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Preface

Christian Hülsebusch, Florian Wichern, Hans Hemann and Peter Wolff

The demand for organically grown agricultural produce is rising fast, leaving empty shelves in the major markets in North America, Europe and Japan. The world wide agricultural area under organic cultivation has tripled between 2000 and 2006 in response to this development. Organic agriculture is particularly expanding in tropical and subtropical regions, where today about 75% of the total agricultural area under certified organic production is found.

Agricultural research and development is responding to this trend and an increasing amount of scientific literature on organic agriculture, processing and marketing of organically produced agricultural commodities has been published during the past decade. Such has grown the number of publications that the need was felt by several authors to summarise the state of the “scientific art” in this field attained so far. Thus a number of monographs have recently appeared on the current status of organic farming and its future perspectives at a global scale. The most recent are “Global Development of Organic Agriculture: Challenges and Prospects” edited by Halberg et al. 2006, “Organic Agriculture - A Global Perspective” edited by Kristiansen et al. 2006, and “Sociological Perspectives of Organic Agriculture: From Pioneer to Policy” edited by Holt et al. 2006. However, although organic farming currently experiences its major growth in tropical and subtropical regions, the aforementioned monographs – as the underlying journal publications – have their main focus on organic farming in Europe and North America, where organic agriculture initially evolved.

Environmental conditions in tropical and subtropical regions differ considerably from those in Europe and most parts of the United States. It is therefore to be expected that problems arising in tropical organic agricultural systems differ largely from those in temperate zones. Based on the observation, that agricultural yields in temperate regions experience a drop when converting to organic production, it is often argued in the general debate, that organic agriculture has little to no potential to contribute to global food security. However, one major principle of organic agriculture is that of maintaining nutrient cycles and soil fertility, thus – so it can be hypothesised – stabilising yields in the long run. Associated with this is the endeavour to make use of allelopathic relations between different ecosystem components – thus increasing the systems’ resilience against shocks resulting from imbalances. Such hypotheses can, however, only be tested in long term investigations, because the balance aimed at will only gradually evolve after conversion to organic management. The history of organic farming and associated research in tropical regions is relatively young, hence predictions of yield developments, ecosystem stability, and even more so of economic viability at different scales after "converting to organic" under tropical conditions still lack a solid scientific basis.

In order to be economically viable, organic production in tropical regions needs to meet the requirements of the organic market, and more than 90% of the organic produce worldwide is consumed in Europe and the United States. This results in a high nutrient export from organic systems in the tropics and subtropics.

It becomes more and more obvious therefore, that an increasing scientific effort – i.e. longer term research projects on organic farming under tropical environmental conditions - is required to provide a clue as to its future potential. In addition to the recently published volumes, the present supplement to the Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS) was initiated with the aim to take stock of the existing literature on organic farming in the non-temperate regions of the world. JARTS is published at the University of Kassel in Witzenhausen, where research and training on organic agriculture – during the last 25 years – has grown to be the major focus at the agricultural faculty. Likewise, the faculty has a strong history of development oriented agricultural research and training in tropical and subtropical regions.

In order to tie a closer network and intensify research efforts on the potential of organic farming under tropical and subtropical conditions, the editors have chosen, in a first attempt, to approach their scientific partners from various organisations and invite contributions to this volume – a quest to which our colleagues have most readily responded. This volume – naturally – is far from being a complete literature review on all relevant topics pertaining to "tropical organic agriculture". A number of relevant topics are not even included - such as plant protection, the different aspects of organic livestock production, certification and product chain development – to name but a few. However, this volume is regarded as a starting point from where to proceed in future. The seven contributions contained therein address crucial questions, which must be critically considered when attempting to predict whether or not organic agriculture can significantly contribute to food security and poverty alleviation at a global scale.

In the first contribution to this volume, Bernhard Freyer of the University of Natural Resources and Applied Life Sciences BOKU in Vienna, Austria, analyses traditional and ecological farming systems using a case study from the Kenyan Rift Valley. Setting out from the historical development of traditional farming systems he compares both environmental risks and economic dependencies of the different systems and pinpoints potentials and difficulties when aiming at developing organic agriculture to become a modern land use system in tropical environments.

Lukas Kilcher of the Research Institute of Organic Agriculture FiBL in Frick, Switzerland, draws in his contribution on a number of case studies from different tropical and subtropical countries to underline his main hypotheses that organic agriculture is sustainable and diverse, conserves resources, can produce more and distinct quality products and thus generate higher income, also through a shift in partner networks, improved market access and added value.

Jan Grenz and Joachim Sauerborn of the University of Hohenheim at Stuttgart, Germany, analyse the potential of organic farming to halt or even reverse nutrient mining particularly in West African agro-ecosystems on poor soils. They discuss different options in organic and conventional farming to close nutrient cycles – or rather narrow gaps in these cycles - and hold that nutrient mining is not a phenomenon limited either to Africa or to organic farming as such. They state different areas in which organic agriculture can contribute to increased sustainability and suggest a number of issues to be considered by the organic movement when aiming at an ecologically sound and sustainable resource use under tropical conditions.

Jan Engels of the International Plant Genetic Resources Institute IPGRI, a CGIAR centre based in Rome, Italy, holds that organic agriculture, apart from being a production management system, also aims at enhancing soil biological activity, biological cycles, agro-ecosystem health, and biodiversity. He argues that organic agriculture therefore must take a keen interest in conserving the existing (agro-) biodiversity and he introduces conservation approaches and methods applied in the CGIAR system to manage crop gene pools. He then suggests ways of how genebanks could be of better service particularly to the organic sector and how the organic sector in turn could better contribute to conserving genetic resources.

Lammerts van Bueren of the Louis Bolk Institute in Driebergen, The Netherlands and co-workers discuss in their paper “European perspectives of organic plant breeding and seed production in a genomics era” the issue of developing varieties and producing seeds particularly suited for organic agriculture. They analyse potential risks and benefits of modern molecular plant breeding techniques for developing “organic varieties” and also address the difficult and controversial issue of co-existence of organic farming and of conventional farming using genetically modified crops.

Set against the drastic expansion of organic agriculture in the tropics and subtropics, Eike Luedeling and Florian Wichern of the University of Kassel in Witzenhausen, Germany, discuss the need of adapting organic standards to site specific conditions in tropical environments. They compare different organic standards with view to how these address a large scale environmental problem, using the case study of salinity in Australian drylands. They analyse, which provisions those standards make to combat this ecologically important problem, thus to foster ecologically sound agricultural production rather than respond to market requirements in the main regions of consumption.

