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Organic farming - stewardship for food security, food quality, environment and nature conservation

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Summary

Conventional agriculture is associated with problems such as pesticide residues in soils and plants, contamination of meat with antibiotics and hormones, and eutrophication of water bodies. An alternative for consumers is the consumption of products from organic farming. Organic management is possible on arable farms, although livestock is often a crucial part of the system as manure and slurry can contribute significantly to maintaining closed nutrient cycles. Independent of the management system, it is not possible to exclude nutrient losses to the environment on agricultural fields, but acceptable loads need to be defined. Organic farming can contribute to environmental protection and nature conservation in many ways, for instance by improving soil porosity which yields higher infiltration rates and thus contributes significantly towards mitigating flooding peaks. It is the objective of this contribution to provide a holistic appraisal of what organic farming is going to deliver.

Key words: authenticity, earthworm, ecobalance, flooding, image forming methods, plant health, sustainability

Introduction

Organic farming, compared to conventional and industrialised farming shows fundamental differences from agricultural, environmental, social and economic point of view. Organic farming is a well defined production concept (Schmidt & Haccius, 1998) which provides practical solutions to various problems of agricultural production (Rundgren, 2002) and therefore meets best the demand for sustainability as outlined by the Brundtland Commission (1997) which stated that "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Additionally, organic farming provides 'authentic' food, an aspect that will supposedly gain increasing significance for consumers in future. It is the aim of this contribution to provide a comprehensive overview of what organic farming can deliver in the sectors food security, food quality, and environment and nature conservation. Here, special attention will be paid to prominent highlights.

Food security

A common argument against organic farming is that it abandons the results of modern agricultural research and thus stands for the deliberate step backwards in history and thus jeopardising food security on a global scale. But quite the opposite is the case: based upon an exhaustive understanding of biological and physiological processes, it will be possible at the end of the day to replace chemical aid by physiological know-how. These studies will certainly involve methods of biotechnology. An actual example of how research provides substantial advances for crop protection is the concept of Sulphur Induced Resistance (SIR). Detailed information about the potential of SIR for organic farming will be given by Haneklaus *et al.* (this volume).

The Rome declaration on world food security "reaffirms the right of everyone to have access to safe and nutritious food, consistent with the right to adequate food and the fundamental right of everyone to be free from hunger" (World Food Summit 1996). A serious, but common allegation is that organic farming aggravates the problem of world hunger because of its lower yields compared to those obtained in intensive farming systems. Kimbrell (2002) points out that "world hunger is not created by lack of food but by poverty and landlessness, which deny people access to food. Industrial agriculture actually increases hunger by raising the cost of farming, by forcing tens of millions of farmers off the land, and by growing primarily high-profit export and luxury crops". Kimbrell (2002) concludes that the only solution to problems related to industrialised agricultural production is a return to sound organic agricultural practices.

Fact is that the per capita food production in sub-Saharan Africa declined in the past 20 years by 20% because of a decline in soil fertility (Nwanze *et al*., 2004). Here, organic farming or small farming enterprises with similar lines of operation offer the chance to improve soil fertility and at the end increase food production (Halberg *et al*., 2006). The same authors pointed out that 'green revolution' technologies were not applicable in sub-Saharan Africa because of the basic problem of low yield potential, political and socio-economic constraints. Apart from this principal coercion, the promise of genetically modified crops to substantially improve food security by higher yields (Conway, 2000; Phipps & Beever, 2000) has not been fulfilled so far and critical researchers even point out the risk that genetic engineering will strengthen the cleft between rich and poor in developing countries (Jordan, 2002). Liebig's law of the minimum should be conjured in so far as it is the strongest limiting factor that determines crop yield. In developing countries where for instance the fertiliser input is up to 26 times lower than in intensive farming systems (Nwanze *et al*., 2004), it seems unlikely that the cultivation of genetically modified crops will bring a real breakthrough in food security.

Interesting is also with regard to developed countries the results of a case study from Austria that even a total switch to organic farming will not compromise food security, however, will fully assert demands of sustainable agricultural production (Kratochvil *et al*., 2004).

Food quality

Food quality is an issue of increasing public interest. The subject targets not only the content of nutritional compounds, health promoting or otherwise beneficial substances and features, but more and more the way food is produced. Agriculture was associated positively with food production and food security less than a century ago. In comparison, it is nowadays commonly linked to problems such as eutrophication of water bodies, enrichment of pesticides in soils and plants and contamination of meat with hormones and BSE (Bovine Spongiform Encephalopathy). Alternatives for consumers are products from organic farming, which aims at closed nutrient cycles, bans synthetic pesticides completely and acknowledges ethical aspects of livestock production. System inherent organic products contain no potentially harmful food preservatives, pesticides and phytochemicals. Organically produced foodstuff may even have significantly higher contents of secondary metabolites (Schlee, 1992; Ebata *et al,* 1993; Brandt & Mølgaard, 2001; Ren *et al*., 2001). Additionally, there are indications that organic food is beneficial for human health but more experimental studies are required to prove this hypothesis (Marckmann, 2000).

