fibre production, storing carbon, filtering water and acting as a home to a huge diversity of life (Blum, 2005). They also provide cultural services, e.g. preservation of archaeological remains. How we manage soils can influence how effectively they are able to perform these functions. As it can take up to 1000 years to form a few centimetres of soil, protecting it is critical. Soils worldwide are under increasing threat from human activity such as sealing as well as climate change. The importance of soils is gaining increased recognition in policy, for example, the inclusion of soil parameters to define Good Agricultural and Environmental Condition (GAEC) in the Common Agricultural Policy.

Soil fertility is fundamental in determining the productivity of all farming systems (Watson et al., 2002) and thus inseparable from food security. Soil fertility is often defined as the soil’s ability to supply nutrients to crops but it can be defined more widely as an ecosystem concept (Swift & Palm, 2000) which integrates the diverse functions of soil that promote

plant growth, including nutrient supply. This broad definition is fitting as organic farming recognises the complexity of relationships between different components of any farming system and that sustainability depends on the functioning of the whole integrated system. A basic concept of organic farming is that "the health of soil, plant, animal and man is one and indivisible" (Balfour, 1943).

Organic farming systems rely on the management of soil organic matter to enhance the chemical, biological, and physical properties of soil, in order to optimise crop production and health. Thus, the supply of nutrients to crops, and subsequently to livestock and humans, is the net result of a set of management decisions including rotation design, manure management, etc., as well as soil management per se. The central concept of soil fertility in these systems is the use of legume-based multi-annual rotations together with the careful use of on-farm manures (Stockdale et al., 2001). Rotations allow nutrient elements to be replenished (Altieri, 1995) within a legume phase with inputs of carbon and nitrogen (by the biological processes of photosynthesis and nitrogen fixation). The use of biological nitrogen fixation in organic farming as the main route for N-supply distinguishes organic farming from most conventional farming, as it removes the need to rely on fossil fuel-derived nitrogen fertilisers. The sequence of crops within a rotation is designed to utilise changing levels of fertility and optimise the utilisation of nutrient resources over the period of the rotation (Stockdale et al., 2001). Crops with high nitrogen demand are normally placed after the incorporation of a nitrogen-rich ley phase. Using crops with a variety of contrasting rooting characteristics also helps to exploit nutrients across the soil profile (e.g. Šmilauerová & Šmilauer, 2010). Where necessary, a small range of carefully-controlled external inputs is allowed. In order to maintain productivity in organic systems it is important that nutrients sold in produce are replaced.

There is currently a very active debate about the importance of land management in contributing to, halting, or even reversing organic matter declines in soil. Robust evidence for differences between organic and conventional farming in accumulating soil carbon is currently limited. Some studies suggest that soils farmed organically are able to maintain or even increase soil organic matter contents (Fließbach et al., 2007; Teasdale et al., 2007). Some features of organic farming such as the inclusion of grass leys have regularly been shown to increase the organic matter content of soils (Clement & Williams, 1967). However, the impact across the whole rotation will depend, amongst other things, on the balance between annual and perennial crops and tillage intensity. Maintaining ground cover throughout the year by using green manures and/or cover crops is another recommended practice which has a number of environmental benefits including protection of soil organic matter, soil structure and water quality (Rinnofner et al., 2008). Management of manures and other organic wastes can also have differential effects on soil organic matter and soil biodiversity, with properly composted manures as recommended in organic farming having a more beneficial effect than fresh manures (Fließbach et al., 2007). Organic farming systems are generally associated with increased soil biological activity and increased belowground biodiversity (Bengtsson et al., 2005; Stockdale & Watson, 2009). The continued use of copper for disease control in organic potato and vine production is recognised as a risk to ecosystem health and efforts are underway to find more sustainable alternatives.

Crop rotations and crop mixtures are designed with a strong awareness of their impact on soil structure (Watson et al., 2002). Soil compaction has serious consequences for yield which organic farmers cannot afford. Crops and varieties with different rooting depths, rates of root extension, lifespan and architecture can be used to maintain carbon inputs to different parts of the soil profile (Ball et al., 2005), but also to help with maintaining soil structure and water retention capacity (Chantigny et al., 1997). Lower rates of run-off and soil erosion have been measured in organic systems (Reganold, 1987), and there is a suggestion that improved water holding capacity in organic systems may support greater yield stability in drought years (Lotter et al., 2003). Features of organic farming such as lower stocking rates can also help to prevent soil compaction and erosion, particularly in upland situations. Careful management of non-crop areas including hedgerows and buffer strips can help prevent erosion and nutrient loss to water courses.