On a different account, Steffen Abele and his co-authors of the International Institute of Tropical Agriculture IITA, based in Uganda, Nigeria and Benin, finally draw a link between the African small farmer and the situation as it develops on the European organic market, which is currently still growing fast, but also shows a tendency of falling prices. The authors critically question whether it is really the certified organic agriculture - as it is currently defined by the guidelines - that may significantly contribute to improving the livelihoods of small farmers in the tropics, or whether certified organic production is merely a business opportunity for larger holdings – while small farmers will profit more from integrated agricultural approaches, which may also permit the use of synthetic inputs.

This leads to the question of guidelines or standards for organic production. The currently existing standards were developed in Europe, North America and Japan, where organic agriculture has initially evolved and where today the main market is. Do those standards – if transferred as they are into many tropical and subtropical countries – really warrant an ecologically sensible mode of production also under the different environmental conditions? Or are they merely yet another hidden mechanism to protect the markets of the northern hemisphere from the developing countries in the South?

The editors hope that the present volume may be a useful contribution to the work in progress of developing local organic standards for sustainable land use. In addition this supplement adds onto the discussion about the perspectives of organic farming between tradition and globalisation – the focal topic of the upcoming 9th scientific meeting on organic farming to be held at the University of Hohenheim, Germany in March 2007. Moreover this supplement may also stir the discussion on how organic agriculture may or may not be used as a sustainable approach to meet peoples needs in view of the Millennium Development Goals, which will be a major topic at the Tropentag conference to be held as a joint conference of the Universities of Kassel and Göttingen in October 2007 in Witzenhausen, Germany.

As editors we are thankful to all the contributors for their effort, their timely submissions and their patience. It is hoped, that apart from adding to the scientific debate, this volume will also serve at tightening the relations between the seven institutions whence the contributions originate, and that it will invite others to join in the effort.

University of Kassel at Witzenhausen
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Traditional and ecological farming systems in (sub) tropical countries – history, interactions and future perspectives

Bernhard Freyer *

Abstract

Climate change, soil degradation and an increase of health problems impede a sustainable development of livelihoods in rural areas in (sub) tropical regions all over the world. Prevalent traditional farming systems have been replaced and modified by the Green Revolution, LEISA (low external input sustainable agriculture) and agroforestry systems.

Today organic farming is discussed as a land use system which could help especially smallholder farmers to achieve a better income and to protect the environmental resources at the same time. This article reflects first conflict areas and interaction possibilities concerning subsistence farming seen from a system-theoretical perspective. A comparison between traditional and organic farming points out the different qualities. Based on a case study in the Rift Valley / Kenya the development of agriculture since the 1950ties along the different land use approaches is demonstrated. The specific environmental risks and the degree of dependency on external inputs, market and economy are shown in a comparison between the different land use approaches. Under specific circumstances organic farming could fail to achieve sound environmental development. Nevertheless because of the system approach, organic farming offers a framework for a sustainable agriculture, integrating forestry, agroforestry, traditional farming techniques and selected approaches from the LEISA system.

Keywords

indigenous knowledge, organic farming, Subtropics, system approach, traditional agriculture, Tropics

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1 Introduction

Agriculture is the central and the most frequently implemented life-securing activity in (sub) tropical countries. But smallholder farmer future perspectives are not bright: it becomes more and more difficult to achieve adequate yields for subsistence, to preserve and regenerate the basic needs for survival. Climatic changes coupled with rapid population growth, overgrazing, depletion of resources such as soil, biodiversity, water and energy, additionally population threats such as HIV/AIDS, malaria, hunger and poverty are all factors that clearly demonstrate the difficult situation of the people who live in low-income countries and regions of the world (Steppler and Nair, 1987: 34; Barbier, 2000; Rwelamira, 2004).

Population growth, extensive deforestation for timber through international companies and also by the local communities deteriorate the situation. Moreover farming systems relying mainly on the use of inorganic inputs (such as mineral fertilizers, pesticides and herbicides, slash and burn methods, species impoverishment), adoption of fallow cycles that are too short to allow forest and soil regeneration worsen the marginalisation of traditional farming systems worldwide. For example, in the Sub-Sahara region, cultivated areas have expanded notably and there is large-scale conversion from sustainable fallow-based cropping to continuous cultivation. As a result, the agricultural productivity has been on a downward trend, per capita food production has been declining by two percent per annum since 1960 (World Bank, 1996).

Nowadays it is characteristic for the small-scale farmers in the (sub) tropics to cultivate only few crops and trees with little or no use of fertilizers and pesticides coupled with weed fallow periods. Purposeful application of tools and methods such as mulching, composting, cultivation of legumes, agroforestry, water harvesting and dripping irrigation is found to be uncommon in these regions.

After the failure of the Green Revolution in Africa, and the application of integrated farming (which was only partly successful) the potential of organic agriculture is now being discussed. Traditional farming systems based on indigenous knowledge[1], which were mainly subject of anthropological studies, have nowadays also become a research topic for agriculturalists, who are increasingly interested in using and integrating indigenous knowledge into the development of current agricultural systems. Considering all the circumstances discussed above, the question is: which points of contact grounds do exist between traditional and the organic farming systems and how can those systems contribute to the problems and threats mentioned above? In order to give some reflections to these questions, I would like to focus on the following topics:

- Conflict areas of subsistence agriculture seen from a system-theoretical perspective
- Background and characteristics of traditional and organic agriculture

[1] The term indigenous knowledge is used close to traditional knowledge"... that is local, orally transmitted, a consequence of practical engagement, reinforced by experience, empirical rather than theoretical, repetitive, fluid and negotiable, shared but asymmetrically distributed, largely functional, and embedded in a more encompassing cultural matrix" (Ellen, 1998; Ellen and Harris, 1997), whereas local knowledge, based on local resources is not always indigenous knowledge (Antweiler, 2003)

- Historical land use system successions with an example of the Rift Valley, Kenya
- Environmental risks caused by land use systems, the dependency on the peripheral system and economic relevance
- Organic Agriculture under pressure – weaknesses and omissions in practice
- Organic Agriculture as an integrated framework for a modern land use system in (sub) tropical environments

The following reflections are mainly oriented to the agricultural development in the East African region. Nevertheless many of the observations and conclusions become a general validity.

