HEINRICH BÖLL STIFTUNG

Less hunger through more ecology

What can organic farming research contribute?

Johannes Kotschi

Berlin, November 2011

Heinrich-Böll-Stiftung
Die grüne politische Stiftung

Schumannstraße 8 10117 Berlin
Telefon 030.285 34-0 Fax 030.285 34-109 **www.boell.de**

1. Introduction

Can the world be fed in the long run? This question has been posed at regular intervals ever since Malthus published his theory of population 200 years ago. Drastic rises in food prices since the beginning of the 21st century, coupled with an increase in the number of hungry in the world to close to one billion people at present have renewed the pertinence of this question.

At the same time, environmental issues in agriculture are increasingly at the forefront of the public debate. This concerns climate change mitigation, the preservation of biodiversity, the sustainable use of water resources and the protection of cultural landscapes with their various ecosystem services such as drinking water, clean air, and recreation space. Food security can therefore no longer be viewed as an isolated issue these days but as part of a multi-dimensional target function of multifunctional agriculture, which, in addition to producing food, must also satisfy numerous ecological and social tasks.

With regard to food security, there would be sufficient food in the world to feed the global population today. The vast majority of the hungry are either too poor to afford food or do not avail of the requisite access to production resources (land, water, seed, etc.) to feed themselves and their families through self-sufficient means. The problem is frequently aggravated by misguided agricultural policies or even wars and conflicts.

As a consequence, the solutions needed to eliminate hunger, malnutrition or undernourishment are highly complex. There is a pronounced need for distributive justice when accessing vital means of production such as land, water and seed; there is also an urgent need for the improved utilisation of scarce resources including the avoidance of post-harvest losses, while, among the poorer classes of the population, long-term income security is required. Moreover, a political framework must be established, in both agricultural and economic policy – and equally in trade and investment policy – which empowers small-scale farming systems and does not lead to a softening of the income situation and, by the same token, a reduction in food security among poor populations.

That said, a mere growth in production does not bring the desired effects. Nevertheless, an increase in food production is highly important. More than ever before it has to be asked how this can be achieved on a sustained basis – given the limited amount of natural resources (land and water), the rising prices of crude oil and the challenges posed by climate change. How can food be secured for those suffering from hunger today, and for the nine billion forecast for 2050?

There is mounting evidence that agriculture must be fundamentally realigned in order for the following three goals to be achieved collectively: food security, adaptation to climate change, and preservation of natural resources. Today, very few people dispute that the ecologisation of agriculture is a core principle for this realignment. Organic agriculture has already provided significant impetus, and it can also be viewed as the driving force behind a renewal of agriculture in the future.

2. Agricultural intensification to date and the need for realignment

Since the middle of the last century, agriculture has undergone unprecedented intensification. Over a period of 50 years (1950-2000), global cereal production virtually tripled (Dyson 1999a). This trend has largely been possible due to the enormous advances in plant breeding, due to the large-scale production of synthetic nitrogen at relatively low energy costs, and due to the systematic use of agrochemicals to control weeds, pests and diseases.

The rise in production is primarily attributable to the fertile soil on which, under favourable conditions (in terms of nutrients and water supply), crops are produced. On a global scale, this equates to only a portion of arable land. Pimbert (2008) estimates that 95% of all farms across the globe are smallholdings, of which most apply traditional methods of farming and largely without using synthetic fertilisers, pesticides and commercial seed. In the 1980s, their share of arable farmland worldwide was estimated to be approx. 60% (Francis 1986). Whilst no current figures are available, an estimate beyond 40% is realistic. Although crop yields in this subsector are, in most cases, low, smallholder agriculture is a major contributor to global food production.

In other words, the majority of people making a living from farming – and, with this, a significant share of arable land across the globe – have barely profited from the intensification strategies of past decades. In many smallholder regions, output per unit area is stagnating, and food security is increasingly becoming a problem. This ties in with the initially surprising findings of the Global Task Force on Hunger (2004), which concludes that 80% of the world's hungry do not live in cities but in rural areas. Two-thirds of these are small-scale farmers.

Food security should therefore not be confused with global yield increases: achieving global food security necessitates people being put in a position to receive sufficient income or to produce their own food as a result of the aforementioned bottlenecks being overcome. The World Agriculture Report (IAASTD 2008) equally confirms that two factors are key to improving global nutrition: the sufficient production of food and access to it for those in need. This entails increasing agricultural production and raising incomes in agriculture (Schmidtner and Dabbert 2009).

It is now anticipated that the global food requirement will rise by 70% in order to feed a global population by 2050 (Bruinsma 2009). Such a statement is contestable, however, since model calculations extrapolate current trends such as the global increase in meat consumption, carry forward current losses such as the destruction of up to 40% of food in industrialised countries, or consider 30% post-harvest losses in numerous developing countries to be immutable (Grethe et al. 2011).

On the other hand, a 70% rise in food production does not in any way presuppose that we will achieve food security. If those in need continue to lack the requisite purchase power or the resources necessary to produce their own food, the required production increase will not be able to solve the hunger problem.

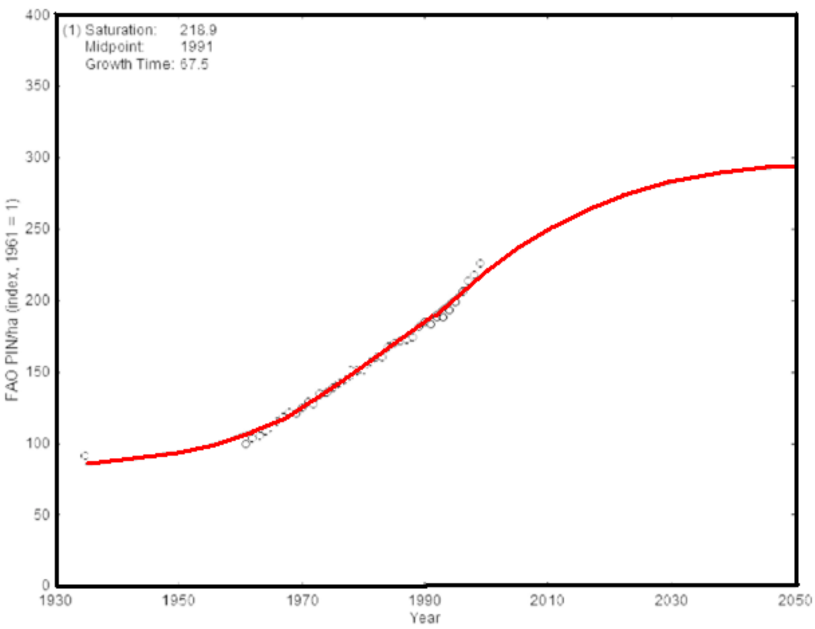
Quite apart from this discussion, it must be assumed that a global production increase can essentially only be achieved through intensification, as the means of expanding arable farmland are very limited. At the same time, fuel crops, which are in competition with food production, will step up the pressure for intensification.

