State of the art of organic agriculture - research, practice and societal benefits

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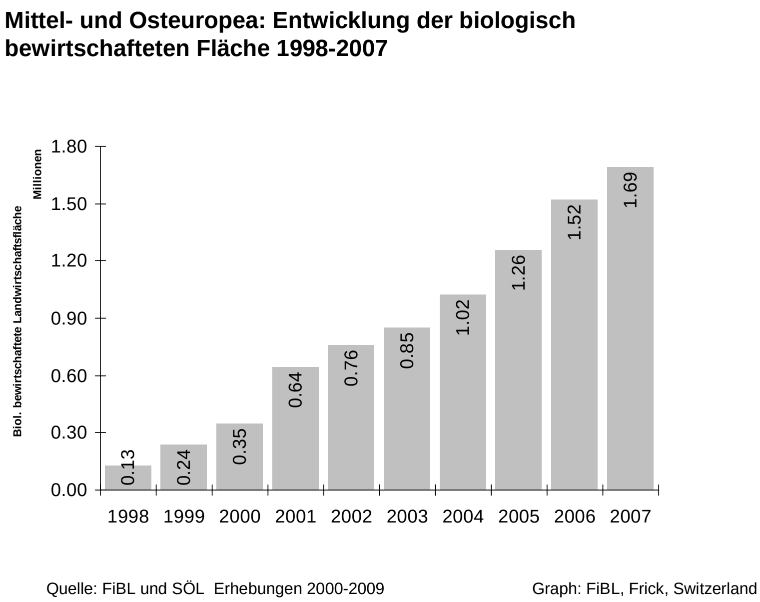
Globally, current agriculture faces unprecedented challenges and exciting opportunities. Unprecedented challenges result from the need of securing food supply to a rapidly growing human population, while at the same time having to minimize adverse impacts of agricultural production on the environment. Exciting opportunities relate to new management options opened up by alternative production targets, technological developments, and changing consumer preferences.

Such a shift towards sustainable agricultural production entails adopting comprehensive, more system oriented strategies. Such strategies include farm-derived inputs and productivity gained from ecological processes and functions. Furthermore, it involves traditional knowledge and entrepreneurial skills from farmers (IAASTD, 2008). Currently, system oriented sustainable practices include organic farming, low external input sustainable agriculture (LEISA), integrated pest management, integrated production (IP) and conservation tillage. The most consequent approach of these is organic farming. Because of the ban or restricted use of many direct control techniques like pesticides, herbicides, fast acting fertilizers or veterinary medicines, organic farmers heavily rely on preventive and system-oriented practices.

Organic Agriculture has developed very dynamically in many countries in Central and Eastern Europe. Since 2000 the organic cultivated areas has quintupled and reached 1.7 million hectares (2007). These markets are still very small and haven't reached 1% of the overall market. The main reasons for that are the low purchasing power as well as a still poor developed processing and distribution structure (Willer, 2009)



Graph: Development of Organic Agriculture in Central and Eastern Europe 1998-2007

Source: FiBL 2009. Details available at www.organic-world.net/background-countries.html

Permanent crops like coffee, tea, cocoa, coco nuts and olives are increasingly produced according to organic standards in order to satisfy the fast changing consumer habits. Global markets for certified organic products have grown to 46.1 billion US Dollars (Willer and Kilcher, 2009).

Multifunctional characteristics of organic farming

In the past, the unsustainable production of food, feed, fibre and fuel has strongly degraded global ecosystems and their services provided for human survival (Millennium Ecosystem Assessment, 2005). Such ecosystem services include, for example:

- the provision of pure water,
- the recycling of organic matter and nutrients as well as
- the regulation of climate and weather events by fertile soils,
- the regulation of crop pests and diseases by biodiversity and natural enemies or
- the pollination of crops by wild animals.