2 Conflict areas of subsistence agriculture from a system-theoretical perspective

2.1 System approach

According to the system-theory, the whole agricultural value / production chain could be embedded in a model based on a core and a frame system approach for studying the differentiation of agricultural systems (following Luhmann, 1977) (Figure 1):

a) a three-parts centre (core system) consisting of a small-scale farm in a village within a region

b) a two-parts periphery (frame system) consisting of a country/nation and the global world of policy, market and consumers

c) a previous and subsystem dependent border in betweenWhile the developments in the central/inner area can be influenced partly by the local actors, the developments on the periphery, even though they affect the central area, can hardly be influenced by the very same.

Within each of the two systems - the core and the frame system - we can differentiate among six subsystems, which themselves are characterized by the same or by different factors and attributes. The following list is not meant to be complete; rather, the focus is put on the topics that are relevant from the perspective of the farm/rural community.

Core system:

(1) Demographic developments: high population growth, high effects of HIV/AIDS and Malaria on family development.

(2) Communication, education and research developments: loss of the culture of communication, little access to modern communication technologies, dominance of consulting in conventional agriculture (loss of traditional knowledge, little increase in knowledge).

(3) Health and food security developments: malnutrition, unbalanced diet, Malaria, HIV/AIDS…

(4) Economic developments: decreasing or no income in rural regions, particularly in the agricultural sector, little investment in the education and health sector, little investment in the natural resource management.

(5) Social society and poverty reduction developments: low status of agricultural activities, little changes concerning acknowledgement of women's rights, poverty increase, instability of the livelihood system.

(6) Environmental and agricultural developments: erosion, diminishing yields, droughts, temporarily water shortages, shortages of energy, low yields, ecological damages, deforestation.

Frame system:

(1) Demographic developments: high population growth.

(2) Communication, education and research developments: expensive communication technologies for local people, concentrated power over the media; dominance of training and research in conventional agriculture (loss of traditional knowledge, little increase in knowledge).

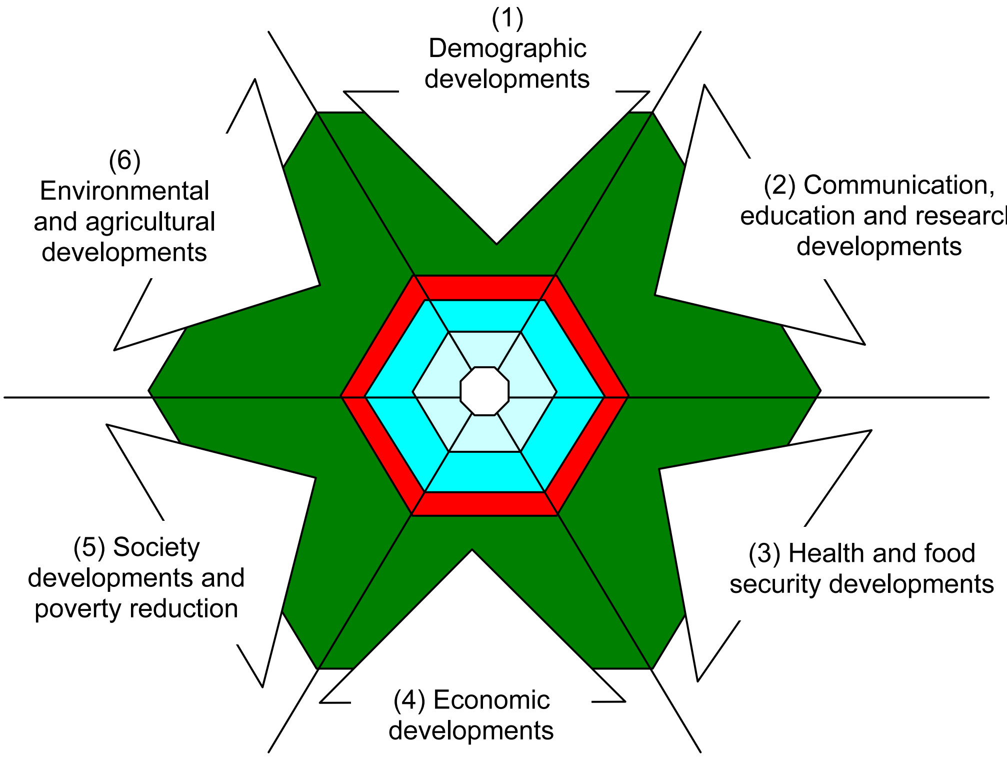
(3) Health and food security developments: health programs are mostly based on cost intensive allopathic approaches; food assistance, which improves food security, while at the same time hinders independency and self-sufficiency.

(4) Economic developments: WTO/GATT-regulations which favour the 'first world'; strategies of companies and policies which contrast the small-scale farmers' interests; pre-regulated prices for the agricultural inputs; monopolized and centralized power over the energy industry; privatisation of water resources; little or limited demand for Fair trade products; concentration of income in cities and countries of the North.

(5) Social society and poverty reduction developments: traditional family patterns are supplemented by new social patterns, egocentric lifestyles are becoming predominant, the society is becoming increasingly divided into rich and poor.

(6) Environmental and agricultural developments: climatic changes particularly disadvantageous for the (sub) tropics; increasing shortages of water and energy; dependencies of agriculture through the introduction of genetic engineering, hybrid seeds…

The external developments are affecting the local societies respective the local agriculture and are regulating and/or hindering the interaction possibilities in the inner area. At the moment it seems that, apart from some strategies which only function in a specific local community, there are no effective strategies for solving the dilemma cited above. The reasons for this situation lie in the frame system as well as in the core system.



Legend: core system: white (centre) – farm, light blue – local / commune, blue - regional; frame system: dark green– nation / country, white – global; triangle: subsystems (1)-(6); red – system border

Figure 1. Model of core and frame system of local agriculturally oriented societies in (sub) tropical low-income countries

2.2 Organic agriculture system approach

The following factors of selected sub-systems give a short description of the organic agriculture in (sub) tropical regions (sub-system number in parenthesis) from a core system perspective:

- (2) Increasing status of organic farming in training and extension.
- (2) Organic faming is becoming more and more relevant in the farmers' practice, the actual farmers' knowledge about organic farming however is unknown (the impression is, that the knowledge about organic farming is often low).
- (2) Comprehensive knowledge is necessary for the implementation of Organic Farming.
- (2) The structures are hardly comprehensible for the farmers (certification bodies, processors, distributors, traders and consumers of the organic food chain).
- (2) The present situation is to describe with indifferent acceptance of organic farming (concerning controls, written notes, labour intensity,

gender, manual work) and the accompanying status of farmers (innovator, outsider…).