Technological optimists work on the assumption that the current intensification approach is sufficient to achieve further rises in land productivity, even in ecologically disadvantaged regions (Dyson 1999a, Waggoner et al. 2001). Others consider genetic engineering a new high-potential rearing method for agricultural intensification. The results achieved to date have been sobering, however. Even after 20 years of research and development, only two genetically engineered properties have gained economic significance: herbicide resistance and the insecticidal impact of cultivated plants. By contrast, genetic engineering has, thus far, failed to raise the yield potential of cultivated plants or reduce negative environmental implications on plant growth, for example through increased drought resistance or salt tolerance.

There are two weighty arguments for not continuing existing intensification strategies, even on fertile land: the resilience of eco-systems and the law of diminishing returns. The burdens on eco-systems and their loss of efficiency are noticeable today in numerous areas. In industrialised countries, this, above all, relates to chemically intensive production. It is common knowledge today that synthetic nitrogen triggers nitrate enrichment in drinking water and that over-fertilised lakes and rivers “die” from the discharge of nutrients from agricultural soil. A lesser well-known fact is that nitrous oxide emissions from mineral nitrogen account for the bulk of greenhouse gas emissions caused by agriculture[1] (Bellarby et al. 2008). In many developing countries, soil erosion, soil salination and the loss of soil fertility are spreading. In addition, a significant decline in agricultural biodiversity is detectable across the globe. Reorientation is therefore a necessity for both groups: chemically intensive, industrial agriculture, and low-input, smallholder agriculture.

The second argument against continuing the intensification used thus far is of an economic nature. The law of diminishing returns highlights the limitations of current intensification strategies. It states that the achieved extra yield diminishes with each further unit of input, for instance fertiliser. Following on from this law, it is to be assumed that an S-shaped curve, as suggested by Kemp-Benedict (2003), would ensue to denote the type of intensification used to date (Graph 1). FAO statistics on global food production support this trend: the annual yield increase of 3% in 1950 fell below 1% in 2001.

Graph 1: Forecast crop yield development (1930-2050)



Source: Kemp-Benedict, 2003

From this, it can be concluded that the intensification strategies used thus far are barely suited to further increasing global food production as the expected yield increase at high-potential areas is either too low or too expensive.

Secondly, conventional intensification strategies are barely suitable for the other subsector, i.e. medium or low potential land farmed by smallholders. At these locations, the yield increase over the past few decades has only been very low, non-existent or even negative. In addition to all the various factors of misguided agricultural development or a lack thereof in these regions, it has repeatedly been seen that conventional production procedures are often unsuited to bringing about sustainable intensification.

[1] Clearance and slash-and-burn agriculture not included.

Three examples may illustrate this:

- Soil acidification: Nitrogen fertilisers (urea, ammonium sulphate) promote soil acidification. This exacerbates the problem of low pH values for the vast majority of tropical soils. As a consequence, phosphate fertilisers (above all readily soluble versions) are predominantly fixed in the soil, are scarcely plant-available and thus contribute little to increasing yield.

- Low nutrient use efficiency: Due to weathering and bedrock, many tropical soils by nature have low sorption capacity. They can only absorb very limited amounts of nutrients as temporary storage, until required by the plant. As a result, a large portion of mineral fertilisers is lost by leaching and their yield-increasing effect is low. The situation can only be remedied by systematically building up soil organic matter through organic fertilisation; only soil organic matter can act as a substitute for nutrient sorption capacity in weathered soils.

- Failure of high yielding varieties: Commercial varieties, which render high yields under optimal growing conditions have low genetic diversity. Under variable environments (e.g. water shortage), they often react poorly, with crop failure a common occurrence.

These and other factors result in conventionally propagated agricultural production methods frequently failing to achieve the desired increase in yield.

For this reason, a paradigm shift in agriculture is being considered across a broad spectrum of professionals. For example, the IAASTD Report is focusing on the development of smallholder farming systems and has called for a reorientation towards sustainable agricultural production. The main aspects (cited in Schmidtner and Dabbert 2009) include the following:

- The promotion of sustainable cultivation methods and agro-ecological concepts (e.g. payment for environmental services, creation of incentives for alternative markets);
- Well-grounded research and knowledge transfer on issues such as the interplay between agriculture and climate change, increased water use efficiency, and reduced water pollution;
- Greater diversification on farms, for example through a more intensive use of biodiversity;
- Reduced dependency on fossil fuels in the agricultural sector.

To achieve this, it is, more than ever, imperative for resources to be used more efficiently – for ecological and economic reasons. Resource productivity has steadily decreased over several decades. The consumption of synthetic nitrogen worldwide is demonstrable proof of this: in the same time that global crop production has tripled, the use of nitrogen has increased eight-fold.[2] A change in trend began in the 1990s. Since then, resource productivity has begun to rise again. A long-term shift towards a more efficient use of production means (raw materials and natural resources) is foreseeable, since resource shortages and rising raw material prices will compel increases in productivity.

Given that present and future intensification in agriculture must be linked to a significant increase in resource use efficiency, conventional agriculture has, thus far, come up with very few approaches – unlike organic agriculture.