No other form of agriculture and food production can claim to offer so many benefits to consumers and to provide such a bounty of public goods as organic farming and food systems. These claims are substantiated by scientific evidence (for a comprehensive review of the literature see Niggli et al., 2008; Twarog, 2006 in UNCTAD, 2006; Scialabba El Hage and Hattam, 2002; Stolze et al., 2000). The most distinct environmental advantages can be summarized as follows:

Biodiversity

Biodiversity is an important driver for the stability of agro-ecosystems (Altieri et al, 2005) and, hence, for a continuously stable supply of food. In organic agriculture, biodiversity is both instrument and aim. As organic farmers cannot use synthetic substances (e.g. fertilizers, pesticides, pharmaceuticals) they depend on restoring carefully the natural ecological balance. At farm level, diversity is practised as multiplicity of farm activities (e.g. by adding value through processing and direct marketing or by combining farming with farm schools, visits and adult courses). In the fields, diversity is achieved by manifold crop rotations or agro-forestry. Ultimately, organic farms cannot be operated in the long run with strongly simplified cultivations focussing only on economically attractive crops.

Reduced negative environmental impact

The high dependency of traditional farming from bought-in chemical fertilizers, herbicides and pesticides has caused environmental damages. Due to the ban of chemical fertilizers on organic farms, 35 to 65 % less nitrogen leaches from arable fields into soil zones where it could deteriorate ground and drinking water quality (Drinkwater et al., 1998; Stolze et al, 2000). Other nutrient elements like potassium and phosphorous are less excessive in organic soils which increases their efficient use (Mäder et al., 2002). Residues of synthetic herbicides and pesticides in soils, surface and ground water do not occur on organic farms as they are not applied.

Stable soils – less prone to erosion

Fertile soils with stable physical properties have become the top priority of sustainable agriculture. Essential conditions for fertile soils are stupendous populations of bacteria, fungi, insects and earthworms which build up stable soil aggregates. There is vast evidence from European, US, Australian and African studies that organic farms and organic soil management yield a good soil fertility. Compared to conventionally managed soils, organically managed ones show higher organic matter contents, higher biomass, higher enzyme activities of microorganisms, better aggregate stabilities, improved water infiltration and retention capacities and less water and wind erosion (Edwards, 2007; Fliessbach et al., 2007; Marriott and Wander, 2006; Pimentel et al, 2005; Reganold et al., 1987; Reganold et al, 1993, Siegrist et al., 1998). The fact that organic farmers use periodically a plough in order to bury weed roots and seeds, does not make their soils more prone to erosion (Teasdale et al., 2007).

Carbon sequestration

Organic farmers use different techniques for building up soil fertility. The most effective ones are fertilization by animal manure, by composted harvest residues and by leguminous plants as cover and catch crops. Introducing grass-clover leys as feed stuff for ruminants into the rotations and diversifying the crop sequences also augment soil fertility, like reducing ploughing depth and frequency. All these techniques also increase carbon sequestration rates on organic fields. Long term field experiments in the US and in Europe reveal significant carbon gains in organically managed plots whereas in the conventional or integrated plots soil organic matter is exposed to losses by mineralization. The average difference of the annual sequestration between the best organic and the worst conventional management in four field trials in the USA, Switzerland and Germany amounts to 590 kg C or 2.2 tons of CO_2 per hectare arable land. A further increase of carbon capture in organically managed fields can be measured by reducing the soil tillage frequency.

More efficient use of nitrogen on organic farms – less greenhouse gas emissions

In organic agriculture, the ban of industrially produced nitrogen and the reduced livestock density per hectare considerably decrease the concentration of easily available mineral nitrogen in soils and, thus, N_2O emissions. Furthermore, diversifying crop rotations with green manure improves soil structure and diminishes N_2O emissions. Soils managed organically are more aerated and have significantly lower mobile nitrogen concentrations, which further reduces N_2O emissions. As a consequence, the limited availability of nitrogen in organic systems requires careful, efficient management (Kramer, *et al.*, 2006). In a long-term field trial in Switzerland run for 32 years, the total nitrogen input into an organic arable crop rotation over 28 years was 64 % of the integrated/conventional rotation; the total organic yields over the same period were 83 % of the conventional ones. Therefore, organic farms use nitrogen in a more efficient and less polluting way (Mäder et al., 2002).

Organic farms are well adapted to climate change

As a result of climate change, agricultural production is expected to face less predictable weather conditions than experienced during the last century. Especially South Asia and Southern Africa are expected to suffer from negative impacts on important crops with possibly severe humanitarian, environmental and security implications (Lobell et al. 2008).