Crop rotation is a key tool for maximising nitrogen retention within the system (Berntsen et al., 2006). Maintaining ground cover using cover crops, together with the appropriate timing of ploughing and manure applications can help minimise nitrogen loss from the arable part of a rotation. Leaching losses can be high on a single field following ploughing of leguminous leys but averaged over a whole farm or catchment these are moderated by lower losses from other parts of the rotation (Stopes et al., 2002). On a land area basis, nitrate leaching is often lower from organic than conventional grassland due to lower stocking rates, but there is a clear relationship between the size of nitrogen losses and nitrogen inputs whether in the form of soluble fertiliser, organic manures or nitrogen fixation. Taken overall, there is no evidence that organic farming systems have a higher risk of nitrate leaching than conventional systems (Kirchmann & Bergström, 2001). Restricted use of pesticides, growth promoters and antibiotics also helps to maintain water quality (Magbanua et al., 2010).

In organic farming, soil management through rotations plays a key role in suppressing weeds, pests and diseases. Soil health is generally enhanced where management and land-use decisions take into account the multifunctionality of soil, and deteriorates where decisions focus only on one function, typically crop productivity. Organic farmers' ability to work with their soils and ecosystems to deliver crop productivity may provide them with important adaptive management skills as farming systems will continue to have to adapt to changes in climate, increasing input costs and the need for maintained levels of productivity.

5 I ORGANIC FARMING AND RESOURCE EFFICIENCY

Myles Oelofse and Andreas de Neergaard, Plant and Soil Science, Department of Agriculture and Ecology; University of Copenhagen - Faculty of Life Sciences, Thorvaldsensvej 40; DK - 1871 Frederiksberg C.

- **Efficient use of resources, in particular concerning energy and nutrient supply and use, is crucial for future farming.**
- **Organic farming aims to use renewable resources, increase system recycling and reduce waste.**
- **The use of plant varieties adapted to organic production and supportive conditions for arbuscular mycorrhizal fungi lead to more efficient nutrient use in organic farming.**
- **Energy savings in organic farming are made through sparing synthetic nitrogen fertiliser.**

Future challenges for agriculture include changing energy systems, the globalisation of food systems and a changing climate (Høgh-Jensen et al., 2010). With the impact of modern agricultural practices upon natural resources becoming increasingly critical, the question for policy-makers seeking to ensure a sustainable future production of food is how these challenges can best be addressed (Spiertz, 2010). Sustainable use of resources in agriculture is imperative if we are to overcome these challenges. A critical question in this regard is which types of agricultural systems, as well as practices, are most resource-efficient, in particular concerning energy and nutrient supply and use. Future energy challenges are based upon impending peak oil coupled with issues relating to climate change, whilst concerns regarding nutrient supply and use are based upon prognoses about limited phosphorus (and limi- ted nitrogen availability determined by expensive energy sources) coupled with environmental concerns resulting from nutrient oversupply (Hildermann et al., 2010; Clabby, 2010). Future farming systems should thus seek to be highly resource-efficient, and profitable, whilst ensuring that practices are environmentally-sound and socially-acceptable (Spiertz, 2010). Organic farming seeks to achieve economic, environmental and social dimensions of sustainability, and a fundamental objective of organic agriculture is to use renewable resources, increase system recycling and reduce waste (Topp et al., 2007). In the following, the virtues of organic farming practices concerning resource efficiency will be discussed, taking departure in nutrient-use efficiency and energy efficiency.

Nutrient-use efficiency

In light of the aforementioned future challenges, the goal for agricultural systems is not only just to replace nutrients lost to the system, but also to find a

sustainable balance between inputs and outputs (Goulding, 2007). This entails shifting focus from yield maximisation through excessive external nutrient input, to finding more efficient ways of using nutrients. The nutrient-use efficiency (NUE) term provides an output/input ratio of nutrient flows into and out of defined pools (Noordwijk, 1999). Organic agriculture practices aim at improving the efficiency in use of limited nutrient supplies. Technologies for improving nutrient use efficiency in organic farming can be considered in two groups: 1) through the development of more efficient management practices; and 2) through the development of more efficient plants (Goulding, 2007). Improved nutrient-use efficiency on organic farms can occur through reduced nutrient losses due to lower stocking rates and fertilisation levels. Furthermore, lower nitrogen losses on organic farms from soils occur due to the incorporation of straw, manure and other compost which bind nitrogen in the soil (Kasperczyk and Knickel, 2006).