[2] According to Tilman et al. (2002), nitrogen fertiliser production increased seven-fold in the period from 1960 to 1995 alone.

3. Potential and impact of organic agriculture

Guiding organic agriculture is the principle that economic management must occur in harmony with nature, or, expressed in more modern terms: in accordance with the laws of ecosystems. Ecological processes should be fostered; material and energy cycles largely closed, and crop growing and animal husbandry interconnected.

For over 80 years, organic agriculture has pursued a production approach that is based on preserving resources. Input optimisation instead of output maximisation is what differentiates it fundamentally from conventional agriculture. Nutrients should be used as efficiently as possible and recycled as often as possible. Organic agriculture is not at all extensive production, but it has a different understanding of intensification; one could call it ecological intensification (Kotschi 2010).

IFOAM (2009) defines four principles of organic agriculture:

- ***Principle of health:*** *Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible.*
- ***Principle of ecology:*** *Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.*
- ***Principle of fairness:*** *Organic Agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities.*
- ***Principle of care:*** *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.*

These four principles equally address the dimensions of ecology, economy and social issues. At the target level, organic agriculture thus meets the call for sustainable development, as specified by the UN Earth Summit in Rio (1992).

Organic agriculture is not just a method of cultivation. National laws in many countries and international regulations link together standards of production and processing with inspection and certification. The interplay between these elements makes organic agriculture a very assertive strategy. Binding standards build trust among consumers, and, in quite a number of countries, organic food has become a significant market share. Among producers and processers, the standards often result in an uncompromising search for technological alternatives. As a result, organic agriculture has become a driving force behind innovations in agriculture – an approach which has seen 80 years of practical experience as well as research and development.

3.1 Agricultural production

Locations with medium and low soil productivity offer significant potential to increase production through organic farming. This relates, in particular, to regions with smallholder agriculture in the tropics and subtropics. For this reason, global food security is less a question of increasing yield in high potential areas (e.g. from 8 to 10 or 12 t of grain per ha) by farming them even more intensively. Instead, the 95% of smallholder farms should be empowered to raise production by using their limited resources to secure food and increase marketing surpluses (Kotschi 2004). Crop yields of 1t/ha must be boosted to 2, 3 or 4 t/ha. Harris (2001) believes it is even possible to lift the yield in the course of several decades to 6 t/ha and thus to feed with ease a population which will have doubled. At the same time, the production risk needs to be reduced by increasing the diverse nature of the cropping systems.

In the meantime, a whole array of tests comparing organic and conventional production exists. A look at small-holder farms in the tropics reveals that organic farms frequently achieve better yields than their conventional counterparts (Parrot and Marsden 2002, Pretty and Hine 2001). This is particularly true in difficult environments and at a low yield level (Kotschi 2004).

In Europe and North America, it is a different story. On comparably fertile soils, organic farmers generally produce lower yields than conventional producers. With respect to wheat in Germany, they achieve between 58-63% of that yielded through conventional production; on average, the range for Europe is between 44-98% (Sanders 2007 cited in TPorganics 2009b). With respect to other cultivated plants, there are cases where the yields from organic and conventional farming do not deviate (Pimentel et al. 2005) and then again others where the yields from organic farming are significantly higher than those from conventional production (Bradford 2008). The great variance in these system comparisons indicates that the intensification potential for organic production has not yet been fully exploited. It is equally not possible to deduce from this that organic agriculture is less capable of feeding the world than conventional production.

Intensification – a nutrient problem? An argument often put forward against organic agriculture is that an organically fertilised plant or crop cannot be provided with enough nutrients and that the only result can be smaller yields and extensive production which does not meet the present or future demands on global nutrition. In quantitative terms, this argument is scarcely tenable. Potassium and phosphorus are allowed as non-synthetic mineral fertilisers, just as they are in conventional agriculture; the same goes for lime and trace elements. The main difference lies in the nitrogen supply. The question is whether organic farming can produce sufficient nourishment without the use of (unapproved) synthetic nitrogen fertilisers, as an increased supply of nitrogen is essential for increasing the yield. Badgley et al. (2006) counter this assertion by maintaining that biological nitrogen fixation methods involving leguminous plants (fodder plants, green manures, agro-forestry) as well as other techniques (Azolla in rice, etc.) are more than capable of generating enough organic nitrogen to replace entirely the need for mineral nitrogen fertilisers to be used in present and future food production. It must be stated, however, that soil nitrogen availability in organic fertilisation is controlled to a greater extent by biological processes and therefore occurs at a steady though admittedly also slower rate. This is apparent, above all, under temperate climate conditions in spring.

Economics: Organic agriculture frequently comes off better in economic comparisons. This is true not just for conditions in Europe but also for organic production in the tropics. A recently published study conducted in three regions in the Philippines (Luzon, Mindanao and Visayas) revealed a typical set of findings (Bachmann et al. 2009). A relatively large sample of organic and conventional farms were compared with one another; in the final analysis (Table 1), it was found that there was virtually no difference in the physical yield – i.e. in the output per unit area – generated by either production system, though organic farms proved to be much more economical, given their lower operating costs, and achieved far higher levels of income despite marketing their products at the same price. Similar findings were obtained by Eyhorn et al. (2007), Reganold et al. (2001) and Welsh (1999).

Table 1: Comparison of output between organic and conventional farms in the Philippines

	Organic		Conventional	
	N = 280		N = 280	
		(%)		(%)
Rice kg/ha and season (2007)	3,424.00	98.45	3,478.00	100.00
Gross income Peso/ha	51,110.71	98.52	51,878.00	100.00
Operating costs Peso/ha	8,473.57	55.50	15,268.00	100.00
Net operating income Peso/ha	42,637.14	116.46	36,610.00	100.00

Average farm size: organic 1.4 ha, conventional 1.5 ha
N = Number of farms in sample

Source: calculations based on Bachmann et al. (2009)

This trend of lower costs is being further compounded by steadily deteriorating *Terms of Trade:* disproportionate rises in input costs, on the one hand, and stagnating or even falling producer's prices, on the other. However, probably the most important argument for avoiding hunger in impoverished areas is that organic production is less prone to the risk of drought periods – repeatedly evident in Africa.