- (3) There are several indications that organic farming is able to increase health (e.g. no health problems based on pesticides, diversity of plants) as well as strengthen the food security.
- (4) Higher income attained with export products.
- (5) By establishing farmer groups linking to the market this will influence societal structures as well as generates additional income to reduce poverty.
- (6) Highly positive effects of the organic agriculture on the environment support their societal status.

Important factors in the frame system are:

- (2) The increasing status of organic farming in training and extension supported by international organizations and private sector.
- (4) Clear definition of organic farming through regulations and through a system of certification.
- (4) Increasing interest for organic products on the part of international traders.
- (4) Slightly increasing interest on the organic production with NGOs and government through provision of infrastructure development as well as on research.
- (4) Increasing consumers' demand for organic products in high income countries.
- (3, 5, 6) Increasing interest on health and food security / poverty reduction and environmental and agricultural developments aspects linked with organic agriculture in the international discussion.

Today organic agriculture is being supported by various actors: local and international NGOs, local and national extension services, international export initiatives, nationally and internationally promoted development programs, church institutions, some initiatives on the part of international research institutions as well as national and international universities, and finally, by the FAO. From this perspective it can be stated that organic agriculture is in the process of consolidation. This process, however, is slow. This is not surprising, because, adoption is a long term process, with unforeseen development in quality, direction and participants, and dependent from internal and external factors of a system resp. a product chain (see also Rogers, 1983).

2.3 Traditional agriculture system approach

Concerning the traditional farming systems, the situation seems quite bad altogether. There is worldwide a decline in the practice of traditional farming methods (core system).[2] Farmers who practiced those methods in the 1950s are

[2] Country-specific developments can as well be observed there: e.g in Ethiopia the Green

decreasing in numbers, the knowledge is hardly recorded, passed on to new generations or taught. It remains open, which of the traditional methods, developed in certain specific ecological and social circumstances in the past would be applicable to the present requirements and circumstances (Antweiler, 2003: 5). Additionally, one has to notice that there is hardly anyone who could give a complete and concrete overall picture of traditional knowledge.

In the frame system there is no excessive interest for traditional farming methods. Except a few scientific institutions and some NGOs, but also UNESCO endeavour to record and make accessible traditional knowledge concerning agriculture, forestry, human nutrition and medicine. The initiatives taken vary strongly from country to country. The interest of economics and politics in organic farming as well as traditional farming is limited. Mainly the pharmaceutical industry is interested in profiting from the knowledge about medicinal plant use, however, has no interest in preserving the system. One important platform for traditional agriculture is the LEISA (low external input and sustainable agriculture) movement with their journal (see http://www.leisa.info) (ILEIA). Traditional farming products hardly play a role on the market. Along with the organic farming products they are sometimes sold as Fair Trade Products in the 'One/Third World Shops', however they can rarely be found in the supermarkets.

The system-theoretical positioning of small-scale farming systems in the (sub) tropics in general and of the traditional and organic farming systems in particular, as described here, represents the present situation in general terms. In the following, I would like to position the development of the different farming systems during the history, as well as to describe the relationship between the traditional and the organic farming system today.

3 Background and characteristics of traditional and organic agriculture

3.1 Development and social embedding

Traditional agriculture was developed and reached its heyday in a time when there was still much more cultivable 'nature' per person available than there is today. The agro-industry, the development and research policy, as well as the agro-policy of the countries concerned, have all contributed to the loss of traditional farming practice. Meanwhile there are some attempts to change this situation. Until today traditional agriculture is wide spread, in doing so, it is often a mixture of some traditional added with conventional, LEISA or conservation farming elements.

In the recent past organic agriculture has experienced a noticeable upswing in the (sub) tropics (Willer and Yussefi, 2004). For example, in Africa there are more than 1.2 Mio ha under organic management (Europe: 6.5 Mio. ha), with 38 percent (320,000 ha) of this in Uganda (IFOAM 2004). As a comparison, Kenya, has only about 400 hectares under organic management, showing that the development is country specific. Nevertheless, these figures doesn't offer an answer about the quality of organic farm management in practise, which are partly similar to those of traditional agriculture (see the chapter "Organic Agriculture under pressure").

Revolution hardly became established, rather, so called "traditional agricultural methods by default" that lead to heavy soil erosion, remained predominant until today.

The European organic agriculture started in the 1920s. Since the 1980s organic agriculture has had to establish itself along with the intensive land use systems and within the highly industrialized society of the western world. That also means, organic farming has to take into account the yield goals (e.g. how to feed the world?) and quality standards (food design) of conventional agriculture. These are relevant aspects which arise also in the (sub) tropics today, when organic agriculture is discussed as an overall perspective for rural development. Both, traditional as well as organic agriculture are in a certain competition with conventional agriculture to show their evidence e.g. to contribute the millennium development goals (MDG).

3.2 Guidelines, certification, premium price and subsidies

Traditional agriculture has no specific written guidelines or control-system, rather, it is embedded in a specific socio-cultural environment, which is usually passed on orally and its production is mainly for subsistence.

The IFOAM guidelines make the basis of all international procedures for organic agriculture; nearly 800 organisations worldwide have already joined it. The guidelines include four principles (IFOAM)[3]:

- **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.

In the context of certification there are three different developments:

- Farming practices which follow the principles of IFOAM guidelines but without any certification process. The production is mainly for own needs and the local market.
- Mainly internationally controlled organic farms, which are producing for the international market, mainly supported by private initiatives. That rarely happens without modernization and intensification of the farming methods.
- Local NGO driven, advised and controlled organic farms, producing mainly for local / national markets.Participating in the market of organic agricultural products and selling them at a premium price has been especially valuable for many poor farmers in developing countries. Nevertheless, often there is no higher price available at the local market. Even any premium for traditional products is

[3] http://www.ifoam.org/about_ifoam/principles/index.html

limited. Further more it seems improbable at the moment that subsidies for any ecological production will be offered in developing countries.

3.3 Characteristics of traditional and organic farming systems

Traditional farming offers plants and animals more ‘time’ and ‘space’. Organic farming too follows such principles (Freyer, 2006). In traditional farming, the cultivated plants and raised animals are mainly used for self-supply of people living in close relation with the very same. Little is being taken out of the system, most organic material stays within the farm or region. When the yield decreases, the place is left and the system recovers after some time, depending on the climatic region and the use intensity. The way the farming is formed is always to reflect with the socio-culturally specific background (Kluckhohn, 1951; Broom and Selznick, 1999). Due to population growth and land shortage, the decrease of shifting cultivation is inevitable. Accordingly, the pressure to use land for food crops more intensively is increasing in the organic as well as in the traditional system.