Nutrient losses in organic systems can furthermore be minimised through improved on-farm nutrient recycling, and through the use of biological nitrogen fixation (Lampkin, 1990). Manures and composts, green manures and cover crops are often recycled to ensure nitrogen is retained in the soil prior to spring sowing (Goulding, 2007).

Research reveals a large variation in NUE in organic farming systems and demonstrates the strong influence of a large range of general environmental and management factors. Watson et al. (2002) calculated nutrient-use efficiencies, defined as farm-gate nutrient outputs/inputs, for a range of 88 organic farms in nine temperate countries and found that NUE was highest in arable systems and lowest in beef systems. However, the results showed considerable variation between farms as well as farm types. Kasperczyk and Knickel (2006) conclude in their review that organic farms generally have smaller nutrient surpluses than conventional farms, particularly with regard to nitrogen. In a meta-analysis of the differences in environmental impacts of organic and conventional farming, Mondelaers et al. (2009) found that, when expressed per production area, organic farming showed lower leaching rates for nitrate and phosphorus than conventional farming and had on average higher soil organic matter contents. However, due to generally lower yields of organic farming, at least in developed countries, this positive effect expressed per unit product is less pronounced or not present at all (Mondelaers et al., 2009).

Lower nutrient surpluses in organic systems do not necessarily entail higher use efficiency, ultimately evident in yields. The use of crop cultivars bred and adapted to conditions in organic systems will enhance organic agriculture's ability to realise higher yields. For example, Murphy et al. (2007) demonstrated higher yields in organic wheat when selecting genotypes better suited to organic conditions. Therefore, efficiency in organic systems can be increased when selecting and breeding crops which can acquire and utilise nutrients more efficiently in environments where, for example, nitrogen supply is limited (Goulding, 2007). Hildermann et al. (2010) compared NUE parameters of different wheat cultivars cultivated in organic and conventional systems with different fertilisation levels and found a higher NUE for nitrogen and phosphorus in the organic systems. They conclude by stating that due to the considerable genetic variation in NUE within the tested cultivars, cultivars for organic low-input farming should be carefully selected. Moreover, they found that the establishment of a functional symbiosis with arbuscular mycorrhizal fungi (AMF) could be a promising strategy for improving NUE from organic sources of nutrients. Farmyard manure, compost and crop residues as used in organic farming and slow-releasing mineral fertilisers such as rock phosphate may promote AMF (Hildermann et al., 2010).

Energy efficiency

One of the objectives of organic farming is to reduce negative impacts on the environment. Therefore, it is important to consider energy consumption and efficiency (Topp et al., 2007). Studies generally show that organic farming has a lower energy consumption when compared to conventional practices. Gomiero et al. (2008) conducted a review of studies comparing energy use and efficiency in organic and conventional systems. The comparisons show that in most cases, organic farming consumed less energy both per unit area as well as per unit yield. These results were similar to those presented in a review by Topp et al. (2007). The primary reasons found for higher energy efficiency on organic farms were based upon the prohibition of use of energy-demanding agrochemicals, including the energy saved from absence of synthetic fertiliser, pesticide and herbicide production and transportation, and the lower use of energy-demanding foodstuffs for livestock (Gomiero et al., 2008). However, it is important to recognise, as Gomiero et al. (2008) conclude, that even though the energy efficiency (output/input) was found to be higher in the organic systems, conventional crop production had the highest total net energy production per unit area (higher yields). Organic grain yields are often lower than conventional yields, as for example Mader et al. (2002) show, presenting data from a long-term field experiment demonstrating that organic management had a much lower energy input compared to conventional, yet the yields were 20 per cent lower. There are a variety of different methodological approaches for comparing energy efficiency of conventional and organic farming (Kasperczyk and Knickel, 2006; Gomiero et al., 2008), thus caution should be shown when comparing systems, particularly when measuring efficiency (e.g. is the unit per unit area or per unit output).

Conclusion

Although it is a challenge to provide a unanimous point of view on which system type is most resource-efficient, it can be said that there is evidence that organic farming has favoured the development of techniques, breeds and practices that are beneficial regarding resource efficiency, since organic farmers generally have to deal with a relative poor nutrient supply. Topp et al. (2007) identify and discuss the methodological challenges of assessing the impacts of multifunctional agriculture on resources and call for the development of new tools and data for such assessments. Taking a holistic view of resource management on organic farms is very important when considering what system type best suits our needs. For example, high-yielding systems might appear more efficient when focussing on energy output alone; however, when considering potential environmental trade-offs (e.g. nutrient leaching or energy consumption), organic systems might be more beneficial.