Irrespective of the research findings, organic production methods have become increasingly popular over the past 30 years. In the meantime, a broad civil society movement of organically oriented grassroots initiatives has emerged which are no longer willing to accept the ecological, economic and health-related burdens of chemically intensive farming in their countries.

3.2 Biodiversity

For the past 150 years, agricultural biodiversity – also known as agro-biodiversity – has been on a steady decline. Increasingly fewer species are being farmed, and today only three crop plants (rice, maize, wheat) account for 60% of the world's food[3]. The number of agricultural crop species is on the decline, as is the genetic variability within the species. By the same token, plant breeding, although it has been fundamental to increasing production, has contributed significantly to the loss of biodiversity.

With regard to food security and the need to adapt to climate change, this genetic erosion represents a threat to the survival of the global population. In order to master the, in part unknown, challenges of the future, the human race requires the still-existent plant genetic diversity. For this reason, preserving agro-biodiversity is a core demand being placed on agriculture today.

Whilst agro-biodiversity barely plays a role in conventional agriculture, it is a universal design principle of organic agriculture. The genetic diversity of the varieties used, numerous crop plants, extensive crop rotations, a form of plant protection, which fosters natural enemies, many enterprises and diversified landscaping are predominant features when carrying out this task. Numerous publications have meanwhile demonstrated that organically managed land use systems exhibit a greater biodiversity and that this has a considerable impact on the productivity and resilience of agro-ecosystems (Altieri 1999, FAO 2002).

In asking how food security and the preservation of biodiversity can be achieved collectively, two answers deserve specific attention.

[3] Calculated in calories

- **Increasing biodiversity within the farming system**: the additional use of “orphan” food crops which have not yet been of economic significance, but which have a high nutritional value and are particularly adaptive to varying environmental conditions, can often radically reduce under-nourishment and malnutrition.

- **Increasing genetic diversity within crop plants:** genetically diverse local varieties can produce satisfactory yields – even under adverse environmental conditions – and avert the risk of crop failures.

Alternative plant breeding methods meanwhile exist in organic farming, which successfully combine the two goals of agricultural intensification and preserving genetic diversity. To this end, two innovations are used: a new breeding method – breeding with composite cross populations – and a new breeding organisation, participatory breeding.

In population breeding with composite crosses (also called evolutionary plant breeding), genetically-different, organically-modified local native breeds of differing origins are brought together and recombined through cross-breeding in order to create new varieties (Phillips and Wolfe 2005). From these, the best progenies are selected and, after remixing, cultivated at various locations. Through this approach, the populations are subjected to natural and artificial selection processes which, ultimately, produce modern but genetically diverse, local native varieties that may well be superior even to conventionally cultivated high-yielding varieties (Ceccarelli 2006). This especially holds true with respect to yield stability at environmentally difficult locations. Enhanced disease resistance is a predominant feature in this respect. This breeding method has led to varieties exhibiting higher drought resistance and better adaptedness to low-rainfall locations.

Composite cross population breeding is combined with **participatory breeding.** Unlike conventional plant breeding, the work here is not carried out by breeders alone. Nor is it only conducted in experimental fields or in laboratories either. Farmers play an equitable and active role in the entire breeding process, with breeding taking place mainly in their own fields. In this way, any bias can be avoided. This point is important, as research stations typically have better soils, possibly irrigation facilities, etc., whereas farmers’ fields offer a full range of environmental (and management) conditions for cropping – hence there is optimal interaction between environment and genotype during the breeding process. This fosters the adaptability of populations to various environments.

Evidence suggests that both methods have the potential to improve global food production significantly. This is particularly true under agriculturally difficult environments and, generally speaking, for the need for agriculture to adapt to climate change (Kotschi 2010).

3.3 Climate protection and adaptation to climate change

Agriculture is one of the main causers of global warming. Recent estimates indicate that, within this sector, clearance and slash-and-burn agriculture employed to create farmland account for 47% alone, nitrous oxide (N_2O) released from the farmland and originating from largely surplus mineral nitrogen for around 17%, and methane production (CH_4) from animal husbandry for around 14% (Bellarby et al. 2007).

Numerous means exist of reducing agricultural greenhouse gas emissions, and organic production methods are of great significance in this regard. Abandoning the use of synthetic nitrogen in organic agriculture is the most effective of these. This approach lowers the consumption of fossil fuels (CO_2) and significantly reduces the level of nitrous oxide emissions from the soil (N_20). By contrast, the emissions resulting from animal husbandry remain high even when organic production methods are applied.

At the same time, agriculture offers significant potential to capture carbon dioxide, and organic methods especially are capable of bringing this about: agro-forestry in the tropics as well as the accumulation of humus on farmland and improved grazing management offer considerable potential for sequestering CO_2.

Both aspects, emission reduction and increased CO_2 sequestration through organic farming technologies, are increasingly becoming the subject of scientific research and have since been summarised in several studies (e.g. Kotschi and Müller-Sämann 2004, ITC/FIBL 2007). This illustrates that agriculture has quite a potential to mitigate climate change. Striving for climate neutrality in agriculture is therefore a minimum goal.

In terms of global nutrition, however, adapting agriculture to climate change is of greater importance. Today, climate change can already be clearly felt in agriculture, and forecasts increasingly suggest that the consequences will be very drastic and far-reaching both for the agricultural and the food sector. Tropical countries will be affected in particular, and crop yields will drop significantly (Rosenzweig and Parry 1994, Fischer et al. 2002) if no adaptation measures are taken. Water shortage, heat stress and increased disease susceptibility are some of the anticipated causes. All in all, the spatial and temporal impact of environmental variability will gradually grow. This requires raising the resilience (elasticity) of agrarian land use systems in order to be able to respond immediately to environmental stress. In this area, organic farming systems, as a result of their biological and functional diversity, are far superior to conventional ones (Bengtsson et al. 2005, Hole et al. 2005, Kotschi 2007).