Diversity is one of the crucial factors in the maintenance of an agricultural system. On this point the two systems are very close to each other too. Traditional systems need a high biodiversity, because the societies relying on such systems have to produce as much for their basic needs as possible within the system area (e.g. medicines for animals and humans, all sorts of food and raw materials, fuel, timber etc.).

Organic farming does not include the application of shifting cultivation. Organic farming only works well when the soil is permanently cultivated and covered with plant biomass, and when the legumes supply the system with the nitrogen by biological nitrogen fixation. Deforestation is not compatible to the system approach of organic farming. The goal of this system is on the one hand to keep the basis for the production intact and on the other hand the production of food and raw materials for the daily use.

People working according to traditional systems produce their own seeds, do not buy additional fertilizers and do not use industrial produced pesticides nor herbicides. Within organic farming one also uses self-produced seeds, at the latest in the case of market oriented production it is necessary to buy additional seeds. Mechanical weed control as well as plant protection based on mechanical methods and on plant extracts, are part of both systems, although organic farming profits from indigenous knowledge and methods. The intensification of organic production makes the amplification of plant protection methods necessary.

One can conclude that the organic farming system in the (sub) tropics has developed based on two different cultural driving forces:

- on the one hand as part of an endogenous development of the traditional agriculture,
- on the other hand as a practice shaped predominantly by the North and connected to agroforestry systems (Steppler and Nair, 1987; Kang, 1993; Carter, 1996; Sills et al., 2003).

Export projects have a substantial influence on the development of farming methods. It is also beyond questioning that many elements of organic farming, as it is represented and propagated in the (sub) tropics by the North, already have been part of the existing traditional farming systems long before. Beyond that, the knowledge about the use of medicinal plants, and plants with aromatic substances (Karki et al., 2003), as well as the knowledge about plant protection derives to a large extent from traditional systems. LEISA Systems[4] also contributed to the innovations within organic farming systems. Integrated agriculture played a crucial role in the development of agroforestry since the end of the 1970s. The concept of 'Eco-farming' supplies important knowledge on the role of agroforestry systems in an organic agriculture (Egger, 1979). Additionally many elements, especially within the agroforestry and the LEISA systems, are based on traditional knowledge.

Based on these general reflections, the succession of the different agricultural systems from the 1950s will be demonstrated with the example of Rift Valley in Kenya.

4 Historical succession of farming systems on the example of the Rift Valleys, Kenya

"Traditional farming practices were productive over thousands of years because they were intuitively ecology-based. But the influence of the West - from the colonial period up through the present era of globalisation - has all but erased the legacy of that experience-based knowledge." (Onwonga, 2006)

The transformation of land use systems are to be interpreted as a result of internal as well as external developments, both of which vary regionally. Using Rift Valley region in Kenya as an example, it can be explained how these changes have developed and how the traditional and the organic agriculture are positioned today. The developments will be reflected according to criteria of the differentiation-theory (see Schimank, 2000: 271). The actors' perspective as well as the formation / transformation of the subsystems (e.g. trade, counselling) within a society are also taken into account. Internal (core system) and external (frame system) driving forces serve as comparison for the agricultural systems along the time axes as well as to structure the contents.

Within 50 years different land use systems have - partly successively, partly simultaneously - dominated the agricultural practice. Until the 1960s the traditional system was driven from within, the relation of the production, the maintenance of the production-basis and the population density were balanced. This system was mainly based on self-sufficiency. There was hardly any external trade, innovation was derived from within and on-farm research was carried out. All the social functions were locally divided within the family/extended family or the community – production, food security, conservation of resources, production of medicines, advising, and trade (see Table 1, Table 2, and Table 3). In their fulfilment of the daily duties, people were dependent on each other. There were barely any innovations, neither negative nor positive, introduced from outside the system.

[4] Remark: whereas in organic farming mineral nitrogen fertilizers, herbicides or conventional pesticides are forbidden, they are allowed in other so-called environmental friendly system approaches, e.g. sustainable agriculture or conservation agriculture (see Dumanski et al. 2006).

The increasing population growths after the colonial period, the land pressure by new Kikuju settlers – an internal factor – lead to a new situation in the 1960s and 1970s, which last until today in the land use conflict mainly between the Kikuju and Masaai ethnic groups.[5] The food shortage resulted in a need for an intensification of the production. The possible internal suggestions to attempt solutions were suppressed by the Green Revolution, which was imposed on the system from the outside. The transfer from communal land to individual one – a decision made on the national level – lead to a disintegration of the functions and responsibilities within the local community (see Table 3). National politics as well as international organisations offered, influenced and partly took over those functions and their contents (e.g. counselling). The development of agriculture was not any more driven from within; rather, it was shaped by governmental programs and other internationally operating agro-chemical industries. Functions such as the local production of medicine have lost their importance. The local indigenous knowledge has either diminished in its status or it has been suppressed and replaced by conventional tools and methods. The collective sense of responsibility for the conservation of natural resources such as forests, biodiversity and soil fertility was lost with the exception of some forest dwelling groups. Nevertheless, there were also internal factors as expanding population which lead to conversion of forest/woodland into farmland.

A process of individualization emerged and there were no concrete alternative directions for development, which would support the public spirit.[6] Farm products did not any more serve the local needs only, but were exported to markets far outside the region of production. This was also necessitated by the fact that communities demanded more products and services from outside (e.g. cooking oil, sugar, tea) and therefore had to trade something to get those. Food security has not increased fundamentally because of the reduction of soil fertility caused by erosion on the one hand and a lack of financial resources for buying additional agricultural equipment and food on the other hand. Cumulatively the agricultural society has transformed from a self-sufficient one to a society dependent on the external developments and based on the money economy. Consequently, there has been a recession in the sense of responsibility for the local resources.

The usual traditional methods undoubtedly could not any more cover the nutritional needs of the growing population. It soon became clear that the Green Revolution (GR) would lead to a social, ecological as well as economic disaster. On the one hand, people realized that farmers could not afford the GR package unless heavily subsidized. On the other hand, the reduction of biodiversity and the over intensification, lead to human and environmental damages. Since the 1980s there was the attempt to counter these developments through the introduction of the LEISA system as well as through the reintegration of agroforestry. The LEISA system could not establish itself as a whole. Only some of its techniques were implemented successfully, particularly since the system did not show any specific advantages on the market.