6 I ORGANIC FARMING - AN EFFICIENT AND INTEGRATED SYSTEM APPROACH RESPONDING TO PRESSING CHALLENGES

Urs Niggli, Christian Schader and Matthias Stolze, Forschungsinstitut für biologischen Landbau (FiBL, Research Institute of Organic Agriculture), Ackerstrasse, CH-5070 Frick.

- **One strict and easily understandable rule in organic farming such as the ban of synthetic fertilisers often results in a number of environmental benefits.**
- **Organic farming support helps to minimise costs for farm support while increasing its environmental effects.**
- **Cost effectiveness of organic farming support can result from consistency of the policy measure, the system approach of organic farming and resulting synergetic environmental effects, as well as increased market values and lower transaction costs.**

Introduction

Agriculture is multifunctional by nature as it produces not only commodities but also many non-commodity outputs such as environmental services, landscape amenities and cultural heritage. The wealth of scientific results given in the preceding chapters of this brochure highlight that organic farming is amongst the best examples for this multi-output activity.

The IAASTD report recommended therefore in the year 2008 that new and successful existing approaches to maintain and restore soil fertility and to maintain sustainable production through practices based on **integrated management systems** and on understanding of agro-ecology and soil science (e.g. agroforestry, conservation agriculture, organic agriculture and permaculture) are paramount for coping with the challenges ahead.

The Tinbergen Rule (1956), which states that efficient policy needs at least as many independent policy instruments as there are policy targets, appears to contradict these IAASTD recommendations. Referring to the Tinbergen Rule, von Alvensleben (1998) argues that organic farming support payments are not economically-sound, as the policy objectives could be achieved more efficiently through using more flexible and targeted combinations of various agri-environmental instruments. Therefore, policy

support for sustainable farming systems is sometimes questioned against the background of limited public budgets and considerations of cost-effectiveness.

Since the beginning of the 1990s, European agri-environmental policy offers the option of providing financial support for organic farming. Area payments have turned out to be the most important financial instrument for supporting organic farming (Stolze and Lampkin, 2009). Will such payments for organic farming meet the requirements of clever targeting and tailoring of policies to achieve maximum effectiveness with a given budget (OECD, 2007)?

Organic farmers have adopted a strategy of complex management responses

Organic standards consist of strict rules, e.g. a complete ban of mineral fertilisers and synthetic pesticides. Thus, they are easy to understand for farmers and plain and simple to control. In order to cope with them, farmers have to respond with complex management measures: For instance, in weed control chemical herbicides cannot simply be replaced by mechanical weeding. Otherwise, infestation of weeds would escalate and become unmanageable a few years after transformation. In order to avoid such problems, farmers' first response is to diversify the crop rotation so that soil cover and root competition adversely affect weeds. The introduction of grass-clover leys into the crop rotation and cover crops further help suppress weeds. As a positive side-effect, soil fertility and nitrogen supply improve, and nutrient losses decrease. On top of prevention, mechanical weeding reduces weeds to residual but often diverse populations which host many (beneficial) insects. In addition, the superficial mechanical disturbance of the soils by harrows and hoes stimulates nitrogen mineralisation of the crop, closes macro-pores and reduces evaporation of water from the soil efficiently.

In a nutshell, a simple ban induces a chain reaction on farmers, resulting in more sustainable and productive farming systems. Similar examples can be given with other pesticides, slow-release fertilisers or veterinary medicaments where simple bans or restrictions unleash cascades of environmentally-sound preventive actions.

Organic farming is highly efficient at using scarce resources

Fortunately, agricultural science was interested in the performance of organic farming at an early stage already. Hence, a considerable number of statistically-designed field trials were started 20 to 30 years ago in different European countries. These empirical data from many years give a comprehensive picture of the

Table 3: **Input and output of organic and integrated farming systems of the DOK trial.** Long-term field trial DOK in Therwil (Switzerland): Data for the years 1977 to 2005.