4. Research into organic agriculture

Modern organic agriculture has its origins in Europe. The first initiatives began to emerge in the 1920s. Until the early 1980s, over a period of 60 years, almost all the funding earmarked for research into organic agriculture came from private or non-profit sources. Only then did state funding begin to flow into the research. A similar trend can be seen internationally**,** though this occurred quite some time later. Notably during the last few years, research into organic farming has increased significantly, as has the number of research institutes dedicated to this sector. The USA, Canada and Australia are among the countries where state-funded research into organic farming has increased most, while in Brazil, the research institute EMBRAPA has 27 centres dedicated to organic farming research (Willer 2009).

According to ORCA (2009a), a total of 78 research institutes are conducting research and development work into organic agriculture at humid and sub-humid locations alone, of which 49 already work in this field, with 29 others interested in doing the same.

Worldwide, however, the amount of public funding allocated to organic agriculture is minimal. Based on its share of organically managed farmland, it would ordinarily be entitled to 5% of all research funding that is ploughed into the agricultural sector. In reality, the percentage is considerably lower. If organic agriculture were to be seen as a strategy of equal standing in the competition for innovative approaches to solving global problems (food security, climate protection and preservation of biodiversity), significantly different amounts of funding would have to be negotiated.

4.1 Scientific understanding and research methods

According to conventional scientific understanding, research should be as value-free as possible in order to ensure the maximum objectivity of its findings. This has led to agricultural research distancing itself more and more from the study of complex correlations and becoming increasingly reductionistic. At the same time, a wide disparity has emerged between the type of knowledge required by farmers and the knowledge base generated by agricultural research (Squire and Gibson 1997). It is for this reason that the lack of practical relevance of research findings is increasingly a source of criticism.

In terms of scientific theory and research methodology, organic farming research is breaking new ground. It calls into question the fundamental principle of value-free, objective research and argues that agricultural science is an applied science which must influence its own field of knowledge. Alroe and Kristensen (2001) refer to this as a “systemic science” that, in no way, can be value-free. Values, they argue, are indeed vital for agricultural science as they are constitutive and normative for sound science and could, at the same time, help to improve the relevance of the research. They assert that the objectivity demanded to date should be superseded by “reflexive objectivity” which is the result of a cyclical cognitive process during which the scientist alternates between the roles of ‘actor’ (inside viewpoint) and ‘observer’ (outside viewpoint), the latter forming the basis for the scientific discourse (Alroe 2000).

Clearly, no less innovative is the on-going discussion surrounding the values, principles and norms of agriculture. This discussion has accompanied organic farming since its inception and is a unique selling point of this line of agriculture.

One of the reasons for the discussion surrounding values being of such significance is that it is not conducted abstractly or theoretically. Such a discussion has helped to shape the method and strategy of organic farming, to develop binding standards for each and every farming association and to establish a control and certification system. Not least of all, it has enabled guiding principles and visions to be developed which convey an idea of what the agriculture of the future might and should look like. In the case of meat production, for example, the question which needs to be asked is: how does society as a whole envisage animal husbandry in the future? Do people want animal production to consist of high-rise pig-fattening units at locations such as the Port of Rotterdam because soya imports from Latin America make it particularly cost-effective to produce meat there? Or will focus be placed on land-based animal production which combines yield optimisation with landscape preservation and climate protection? Visions and guiding principles are also the basis for identifying relevant research questions.

The recently launched EU technology platform, TPorganics (2009a), formulates three research goals and – in keeping with these – supplies visions for the agriculture of the future (see box 2).

Box 2: Visions for the agriculture of the future

Eco-functional intensification of food production (...):

> *By 2025, the availability of food and the stability of food supply will be noticeably increased through eco-functional intensification, and access to food will be considerably improved thanks to revitalized rural areas. Knowledge among farmers about how to manage ecosystem services in a sustainable way will be much greater, and animal welfare and environmentally sound farming will be cutting-edge technologies in food production.*

Empowerment of rural areas and economies (...):

> *By 2025, new concepts, knowledge and practices will halt or even reverse migration from rural areas to urban centres. A diversified local economy will attract people and improve livelihoods. Organic agriculture, food processing and eco-tourism will become important drivers of the empowerment of rural economies. The dialogue between urban and rural populations will improve considerably and intensified forms of partnership between consumers and producers will emerge.*

Production of food for health and human wellbeing (...):

> *By 2025, people will have more healthy and balanced diets. Food and quality preferences will have changed: fresh and whole foods will be the ultimate trend and processing technology will produce foods with only minimal alterations to the intrinsic qualities. The specific taste and its regional variation will be more appreciated than artificially designed.*

Source: TPorganics (2009a)

All three of the guiding principles listed above bear reference to world food affairs and, at the same time, keep in mind the three sustainability dimensions of ecology, economy and social issues.

There is no room, at this juncture, for an extensive discussion and assessment of the content conveyed by this discussion. It can, however, be said that a discussion as such is essential if the social tasks facing agriculture are to be accomplished. It can also be said that organic farming research plays a leading role in this process.

Organic farming research deviates greatly from classic agricultural science in its choice of generally applicable analytical methods. One of the focal points of long term trials, case studies and surveys is hard to miss. Participative methods, e.g. in plant breeding, are also of comparably great significance. Emphasising such methods equates to generating increasingly holistic knowledge. At the same time, however, a surge in single-discipline analyses and studies is also apparent.

Although research into organic farming employs largely conventional methods, its points of focus differ from those of classic research into agriculture. Through this approach, it seeks to lend consideration to a more holistic view of agro-ecosystems; however, even greater changes in scientific methods are required if advancements in organic farming are to be achieved.

5. Future direction of research – a pool of ideas

5.1 General considerations

The direction to be taken by research into organic agriculture in the future requires an alignment of the research methodology and content. With regard to methodology, organic farming research needs to enter virgin territory if it is to do justice to the holistic approach towards agriculture under which agricultural landscapes and their individual agrobusinesses are perceived as ecosystems. The following criteria come into play:

- **Transdisciplinarity:** solutions tailored to the environment can only be found with the involvement of local stakeholders. For this reason, transdisciplinarity is of utmost priority. This means that, wherever possible, relevant research topics should not be identified, planned and implemented by scientists alone but with the involvement of various stakeholders (e.g. active farmers, consultants, etc.).