[5] Moi government capitalized on unaddressed land ownership and tenure issues created during the colonial period, 1960-2001 (http://www.internal-displacement.org/idmc/website/countries.nsf/(httpEnvelopes)/812DE3AE9D3134BC802570B8005AA901?OpenDocument)

[6] To judge the degree of influence of the church on agricultural development is not focused by this paper.

Table 1. Impact of land use methods on farm and nature development in the Rift Valley / Kenya since the 50ties

Characte-ristics	**Traditional agriculture until the 60ties**	**Trad. agriculture, Green Revolution (conv. agriculture) up to the 60ties until the 80ties**	**Conv., trad. agriculture, some investments into LEISA / Agroforestry in the 90ties**	**Conv., trad., some environmental oriented agriculture end of the 90ties, beginning 2000**
Land use system	Mainly shifting cultivation (slash and burn in some cases), fallow system	Gradual shift from traditional farming methods to modern (Conventional agriculture) but still majority of the farmers to date practice the former. Loss and/or non application of indigenous technical knowledge (ITK)	Aware of the faster disappearance of the ITK, efforts were made towards their revival especially in regard to crop and livestock disease control. Gradual introduction of LEISA and rapid promotion of agroforestry techniques	Reinventing the wheel i.e. concerted efforts to revert back to agricultural production practices that are environmentally friendly hence the concerted efforts by the NGOs and mainstream churches in the promotion of Organic / LEISA techniques
Soil status	High fertility	Gradual depletion of soil fertility	Soil degradation through soil erosion with consequent loss of soil fertility and other soil physical characteristics	Continued soil degradation as a result of escalating costs of fertilizers and the non visible impact of the LEISA and/or Organic farming technologies that were and are being promoted due to the fact that the soils had got quite degraded and hence needed some time to have the soil fertility regenerated
Planting techniques	Broadcasting, crop rotation, intercropping	Row planting, encouraged monocropping	Row planting still practised with introduction of specific spacing recommendations for different crops	Mono cropping is dominating. Row planting with specific recommendations on spacing
Agroforestry	No specific system, prominent species was *Sesbania sesban*	Gradual promotion of agroforestry with *Grevillea robusta* being easily adoptable by farmers alongside *Sesbania sesban*	Intensified promotion of agroforestry techniques. ICRAF, KEFRI, and NGOs at the fore front. Research on suitable tree species for the various agroecological zones conducted for both livestock and soil fertility enhancement	Limited investments in agroforestry but farmers continually take care of those they had already planted. Aggressive campaigns being mounted to encourage farmers to establish agroforestry trees on their farms

Table 1. continued

Forestry	Indigenous types, minimal deforestation	Gradual disappearance of community and individual forests as a result of indiscriminate cutting to pave way for additional land for cultivation, charcoal burning and even for human settlement	Tremendous deforestation due to rapid population increase that required more land and cheaper energy sources	Tremendous deforestation with concerted efforts for reforestation /afforestation. Hence the introduction of the Shamba system and environmental day: trees are planted on public land and farmers encouraged to plant also on their farms
Main crops	Sorghum, finger millet, maize, cassava, sweet potato	Loss of a broad spectrum of crop varieties with maize and common bean being ubiquitous	Tendency to plant few crops such as maize and common bean. With other additional crops (e.g. potatoes) that were being site specific	Tendency to plant few crops (maize, common bean) either as sole crops or intercrops. With other additional crops being site specific. There is also continued research efforts by Kenya Agriculture Research Institute and encouraging farmers to domesticate drought resistant crops such as cassava and also other higher yielding crop varieties (fruits e.g. bananas), new or old (e.g. maize and common bean)
Yield level	Generally higher crop yields were realized	Medium yields; health and nutrition problems	Decreasing yields	Decreasing yields
Fertilizer, compost	Compost - mainly animal manure with mulching/use of crop residues	Three approaches: 1. Continued use of compost for farmers who could not afford fertilizers 2. Use of mineral fertilizers only and 3. Use of a mixture of mineral fertilizers and compost/animal manure in varying proportions	As a result economic constraints, fertilizer use was on the decrease (lack of N and P) with increased use of compost and crop residues. Emergence of integrated nutrient management i.e. to ensure that farmers use compost a alongside limited amounts of fertilizers	The emphasis is on LEISA especially for the resource poor farmers and hence focus mainly on the use of manure even though fertilizer use is still possible among the well do of farmers

Table 1. continued

Pest and diseases	Incidences of pest and disease were low and herbs alongside other traditional concoctions were used as pesticides	Disease and pest incidences were on the increase. Herbicides and pesticides introduced; higher risks on pest, diseases	Disease and pest incidences high with the emergence of other diseases that was unknown before. To avoid mass crop failure farmers use pesticides and in some incidences the government comes to the aid of farmers in terms of buying them chemicals	Disease and pest incidences high. To avoid mass crop failure farmers use pesticides and in some incidences the government comes to the aid of the resource poor farmers in terms of buying them chemicals. The proponents of sustainable agriculture are however promoting the indigenous techniques in disease and pest control
Weeds	Medicinal and fodder plants. No indiscriminate weeding	Emergence of problematic weeds with limited domestication of medicinal and fodder weeds	Presence of problematic weeds with limited domestication of medicinal and fodder weeds	Presence of problematic weeds with aggressive campaigns for domestication of useful weeds such as medicinal weeds and some that are of human nutritional value
Plant breeding	On farm, criteria seed size and appearance	New seed material¸ new fodder grasses. Limited use of own seed	Promotion of hybrid seeds both from within and outside the country Limited use of own seed by the resource poor farmers	Promotion of hybrid seeds both from within and outside the country. Limited efforts by farmers to raise their own seeds. Continued use of own seed by the resource poor farmers
Plant and biotope diversity	Medicinal herbs, high tree and shrub diversity	Lower/intermediate biodiversity	Tremendous loss of biodiversity	Continued loss of biodiversity
Natural resources	Balanced, high and diversified	On the decline	Continuous decline, polluted water (nitrogen, pesticides)	Continued decline of natural resources (management) (NRM) with concerted efforts to reverse the scenario hence the focus on integrated NRM