Organic farming has been stirring the emotions of conventional farmers since its beginnings with the organic farming movement initiated by Sir Albert Howard (1873-1947) and the anthroposophic agricultural lectures of Rudolf Steiner in the early 1920's (Barton, 2001; Steiner, 1924). Extended investigations were carried out in order to identify qualitative differences between products from both management systems (Woese *et al.*, 1995 and 1997) and organic products usually had a significantly higher dry matter content and lower nitrate concentrations (Woese *et al.*, 1997). But nutritional quality implies not only physico-chemical parameters, which can rapidly be determined by laboratory analysis, but also 'dynamic' features, which Balzer-Graf (1987) describes as vitality, differentiation and regeneration. These can be assessed so far only by image forming methods. Tingstad (2001) illuminates the terms quality and provides insight in the potential of the picture rising method. A validation of the method is currently carried out (Busscher *et al.*, 2004).

Non-protein nitrogen compounds

The enrichment of non-protein nitrogen (N) compounds such as amides is primarily a problem of an excess N supply, and is promoted if sulphur (S) deficiency occurs at the same time. On intensive livestock farms values for the N fertiliser input of up to 340 kg ha^{-1} to sugar beet were found (Haneklaus *et al.*, 1997) and the N surplus is on average 154 kg N ha^{-1} yr^{-1} in the UK (Lord *et al*., 2002). In contrast, N is regularly the strongest limiting factor in organic farming. It is the use of growth regulators that enables an excessive use of N in conventional farming as undesired side effects of over-fertilisation are compensated. Growth regulators such as chlorocholinchloride (CCC) accumulate in crops in dependence on N fertilisation and thus enter the food chain (Bier & Dedek, 1972; Landazuri *et al.*, 1993). Due to the toxic effects of CCC in animals, adverse effects in humans cannot be excluded (Landazuri *et al*., 1993).

The most important non-protein N compound enriched following S deficiency is nitrate. Nitrate is prone to microbiologically induced reduction to nitrite by nitrate reductase during storage and processing of vegetables and nitrite is toxic to humans by blocking the oxygen carrying capacity of haemoglobin or as a potential precursor for carcinogenic nitrosamines. Ellen *et al.* (1982), however, found no formation of nitrosamines in humans after intake of nitrates. Nitrosamines are carcinogen and mutagenous (Hodgson & Levi, 1997). An intake of 0.17 mg nitrate per kg body weight yielded a spontaneous mutation rate of 12.5% (Wiesner, 1984). There is a still ongoing discussion whether an increased intake of nitrate enhances or reduces the risk of gastro-intestinal cancer. Leifert & Golden (2001) attribute a reducing effect to the fact that nitrate is reduced in the oral cavity to nitrite, which is protective against intestinal pathogens. In contrast Schlatter (1984) found a close relationship between nitrate intake and nitrite synthesis in the oral cavity and stated that the synth1esis of nitrosamines increased over-proportional with increasing nitrate and nitrite intake.

Sensory characteristics

Rembialkowska (2000) states that particularly fresh organic vegetables had significantly better sensory features (taste, scent) than conventional products. Marckmann (2000) expects a higher intake of organic food because of favourable sensory features, which in return may positively affect diseases such as obesity and type 2 diabetes. It is known that sensory features of vegetables are linked to plant nutritional factors: glucosinolates and alliins cause for instance the pungency of mustard, radish, onion and garlic. Both components contain S and experimentation proved that their content was closely linked to the S nutritional status (Bloem *et al.*, 2004). Besides that both components are supposed to have a high health protective effect (see above).

Medicinal plants

There are many plants with therapeutically active compounds claiming to act as anti-carcinogenic, antibiotic, anti-hypertensive and cholesterol reducing agents (Verhoeven *et al.* 1997). There is an increasing market for phyto-pharmaceuticals and such products are of interest for human and animal application. The latter aspect is of prime interest as medicinal substances are strictly regulated in organic farming and infectious diseases of the gastrointestinal tract a severe problem (Jacobsen & Hermansen, 2001). But also conventional farmers look out for effective substitutes of antibiotics since their use as feedstuff additives is prohibited in the EU since January 1, 2006.

The validation of the curative effect of different medical plants is important for developing new, efficient phyto-pharmaceuticals. The cropping of medicinal plants could positively contribute to the income of organic farms as the guidelines for good agricultural practice for medicinal and spice plants demands products, which are not contaminated by pesticides (Europam, 1998).