Parameter	Unit	Organic farming	Integrated farming (IP) with farmyard manure	Organic in % of IP
Nutrient input	kg Ntotal ha^{-1} yr^{-1}	101	157	64%
	kg Nmin ha^{-1} yr^{-1}	34	112	30%
	kg P ha^{-1} yr^{-1}	25	40	62%
	kg K ha^{-1} yr^{-1}	162	254	64%
Pesticides applied (active ingredients)	kg ha^{-1} yr^{-1}	15	42	4%
Fuel use	Lha^{-1} yr^{-1}	808	924	87%
Total yield output for 28 years	%	83	100	83%
Soil microbial biomass "output"	tons ha^{-1}	40	24	167%

Explanation: Input of nutrients, organic matter, pesticides and energy as well as yields were calculated on the basis of 28 years. Crop sequence was potatoes, winter wheat followed by fodder intercrop, vegetables (soybean), winter wheat (maize), winter barley (grass-clover for fodder production, winter wheat), grass-clover for fodder production, grass-clover for fodder production. Crops in brackets are alterations in one of the four crop rotations. Integrated production (IP) is an improved conventional farming system.

ecological performance and yields of organic farming systems. Mäder et al. (2002) showed that an organic crop rotation used only 30 to 64 per cent of the nutrient input of the same conventional and integrated farming (IP) rotation, respectively (table 3). Average organic yields calculated for a period of 28 years on the other hand produced 83 per cent of the yield gained in IP farming systems and the living biomass of the organic soil topped the IP one by 167 per cent. The resource use efficiency – an important criteria for limited or non-renewable resources – is invincibly high for organic farming.

Organic farming support – an effective and efficient policy instrument

Policy instruments are evaluated against the criteria 'environmental effectiveness' and 'economic efficiency'. While effectiveness requires that the policy instrument is able to deliver effects that help to meet policy targets, efficiency ensures that these targets are met at lowest cost.

By using a mathematical optimisation model (linear programming), Schader (2009) could show that support schemes for organic farming as one part of a larger portfolio of agri-environmental measures helps to minimise costs for farm support while increasing its environmental effects. Therefore, there is no contradiction between the Tinbergen Rule and organic farming support payments. Introducing organic farming support payments in addition to independent and targeted policy instruments (e.g. payments for nature conservation, a carbon tax) may result in either lower costs for achieving the same level of policy targets or in a better target achievement with less expenditure as it tackles all three policy targets at once. In order to verify the theoretical models, Schader (2009) analysed empirical data of the Swiss agri-environmental scheme for three policy targets: 'reduction of fossil energy use', 'improvement of habitat quality (landscape and biodiversity)' and 'reduction of eutrophication (N and P)'. Area payments for organic farms were both very effective and efficient at achieving the targets, comparable to policy instruments targeted to specific environmental problems.

Cost-effectiveness of organic farming compared to specific agri-environmental measures

What could be reasons for a better cost-effectiveness of organic farming compared to specific agri-environmental measures?

Firstly, organic farming is perhaps the only way to pursue different challenges at the same time within one consistent policy instrument. For example, a basic element of organic farming is compost use which leads i) to higher yields in low-input systems, while at the same time ii) the increased soil organic matter is beneficial to biodiversity and soil structure, and iii) the abandonment of mineral nitrogen fertiliser reduces energy use and thus contributes to climate change mitigation. Organic agriculture therefore is likely to deliver cost-efficient solutions to complex global challenges of agriculture.

Secondly, organic agriculture guides farmers to solve the perceived discrepancy of integrating environmentally-friendly measures in the daily farm management business. Various authors showed organic farmers consider professional honour not only to be determined by maximum yields but also by successful implementation of nature conservation measures (Stotten, 2008). Thus, farmers' acceptance of agri-environmental policies could be considerably increased by organic agriculture (Schader et al., 2008).

Thirdly, the system approach of organic farming, e.g. the combination of many different rules, may induce synergetic environmental effects additional to the effects of each single restriction. The promotion of high nature value elements on farms, such as hedgerows, beetle banks and habitats for other beneficial insects in grass or wildflower strips along field margins becomes ecologically and agronomically much more attractive in combination with a ban on pesticides (Niggli et al., 2008).

Fourthly, organic agriculture is the only farming system which consistently succeeds in generating higher market values through premium prices. Due to consumers' trust in the organic labels and additional willingness-to-pay for organic products, payment levels do not need to cover the full costs of implementing organic farming. This makes organic farming attractive to policy-makers aiming at generating public benefits through both policy support and market mechanisms.

Fifthly, the multi-purpose character of organic agriculture could increase its cost-effectiveness due to potentially lower transaction costs compared to targeted agri-environmental measures (Dabbert et al., 2004). According to Lippert (2005), savings of transaction costs in organic agriculture include: a) lower administrative costs, because less agri-environmental measures have to be administered per farm

(economies of scope in administration); b) generally lower control costs, because the full ban of synthetic pesticides and mineral fertiliser is easier to control than thresholds; c) lower costs of control due to a combined control of several attributes (economies of scope at inspection level); d) lower fixed administrative costs due to the use of existing structures for the establishment of control systems; and e) lower intensity of control, as organic farmers risk their reputation if convicted of violation of standards.