  Interdisciplinarity: research should integrate concepts from different disciplines in a coherent whole research methodology. During the planning stage, research projects should be examined more closely to determine the extent to which interdisciplinary research approaches are advisable and to search for respective research methods. This is especially the case whenever natural scientists and social scientists are working hand in hand.

- **Combination of knowledge systems:** the generation of new findings should not only be founded on formal scientific knowledge but also include traditional, collective knowledge- and experience-based systems.

- **Areas of geographic focus:** significant potential for increasing global food production – namely through organic production methods – can be found in the tropics and subtropics. For this reason, organic farming research should be conducted just as intensely in the tropical climate belt as in the northern hemisphere under moderate climatic conditions.

- **Focus of content:** greater emphasis should be placed on the aspects of yield increase and sustainable intensification than has been the case in the past. At the same time, climate protection and the preservation of biodiversity should not be kept out of the loop.

Consistently including these criteria in the considerations could significantly heighten the profile of organic farming research and allow organic agriculture to play a vital role in food security.

The following sections outline a pool of topics that should be given precedence when conducting agricultural research into organic farming. While most certainly not covering the entire spectrum of relevant issues, they may provide some guidance for the direction future research should take.

5.2 Focus on the tropics and subtropics

Organic agriculture has its origins in the north and, up to the present, has essentially served the organic markets in Europe, North America and Japan. This explains why organic farming research for tropic and subtropical locations has, thus far, played an insignificant role.

However, if organic agriculture wishes to focus on global nutrition, it should make the tropics and subtropics an area of geographic focus for research and development. The regions in question are characterised by small-scale agriculture and are, above all, locations where farming is done under moderate to marginal ecological conditions. Here, socio-economic and technical issues are of equal importance.

The overriding **socio-economic issues** relate to the establishment of regional markets for organic products as these directly impact production. These include:

- developing new **regional marketing concepts,** e.g. through direct cooperation between producers and consumers (*Community Supported Agriculture, CSA*), through regional farm box schemes and other regional food distribution networks (TPorganics 2009b).
- **developing standards and guarantee systems** which are also affordable and manageable for small-scale farmers and which equally incorporate the aspects of climate protection and preservation of biodiversity. Binding and transparent standards and guarantee systems build consumer trust and help to boost local organic markets. Demonstrable climate protection and the preservation of biodiversity open up the possibility of compensation payments being made by other sectors in order to promote agriculture; they also allow it to perform environmental services for society as a whole.

With regard to **agricultural production issues,** a survey among scientists in organic farming revealed that two aspects are of exceptional importance: raising soil fertility, plus managing agricultural biodiversity (Kotschi 2010). Both are not only geared to soil science and agronomy but also include animal husbandry. The utilisation and refinement of low-value biomass through animal husbandry enhances the nutrient cycles. For this reason, optimising land-based animal production systems is particularly important for increasing soil productivity and is of indispensable value to organic agriculture.

Of all the issues concerning agricultural production, the following take precedence:

- **Enhancement of organic fertilisation:** systematically building up soil organic matter remains the basis for organic production. However, plant and animal biomass – which can be fed into the soil – tends to be in scarce supply and is a limiting factor in organic fertilisation. For this reason, every means of possibly increasing biomass volumes on farms needs to be explored. This includes methods used in agroforestry, mixed cropping, green manuring as well as the integration of animal husbandry with cropping systems. Raising the amount of biomass is one aim, improving the quality of the soil humus (the composition of humic substances) is another. In this regard, composting techniques that improve the processes of mineralisation and humification need to be systematically refined.

- **Rehabilitation of soils with low-nutrient status:** the impact mineral fertiliser has on the rehabilitation process of low-nutrient soils should be systematically examined[4]. Biological nitrogen fixation should equally be refined. And finally, mature methods need to be developed for using mychorrhizae as a means of increasing the availability of phosphate in tropical soils.

- **Optimised water management in rain-fed farming:** the existing erosion control techniques are quite effective in terms of their ability to prevent soil loss and to retain rainwater. These techniques need to be combined with soil amelioriation measures by systematically building up soil organic matter to improve the infiltration rate, field capacity and amount of soil water available to plants. As water limits yield in many situations, there is significant potential for raising yield here. Location-specific solutions need to be developed for semi-arid, sub-humid and humid tropical locations.

- **Use of agro-biodiversity as a means of increasing food production:** as climate change intensifies, environmental variation (both temporal and spatial) will increase dramatically and tropical sites will be affected in particular. For this reason, resilient production systems need to be created that enable a more flexible response to environmental changes. The systematic use of genetic diversity in agriculture – a higher number of crops and more intra-species diversity – offers great potential here.

  At the same time, it is necessary, for the main food crops, to breed modern native varieties which, given their genetic variability, perform better under genotype-environmental interaction, have greater yield security and offer greater yield potential than traditional native breeds. Evolutionary plant breeding, when supported by marker-assisted selection and including participatory breeding with farmers, proffers to be a highly promising research method.

  In doing so, the resilience and output per unit area of production systems can also be significantly increased. The corresponding cultivation systems need to be developed.

- **Animal breeding as a means of optimising production conditions:** with regard to area-based livestock keeping (cattle, sheep and goats), local populations should be crossbred with high-performance breeds to increase the performance of the former whilst largely preserving their genetic variability. Performance improvement should be combined with the ability to adapt to varying environmental conditions and increasing environmental stress. In doing so, properties such as heat tolerance, resistance to illness or disease, and the usability of lower-quality fodder are the main areas of focus. At the same time, the development of a widely-useable method of breeding management is of central importance.

- **Reduction of methane production in animal husbandry:** although ruminants are a significant contributor to global warming, they are nevertheless essential for eco-intensification. For this reason, research into how to reduce ruminant methane emissions is of decisive importance.