Thus, the adaptive capacity of farmers, farms and production methods will become especially important to cope with climate change. But the capacity of farms to adapt to climate change does not only depend on soil qualities but also on their diversity and diversification. A greater mix of different farm activities is the best way to cope with failures. The parallel farming of many crop and livestock species reduces weather induced risks to a great extent. Landscapes rich with natural elements and habitats buffer climate instability effectually. New pests, weeds and diseases – results from global warming – are likely to be less invasive in natural, semi-natural and agricultural habitats which are buffered by a high number and abundance of species (Zehnder et al., 2007; Altieri et al., 2005; Pfiffner et al. 2003).

Can organic farming feed the world?

The picture painted by many critics of organic farming to be unproductive and technophobic is misleading. In many cases, organic farming is a very productive way of producing food. In addition, organic farming systems use many modern technologies like bio-pesticides, natural fertilizers and parasitic or predatory insects or microorganisms in a smart way. Even in the case of highly controversial technologies like genetic engineering, organic farming uses selectively some tools (e.g. molecular markers in breeding or in the diagnosis of pest and disease incidences in crops and livestock). Actually, there is no contradiction between organic rules and cutting-edge technologies. Technologies are banned in cases where risks are increased, where precaution is necessary and prevention offers better solutions. The ban of synthetic nitrogen showcases this strategy: Organic farmers manage nitrogen derived from organic matter, soils and legumes more carefully and with fewer losses as nitrogen is scarce. As a result, organically managed soils are more fertile and resilient to diseases and drought. This also makes organic farmers independent from rising oil prices, imported synthetic inputs and reduces the environmental impact of farming considerably (Granstedt, 2006; Crews and Peoples, 2004).

Conclusion

Sustainability in food production entails more than merely balancing economy and ecology. Its purpose is to ensure human well-being. Ethical and cultural issues are of equal importance in this vision. Ethical issues concern, for example, animal welfare, good governance and well-informed, independently-minded citizens who are capable of making decisions about the quality and the diversity of food they consume. In the context of sustainability, ethical farming, trade and consumption are existential issues for the human species. Organic agriculture is more than a less polluting form of food production. It basically questions food habits of people in developed and emerging regions of the world. As organic farms have lower livestock densities because of their environmental impact and because of the ban of factory farms, more land is available for vegetable production with a seven times higher calorie output for human nutrition. In consequence, organic agriculture implicates a more reasonable eating pattern, less based on meat and dairy foods, and a higher proportion of vegetable foods. Good for health, good for the environment and good for global food security!

Literature

Altieri, M. A., Ponti, L. and Nicholls, C. (2005): Enhanced pest management through soil health: toward a belowground habitat management strategy. *Biodynamics* (Summer) pp. 33-40.

Beverly D. McIntyre et al.. Island Press, Washington. Download at http://www.agassessment.org/reports/IAASTD/EN/Agriculture%20at%20a%20Crossroads_Global%20Report%20(English).pdf

Crews, T. E. and Peoples, M. B. (2004) Legume versus fertilizer sources of nitrogen: ecological tradeoffs and human needs. *Agriculture, Ecosystems & Environment* 102, 279-297.

Drinkwater, L.E. et al, 1995. *Fundamental Differences between Conventional and Organic Tomato Agroecosystems in California.* Ecological Applications, v. 5 (4) p. 1098-1112

Edwards, S. (2007): The impact of compost use on crop yields in Tigray, Ethiopia. Institute for Sustainable Development (ISD). Proceedings of the International Conference on Organic Agriculture and Food Security. FAO, Rom. Obtainable at: ftp://ftp.fao.org/paia/organicag/ofs/02-Edwards.pdf

El-Hage Scialabba, N. and Hattam, C. (Eds.) (2002): Organic agriculture, environment and food security. Environment and natural resources series, no. 4 . Rome : Food and Agriculture Organization of the United Nations, 2002.

Fließbach, A., Oberholzer, H.-R., Gunst, L., Mäder, P. 2007. Soil organic matter and biological soil quality indicator after 21 years of organic and conventional farming. Agriculture, Ecosystems and Environment, 118: 273-284.