Conclusions

Recent scientific publications showed that designing policy instruments on the grounds of the Tinbergen Rule is neither a knock-out criterion against organic farming policy support nor does it imply that multi-objective policy instruments like organic farming are per se inefficient. On the contrary, we demonstrated on the basis of most recent scientific literature that organic farming policy support and specific tailored policy instruments are complementary while focusing only on one of these approaches could bear inefficiencies.

Therefore, we suggest building future agri-environmental policies on two floors:

1. The solid basement addresses the main objectives of European agricultural policy, especially climate change, biodiversity and global food security through organic farming support. This multi-objective policy instrument is a perfect means to capture both the strong interrelations and potential trade-offs between separate food security, biodiversity and climate change policies in a consistent policy concept.
2. The second level consists of tailored policy instruments which will be built on top of this basement. These tailored policies accommodate the regional differences in the EU and are to ensure that the targets for biodiversity, climate change and food security can be fully met in all EU regions. In this respect, tailored policies need to be flexible and region-specific, making reference to geographical, natural and socio-cultural conditions.

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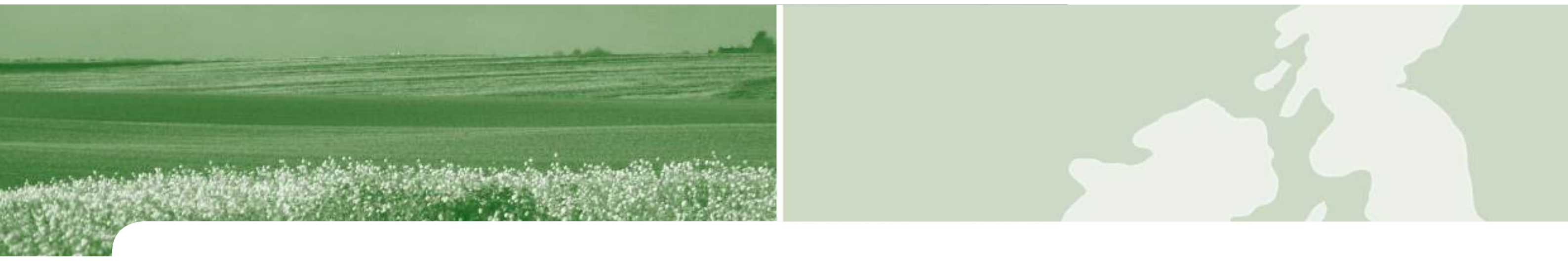

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Organic food production - a comprehensive tool box to meet the sustainability challenge

Climate change, biodiversity loss, soil degradation, water pollution and increasing pressure on natural resources, such as soil nutrients and fossil fuels are amongst the most pressing challenges for society. Agriculture and food production play an important part in both causing harm and offering solutions to meet these challenges. The EU with its Common Agricultural Policy (CAP) has a policy instrument available, of which best use must be made to shape agriculture towards best practices that allow meeting the above-named challenges.

Policy support favouring organic farming and specific tailored policy instruments are complementary, effective tools to tackle environmental challenges under the CAP. Whereas specific agro-environmental measures can help tackle problems one by one and are in particular useful to react to specific local problems, the concept of organic farming offers a holistic approach to meet several environmental challenges at once, while at the same time also supporting animal welfare and delivering high-quality food. Due to synergy effects, an efficient European-wide control system in place and organic food being a quality label with an enhanced market value, structurally supporting organic farming is not only an effective, but also a cost-efficient tool to reach sustainability objectives within agricultural policies.

The dossier “Organic food and farming – a system approach to meet the sustainability challenge” delivers scientific data that underpin the value of policy support for organic farming as effective tool to tackle sustainability challenges in the food sector.

The IFOAM EU Group is the European working level within the International Federation of Organic Agriculture Movements. It brings together more than 340 organisations, associations and enterprises from all EU-27, EFTA and candidate countries. IFOAM´s goal is the worldwide adoption of ecologically, socially and economically sound systems that are based on the principles of Organic Agriculture.

Rue du Commerce 124, BE - 1000 Brussels, Phone: +32 2 280 12 23 - www.ifoam-eu.org - info@ifoam-eu.org