Table 1. continued

Animal diversity	Wild animals, high bird variety	Gradual decrease of wild animals with decreased forest cover. Confinement of wild animals in parks, game reserves to guard against indiscriminate hunting	Continued decrease of wild animals with increased efforts of the government to conserve wild animal within the parks and national game reserves	Most wild animals in game parks and reserves with only a few and in most cases that do not pose a danger to human beings roaming the countryside
Animal husbandry	High diversity, use of harvested crop fields	Indigenous cattle breeds, new cattle breeds and livestock varieties and mixtures of the exotic livestock breeds with indigenous breeds	Increase of mixed livestock breeds with limited exotic breeds. Indigenous livestock breeds however continue to be the darling of many farmers	Increase of mixed livestock breeds with limited exotic breeds. Indigenous livestock breeds however continue to be the darling of many farmers
Hunting	Common and a way of life	Limited to specific communities in some remote parts of the region	Limited to some communities in the remoter parts of the region	Limited to some communities in the remoter parts of the region

(Source: Onwonga 2006, added and adapted)

Table 2. Farm economy development in the Rift Valley / Kenya since the 50ties

Characteristics	Traditional agriculture until the 60ties	Trad. agriculture, Green Revolution (conv. agriculture) up to the 60ties until the 80ties	Conv., trad. agriculture, some investments into LEISA / Agroforestry in the 90ties	Conv., trad., some environmental oriented agriculture end of the 90ties, beginning 2000
Labour	Household, work day exchange with other households	Household labour dominant. With exchange labour but on the decline. Start of hired labour	Household labour coupled with a few pockets of exchange labour. Increase in hired labour	Frequent lack of labour for environmental friendly techniques.** Household labour continue being the norm. Hired labour limited for additional farm work
Production, market	Demand for family and relatives; Barter trade* (mainly subsistence farming)	Export crops (coffee, tea, pyrethrum; most crops grown for subsistence such as maize also gets there way into the market)	Export of tea dominates but coffee and pyrethrum experience a marked decline due to changes of market forces. Production of maize for market is increased. Increased horticultural production is also realized	Export crops: Export of tea still dominates but coffee and pyrethrum start picking up at a slow pace. Production of maize and other horticultural crops for market is increased
Farm economy	Mainly subsistence based	Still subsistence based with a small fraction of farmers engaging in commercial farming especially in the production of wheat, pyrethrum and tea. Economic dependency on credits on a steady increase; escalating prices of the external inputs	Subsistence based with a number of farmers engaged in market oriented production of crops such as tea, wheat, pyrethrum and also maize for market increasing	Poverty, income by farm products limited as well as additional income (charcoal) – Due to poor market prices for farmers' produce both locally and in the international markets

* exchange of commodities e.g. bags of maize being exchanged for a cow
** farm work is no more longer attractive
(source: Onwonga 2006, added and adapted)

Table 3. Socio-economic and political environment of the agricultural development in the Rift Valley / Kenya since the 50ties

Characteristics	Traditional agriculture until the 60ties	Trad. agriculture, Green Revolution (conv. agriculture) up to the 60ties until the 80ties	Conv., trad. agriculture, some investments into LEISA / Agroforestry in the 90ties	Conv., trad., some environmental oriented agriculture end of the 90ties, beginning 2000
Land tenure	Communal, in the 60ties shift from communal land ownership to individual land ownership	Land mainly individual ownership with scattered pockets of communal land	Individual land tenure but with increased population, the land holdings becomes small and hence need for them to be used intensively, thus the emergence of farming techniques such as LEISA - demand on farm land is high	Decreased land holding (Smallholder farmers)
Land size	“No” limitation. Expansive land sizes that were communally owned and used	With land adjudication, disparities in size of land holdings was evident but were still adequate for family use	Beginning of land scarce With increase in population, rampant land subdivision set in with resultant small land holdings	Extremely limited land
Advisory/ extension	Not available, indigenous knowledge	Formal advisory and outside extension services by the Ministry of Agriculture (MoA) on the lead	Loss of indigenous / traditional knowledge Other extension agents such as NGOs and mainstream Churches started offering advisory services to the farmers alongside the MoA	Mushrooming of institutions promoting the LEISA (and organic farming) among other farming technologies
Education/ University	High levels of illiteracy was common among the rural households and farming was largely based on the use of indigenous knowledge/Techniques	Pockets of illiteracy levels were still evident especially among the old citizens but the reverse was the case for the young ones. Adult education was also encouraged. Efforts were also made to train farmers on new farming techniques	Conventional farming techniques are dominating	Shift to new environmental friendly techniques

Table 3. continued

Policy	The policy which was there then was in favour of the colonialists and oppressive to the Africans as the latter were not allowed to grow cash crops	Agricultural policy had to be reviewed immediately after independence to be pro-indigenous Kenyans	Collaboration with the international Community especially in matters of marketing agricultural produce, acquisition of farm inputs etc was encouraged	Shift to new environmental friendly techniques; organic farming and traditional agriculture are option but not a priority
Poverty / health	Minimal	Intermediate	Increasing	Increasing
Population	Low	Intermediate	Increasing	Increasing

(source: Onwonga 2006, added and adapted)

From the 1990s on, the organic farming has increasingly become a subject of discussion. Some of the newly founded social subsystems (NGOs, church institutions, e.g. Baraka agricultural college), institutions for counselling and controlling (Kenya Institute of Organic Farming (KIOF)) and some individual actors became interested in this system. In practice however, today there are only few certified organic farms in the Rift Valley, on the other hand there are many farms which apply no herbicides, pesticides of mineral fertilizers but which only rarely established a diverse legume based cropping systems.[1] Their methods therefore are not considered as organic. Organic farming in Kenya is not a mainstream method because it is neither promoted systematically by the state nor by the Universities (except for the Egerton University).

Consequently, the observations specifically describing the developments in the Rift Valley, though they apply to many other regions likewise. While until the 1950s[2] the agricultural practice and its various subsystems were mostly driven from within, after the 1950s the use of land increasingly became shaped by external guidelines. The population growth has on the one hand set limits to the potentials of traditional farming. While on the other hand none of the succeeding systems and subsystems has managed to establish itself on a large scale or to contribute comprehensively to the solution of the existing problems. The knowledge about some traditional methods which are of enormous importance today (e.g. natural plant protection methods or herbal medicine), are also about to disappear. Organic farming, which could offer potential solutions for the conflict areas mentioned above, could so far not establish itself as a guiding model, even though more and more organisations supporting organic farming are being founded. The LEISA system is experiencing a similar fate.