Granstedt, A. 2006. Baltic Ecological Recycling Agriculture and Society (BERAS). Executive Summary. http://www.jdb.se/beras/files/BERAS%20executive%20summary%20final.pdf

International assessment of agricultural knowledge, science and technology for development (IAASTD) (2008): Global report / edited by

Kramer, S.B., Reganold, J.P., Glover, J.D., Bohannan, B.J.M., Mooney, H.A. 2006. Reduced nitrate leaching and enhanced denitrifier activity and efficiency in organically fertilized soils. Proc. Natl. Acad. Sci. USA 103:4522- 4527.

Lobell, D.B., Burke, M.B., Tebaldi, C., Mastrandrea, M.D., Falcon, W.P. and Naylon, R. L. (2008): Prioritizing Climate Change Adaptation. Needs for Food Security in 2030. *Science* 319: 607 – 610.

Mäder, P., Fließbach, A., Dubois, D., Gunst, L., Fried, P. and Niggli, U., 2002: Soil fertility and biodiversity in organic farming. Science, 296: 1694-1697.

Marriott, E.E. and Wander, M.M. (2006): Total and Labile Soil Organic Matter in Organic and Conventional Farming Systems. Soil Sci. Soc. Am. J. 70, 950-959.

Millennium Ecosystem Assessment, 2005. *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, DC.

Niggli, U., Schmid, H., Fließbach, A. 2008. Organic Farming and Climate Change. In: Kasterine, A. (ed.), International Trade Centre UNCTAD/WTO, Geneva, International Trade Centre. 30pp.

Pfiffner, L., Mäder, P., Besson, J.-M., Niggli, U., 1993. DOK-Versuch: Vergleichende Langzeit-Untersuchungen in den drei Anbausystemen biologisch-dynamisch, organisch-biologisch und konventionell. III. Boden: Untersuchungen über die Regenwurmpopulationen. Schweiz. Landw. Fo. 32(4): 547-564.

Pimentel, D., Hepperly, P., Hanson, J., Douds, D., Seidel, R. 2005. Environmental, energetic, and economic comparisons of organic and conventional farming systems. Bioscience, 55(7): 573-582.

Reganold, J., Elliott, L. and Unger, Y. (1987): Long-term effects of organic and conventional farming on soil erosion. Nature330, 370-372.

Reganold, J.P., Palmer, A.S., Lockhart, J.C., Macgregor, A.N. (1993): Soil Quality and Financial Performance of Biodynamic and Conventional Farms in New Zealand. *Science* 260, 344-349.

Stolze, M., Piorr, A., Häring, A.M., Dabbert, S. 2000. Environmental impacts of organic farming in Europe, Stuttgart-Hohenheim.

Teasdale, J.R., Coffman, C.B., Mangum, R.W. 2007. Potential long-term benefits of no-tillage and organic cropping systems for grain production and soil improvement. Agronomy Journal, 99 :1297-1305, DOI:10.2134/agronj2006.0362

Teasdale, J.R., Coffman, C.B., Mangum, R.W. 2007. Potential long-term benefits of no-tillage and organic cropping systems for grain production and soil improvement. Agronomy Journal, 99 :1297-1305, DOI: 10.2134/agronj2006.0362

Twarog, Sophia (2006): Organic agriculture: a trade and sustainable development opportunity for developing countries = CHAPTER 3: PART I of: TRADE AND ENVIRONMENT REVIEW 2006. United Nations Conference on Trade and Development. Geneva. Download at http://www.unctad.org/en/docs/ditcted200512ch3p1_en.pdf

Willer H. and Kilcher, L. (Eds.) 2009: The World of Organic Agriculture. Statistics and Emerging Trends 2009. IFOAM, Bonn, FiBL, Frick, ITC, Geneva

Willer, H. (2009): Die Biomärkte in Mittel- und Osteuropa: Dynamisches Wachstum. In: Biosigel-Report 2/2009, S. 9-10. Download at http://www.bio-siegel.de/fileadmin/user_upload/Dokumente/Reports/BioSiegel-Report_02_2009.pdf

Zehnder, G., Gurr, G.M., Kühne, S., Wade, M.R., Wratten, S.D., Wyss, E. 2007. Arthropod pest management in organic crops. Annual Revue of Entomology, 52: 57-80.