Environment

Precision Agriculture technologies

Independent of the management system, it is not possible to exclude nutrient losses to the environment on agricultural fields, but acceptable loads need to be defined. For an efficient reduction of non-point N losses it is necessary to take the spatial variability of soil features, which affect N dynamics in the soil and N utilisation by the plant into account. It is therefore not satisfying to define a field as the smallest operational unit. This should be the pedon, which represents the smallest homogenous unit or area in a field. The size of a pedon depends on the landscape and can be small as 10 m^2. A site-specific, variable rate nutrient management could therefore be the solution to this universal problem.

In organic farming systems where legal guidelines exclude or restrict their use (Schmidt & Haccius, 1998), the relative significance of soil-borne nutrients for the nutrition of plants increases. This stresses the particular value of a variable rate nutrient management for small farming and low input systems, while usually precision agriculture technologies focus on large-scale farming (Haneklaus & Schnug, 2006). The strategy would imply spatially variable measures, which increase the utilisation of soil nutrients by improving their mobility or uptake efficiency by the crop. The first option would be feasible for nutrients with an expressed dependency on soil pH such as micronutrients and phosphorous, the second by promoting root growth in order to improve the source:sink ratio of nutrients (Haneklaus & Schnug, 2006). The use of raw phosphates requires methods to efficiently improve their solubility (Schnug *et al*., 2006). Besides that their heavy metal content needs to be considered in order to avoid an undesired accumulation in soils (Schnug *et al*., 2006). Suitable measures for a variable rate management would also involve variable tillage and sowing operations, variable rate applications of lime or acidifying fertilisers such as elemental S.

Precautionary measures for soil and flood protection

The infiltration rate (mm h^{-1}) defines the velocity with which water passes through the soil profile. High values minimise not only the risk of run-off and erosion, but also local flooding events by reducing peak values during extremely high precipitation. Sparovek *et al.* (2002) showed that the risk of extreme floodings increased over-proportionally if infiltration rates were lower than 15 mm h^{-1}. Important factors causing reductions of infiltration capacity in agricultural soils are compaction, loss of mechanical stability and biological activity. Maintaining a high infiltration capacity of soils is one of the most significant achievements of agriculture, which is not covered by the prices of agricultural products. Independent of the production system conservation soil tillage improves significantly the infiltration capacity (Schnug *et al.*, 2004). On organic farms there are, however, a number of factors with positive effects on infiltration rates such as a wide crop rotation, abandonment of pesticides and higher organic matter content together with the stimulation of soil life. Organic farmed soils have more "biopores" because of a larger biomass and density of earthworms and particularly a higher number of anecic earthworm species so that finally infiltration rates were twice as high than on conventionally farmed soils (Schnug *et al.*, 2004). The spatial extension of organic farming provides therefore an efficient counter-measure against the adverse effects of anthropogenic sealing of soils.

Nature conservation

A comparative study on the influence of the farm management system on nature and landscape in Ireland revealed that organic farming had a positive effect in every respect (MacNaeidhe & Culleton, 2000). Organic farming contributes distinctly to nature conservation on different levels: it stimulates the micro-flora and micro-fauna in the soil, yields a higher number and biodiversity of meso, macro and mega-fauna (Pfiffner, 2004). The reason behind this effect is the diversified crop production with a balanced nutrient supply. A higher diversity of arable field plants is part of a successful pest and disease control (van Elsen, 2000). Such higher biological activity of soils favours self-regulatory mechanisms so that organically managed soils are more stable under adverse biotic and abiotic growth conditions than soils under intensive management. A strong beneficial effect of organic farming was also found for birds, butterflies and bumblebees and herbaceous plants with two to five times higher figures compared to conventional farms (Belfrage *et al.*, 2005). Noteworthy is that in these studies the extent of this effect was also closely related to farm size of the organic farms. A higher biodiversity can also be found with respect to housing of endangered animal breeds. These environmental effects of organic farming are components of the ecobalance (Haas, 2003). Haas (2003) addressed the following general and agriculture specific parameters that should be assessed in each ecobalance: consumption of fossil resources, emission of greenhouse gases, odour and noise emissions, (drinking) water quality, eutrophication, ecological and human toxicity, soil functions, natural scenery, diversity of biotopes and species, cultivation of GMOs, animal welfare. In such system-based comparative studies organic farming proved to obtain better appraisals (Haas, 2003). Different results might be the outcome if exclusively individual parameters are examined. So, Kumm (2002) showed that organic beef and lamb production had advantages with view to nature conservation, while in case of pork the discharge of nitrogen and greenhouse gases per kg meat was higher than on conventional farms.

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