[4] This relates, in particular, to the nutrients of phosphorus, potassium, calcium and magnesium

6. Conclusions and recommendations

Conclusions

Agriculture must be fundamentally realigned in order for the following three goals to be achieved collectively: food security, adaptation to climate change, and preservation of natural resources. Today, very few people dispute that the ecologisation of agriculture is a core principle for this realignment. Where they disagree is what development it should undergo.

Organic agriculture has already provided significant impetus for such realignment, and it can also be viewed as a future driving force. In contributing to a renewal of agriculture, it serves a dual system: for highly intensive, large-scale and industrialised agriculture, it generates innovations that can help to use resources more efficiently and in an environmentally friendly way; for smallholder agriculture, it provides systems of food and livelihood security which are, in many instances, ecologically and economically superior to other forms of agriculture.

Compared with the goals of food security and sustainability in production, organic agriculture in its present state is not yet efficient enough, but it does offer plenty of development potential and is perhaps the most future-proof option available today. Though still in its infancy, research into organic agriculture is vested with the task of tapping this potential. For this to be realised, research into organic agriculture needs to be given a significant boost of funds and realigned.

When determining the content of future research, more emphasis should be placed on the intensification of production, yield increase and global nutrition than has been the case thus far. In this context, two fields of work in urgent need of being addressed are plant breeding and soil productivity.

At the same time, the geographical focus needs to be changed. To date, organic farming research has centred on the industrialised nations of Europe and North America. Organic agriculture has a significant role to play in the future food security of countries in the south. This must be taken into account when determining the geographical scope of agricultural research.

Research into organic agriculture – which, until a few decades ago, had been funded almost exclusively by private and non-profit sources – has since managed to secure state and international funding. However, public funding remains extremely low. It is not in proportion with the share of land assigned to organic agriculture, and most definitely not to the importance of organic farming in modernising agriculture. Cost-benefit considerations are yet another reason for boosting funding, given the high efficiency with which research funds have been used to date.

Recommendations for agricultural scientists

(1) The issues of global nutrition and sustainable intensification in production should be afforded greater consideration. In this context, plant breeding and an increase in soil productivity should be given priority.

(2) Organic farming research in the tropics and subtropics has, thus far, played a very minor role. In keeping with the available and, as yet, untapped potential, this climatic region (in addition to the northern hemisphere) should be turned into a second pillar.

(3) To be able to fundamentally understand and to further develop organic agriculture, repeated calls have been made for holistic and system-based research methods. Their application is still in its infancy and should be advanced with greater forcefulness than has been the case to date. In doing so, in particular the principles of transdisciplinarity and interdisciplinarity should be afforded greater consideration.

(4) The latest initiatives designed to bolster international networking and cooperation within organic farming research are ground breaking and should be developed further.

Recommendations for policy-makers

(5) To date, the amount of public funding allocated to organic agriculture has been minimal. Such neglect is unjustified. Organic agriculture should be perceived as a serious strategy for solving global problems, namely food security, climate protection and the preservation of natural resources. Accordingly, the amount of funding allocated to research and development activities in organic agriculture should be raised significantly.

(6) National governments should initiate a discourse on the goals, strategies and methods of a future agriculture. In this process, organic agriculture needs to be viewed as one of the options, and one which must be afforded no less attention than other strategies. Those to be included in such a discourse should, on the one hand, be all stakeholders involved (farmers, consumers, scientists and politicians), and, on the other, the key political departments (not just the ministry for agriculture). The process should be moderated across different departments so as to achieve the requisite political coherence. This could ultimately lead to the emergence of agro-political visions and a coherent agricultural research agenda in individual countries.

References

Alroe, H.F. (2000): Science as systems learning. Some reflections on the cognitive and communicational aspects of science. Cybernetics and Human Knowing /(4): 57-78.

Alroe, H.F. and E.S. Kristensen (2002): Towards a systemic research methodology in agriculture: rethinking the role of values in science. Agriculture and Human Values 19:3-23.

Altieri, M. (1999): The ecological role of biodiversity in agroecosystems. Agriculture, Ecosystems and Environment. 74:19-31.

Bachmann, L., E. Cruzada and S. Wright (2009): Food Security and Farmer Empowerment. A study of impacts of farmer-led sustainable agriculture in the Philippines. Masipag. Los Banos.

Badgley, C. J., E. Quintero, E. Zakem, M.J. Chappell, K. Avilés-Vázques, A. Samulon and I. Perfecto. 2006. Organic agriculture and the global food supply. Renewable Agriculture and Food Systems: 22(2); 86-108.

Bellarby, J., B. Foereid, A. Hastings, P. Smith (2007): Cool farming: climate impacts of agriculture and mitigation potential. Greenpeace International, The Netherlands. http://www.greenpeace.org/international/press/reports/cool-farming-full-report .

Bengtsson, J., Ahnström, J. and Weibull, A.-C. (2005): The effects of organic agriculture on biodiversity and abundance: a meta-analysis. Journal of Applied Ecology, 42, pp. 261-269.

Bradford, J.M. (2008). Organic Pecans: Another Option for Growers. November/December 2008, Agricultural Research magazine. US Agricultural Research Service (ARS).

Bruinsma, J. (2009): The resource outlook to 2050: By how much do land, water and crop yields need to increase by 2050? Paper presented at the FAO Expert Meeting, 24-26 June 20090, Rome on „How to feed the World in 2050. Economic and Social Development Department. FAO. Rome.

Cecarrelli, S. (2006): Decentralized – Participatory Plant Breeding: Lessons from the South – Perspectives in the North. In: D. Desclaux and M. Hédont (ed.): Proceedings of the ECO-PB Workshop: „Participatory Plant Breeding: Relevance for Organic Agriculture?“ 11-13 June 2006, La Besse France.

Dyson, T. (1999a): World food trends and prospects to 2025. Proc. Natl. Acad. Sci. USA. Vol. 96. 5929-2936.

Eyhorn, F., M. Ramakrishnan and P. Mäder (2007): The viability of cotton-based organic farming systems in India. International Journal of Agricultural Sustainability 5(1), p. 25-38.

FAO (2002): Organic Agriculture, environment and food security. Environment and Natural Resources Service. Sustainable Development Department. FAO. Rome.

Fischer, G., M. Shah and H.v. Veldhuisen (2002): Climate change and agricultural vulnerability. International Institute for Applied Systems Analysis. Report prepared under UN Institutional Contract Agreement 1113 for World Summit on Sustainable Development. Laxenburg. Austria.

Francis, C.A. (1986): Multiple Cropping Systems. New York: Macmillan 383 pp.

Harris, J. M. (2001): Agriculture in a Global Perspective," Global Development and Environment Institute Working Paper No. 01-04, February 2001. Available from http://ase.tufts.edu/gdae/publications/working_papers/agric4.workingpaper.pdf

Grethe, H., A. Dembélé, N. Duman, (2011): How to feed the worlds growing billions. Understanding FAO world food projections and their implications. Heinrich Böll Foundation and WWF Germany.

Hole, D.G., A.J. Perkins, J.D. Wilson, I.H. Alexander, P.V. Grice and A.D. Evans (2005): Does organic farming benefit biodiversity? Biological Conservation, 122, p 113-130.

IAASTD (2008): International Assessment of Agricultural Knowledge, Science and Technology for Development. http://www.agassessment.org

IFOAM (2009): Die Prinzipien des Ökolandbaus. http://www.ifoam.org/germanversion/ifoam/prinzipien_des_oekolandbaus.html

ITC/FiBL (2007): Organic Farming and Climate Change. International Trade Centre UNCTAD/WTO and Research Institute of Organic Agriculture (FiBL).

Kemp-Benedict, E. (2003): The Future of Crop Yields and Cropped Area. Case Study No 1. IPAT a scripting language for sustainability scenarios. http://www.altavista.com/web/results?itag=ody&q=kemp-benedict+yield&kgs=0&kls=0

Kotschi, J. (2010): Reconciling Agriculture with Biodiversity and Innovations in Plant Breeding. GAIA. 19/1. 20-24.

Kotschi, J. (2007): Agricultural Biodiversity is Essential for Adapting to Climate Change. GAIA 16/2. 98-101.

Kotschi, J. (2004): Mehr Ökologie – weniger Hunger? Ernährungssicherung und Ökologische Landwirtschaft. Politische Ökologie 90, 59-61.

Kotschi, J. and K. Müller-Sämann (2004): The Role of Organic Agriculture in Mitigating Climate Change. A Scoping Study. IFOAM Bonn.

Parrot, N. and Marsden, T., (2002): The Real Green Revolution, Organic and agro-ecological farming in the South. Greenpeace Environmental Trust, London.

Pimbert, M. (2008): Towards Food Sovereignty. IIED

Pimentel, D. P. Hepperly, J. Hanson, D. Douds and R. Seidel (2005): Environmental, Energetic and Economic Comparisons of Organic and Conventional Farming Systems. Bioscience 55/7. 573-582.

Phillips S.L., M.S. Wolfe (2005): Evolutionary plant breeding for low input systems. Journal of Agricultural Science 143: 245-254.

Pretty, J.N. and Hine, R.E. (2001): Reducing food poverty with sustainable agriculture. A summary of new evidence. Final report form the “SAFE World” research project. University of Essex. Essex.

Rosenzweig, C. and ML Parry (1994): Potential impact of climate change on world food supply. Nature Vol. 367. 133-138.

Reganold, J., Glover, J., Andrews, P. and Hinman, H. (2001), Sustainability of three apple production systems. Nature 410, 926-930 (19 April 2001) | doi: 10.1038/35073574

Sauter, A. (2008): Transgenes Saatgut in Entwicklungsländern – Erfahrungen, Herausforderungen, Perspektiven. Endbericht zum TA Projekt „Auswirkungen des Einsatzes transgenen Saatguts auf die wirtschaftlichen, gesellschaftlichen und politischen Strukturen in Entwicklungsländern. Arbeitsbericht 128. Büro für Technikfolge-Abschätzung beim Deutschen Bundestag.

Schmidtner, E. und S. Dabbert (2009): Nachhaltige Landwirtschaft und Ökologischer Landbau im Bericht des Weltagrarrates (International Assessment of Agricultural Knowledge, Science and Technology for Development, IAASTD 2008). Institut für landw. Betriebslehre, Universität Hohenheim. Stuttgart.

Squire, G. and G.J. Gibson (1997): Scaling up and down: matching research with requirements in land management and policy. In: Gardingen, Food and Curran (eds.): Scaling up, from cell to landscape. pp.17-34. Cambridge..

Task Force on Hunger (2004): Halving hunger by 2015: A framework for action. Interim Report, Millennium Project. United Nations, New York.

TPorganics (2009a): Forschungsvision 2025 für die ökologische Lebensmittelwirtschaft. Technologie-Plattform „Organics“. IFOAM-EU und ISOFAR. Brüssel und Bonn.

TPorganics (2009b): Strategic Research Agenda. Technology Platform for organic food and farming. IFOAM-EU. Brussels

Waggoner, P.E. and J. Ausubel, “How Much Will Feeding More and Wealthier People Encroach on Forests?” Pop. Dev. Rev. 27(2):239-257, June 2001. Available from http://phe.rockefeller.edu/encroach/encroach_waggonerausubel.pdf.

Welsh, R. (1999). Henry A. Wallace Institute, The Economics of Organic Grain and Soybean Production in the Midwestern United States, Policy Studies Report No. 13, May 1999.

Willer, H. (2009): Organic Farming Research Worldwide – an Overview. Ecology and Farming. S. 4-8. November 2009.

Zeddies, J. (2002): Vermeidungspotentiale der Landwirtschaft. Ziele und Handlungsoptionen. In Böcker, R. (Hrsg.): Tagungsband zur 34. Hohenheimer Umwelttagung „Globale Klimaerwärmung und Ernährungs-sicherung. 25. Januar 2002. Vlg. Heimbach.