5 Environmental risks caused by land use systems, the dependency on the peripheral system and economic relevance

In an agrarian society with a low income potential, the handling of one’s own resources and the degree of dependency on peripheral systems play a significant role. Based on the differentiation theory (Schimank, 2000) the farming systems can be evaluated according to the following characteristics:

- The risks for the natural resources and their consequences for the human nutrition
- The degree of dependency on system-specific production equipment, which cannot be self-produced
- The degree of dependency of the systems on the external economy and market developments

The possibility of evaluating agricultural systems is limited – except for the certified organic farming - because the systems – even the certified – do not follow a strict scheme. It can happen for example that in a traditional system, pesticides and herbicides are applied once in ten years or always, but only for one out of 20 crops which are cultivated.

[1] To be described as “organic by default”.
[2] There is some overlapping with the colonial period. Their agricultural systems are not part of this analysis.

According to this differentiation-theoretical evaluation described above, organic farming has from the theoretical point of view, apart from the system of hunters and gatherers, the estimated lowest risks for an impairment of natural resources, because of the practice of cultivating the humus content (see Table 4). A somewhat higher risk is assigned to other environmental friendly farming methods, if they do not include the practice of soil covering or the cultivation of legumes, or if their livestock numbers are not site adapted. Concerning the biodiversity, the traditional system is most positively assessed, but often could not be fulfilled today.

The positive assessment of the traditional system in the 1950s is obvious. The relatively high independency of the traditional system means that the consumption of domestic requirements was regularly covered by the system. Of course, in each of the represented systems there may be situations where this is not possible (e.g. crop failure).

The traditional system is to a large extent self-sufficient concerning the agricultural inputs. Nowadays the production within the system does not cover the food needs. Because of the currently rather low yields, the high land pressure and the temporary water scarceness the system cannot afford to purchase additional food to cover all the needs. If we assess the traditional system under present conditions, where the relation of people to the size of land is more disadvantageous, the risks for the natural resources increase more and more. The pressure to use high yielding crops in order to realize some more harvest leads to low diversified cropping systems with all its environmental problems, as well as to human malnutrition. The system thus becomes partly conventional. Following the "Sustainable Livelihoods Framework (SLF), which is based on the premise that livelihood is not about resource productivity but it is about people and their lives" (Karki et al., 2003), we can conclude that in overpopulated regions the traditional systems are in a crisis, and – because of resource destruction – the livelihood is unbalanced.

The opinion that "organic production methods usually develop their yield-increasing effect more slowly than those incorporating the use of chemicals" (Johannsen, 2005: 16), which hinders the use of organic methods, is to be scrutinized. Against the convictions of organizations or researchers, who criticize organic farming for being a system which needs several years more in order to realize yields which are higher than those of the traditional systems, there are already several examples which prove the contrary. Further more there are examples which demonstrate that the yields of organic farming are just as high as those of the conventional production (Greenpeace and Bread for the World, 2002). Legume based fallows in the short rains have shown that maize yields in the long rain season can increase tremendously (see e.g. Leley-Ndemo, 2004). Compared to conventional farming one has to stress that the yields in organic farming can be lower in the short term, but in the long term the output per unit of area is higher because there is no loss of cultivation area and the natural resources are saved.

The more the organic farming system is connected to the international market, the higher is the number of players involved in the production chain and the higher is the risk for dependency on decisions made externally. Because the establishment of a natural resource management and of a certification is costly, additional income is necessary in order to afford it. A balanced price-costs relation is ensured also if Fair Trade rules are considered/respected. However, with the establishment of the Fair Trade approach not all economic obstacles are overcome, because only a limited part of the premium is paid directly to the farmer.

High market orientation leads to a change in the subsistence-type from pure subsistence, over a quasi-subsistence with max. 25% time expenditure on the cash crop production, to a subsistence with up to 50% of cash crop cultivation (Symons, 1978). This type of intensification of the system entails an increase in labour intensity and in the dependency on the outside.

The increased export of products leads to a new constellation of the nutrient and humus balance, to a higher dependency on external sources of nutrients and, if there is an intensification of the cropping systems, to an increased dependency on the plant protection products. Accordingly, the technical requirements increase.

The traditional system of the 1950s shows the highest independency of the frame system processes. This also applies for some elements of the Resilience Theory (see Carpenter et al., 2001), such as for example the buffer capacity of the degree of self-organization. Network and exchange processes (Meyer and Rowan, 1977) within traditional systems are well developed and quite intensive, although the traditional systems are, as opposed to the organic farming, mostly part of an (often ethnically) enclosed community. Today the traditional system faces a new situation.

The potential buffer capacity against environmental risks and the capacity of self-organization are getting lost in those cases where the pressure on the agricultural land is high and industrialization and urbanization processes determine more and more the rural development.

The comparison underlines that the environmental risks of the extensive systems is slightly but different, and it is a question of careful handling of farming methods to reach the goal. In terms of resource management the dependency is increasing with the intensity as well as the economy and market dependencies.

To come to a conclusion concerning the different land use systems future potential, the organic system, which is an ethically independent and world-wide oriented movement, seems to be more robust, interactive and open for innovations as well as for learning processes.[3] At the same time farmers are dependent on a comprehensive knowledge. But some reflections also point on the fact that the organic farming system can come under pressure and that this can have negative consequences for the natural resources. In the following I will deal with that issue in greater detail.

[3] Excluded from this statement are e.g. traditional systems in the rain forests.

Table 4. The different land use systems' risks for the natural resources and their dependencies on the peripheral organizations and developments

Land use systems	hunters and gatherers	„Traditional" agriculture in the 50ties	OA with**o**ut **c**ontract OA_{woc}	OA **w**ith **c**ontract OA_{wc}	LEISA/ Integr. agr. appr.	Green rev. / conv. agric.
Risks for natural resources						
Soil erosion	x(x)	x(x)*	x*	x*	x(x)*	xxx
Soil fertility level	x	x(x)	x(x)	x(x)	x(x)	x-xxx
Water quality and quantity	x	x(x)	x	x(x)	xx	xxx
Biodiversity	0-x	0-x	x	x	x	xxx
Human nutrition security	0-x	0-x	0-x	0-xx	x-xx	x-xxx
Human nutrition quality**	0	0	0	0	x-xx	xxx
Resource management input dependencies…						
Phosphorous, potassium	0	0	0-x	x	xx	xxx
Nitrogen	0	0	0	0	xx	xxx
Plant breeding / seeds	0	0-x	x-xx	xx	xx	xxx
Animal breeding / animals	0	0-x	x	x-xx	-	xxx
Weed control	0	0	0	0	xx	xxx
Pest and disease control	0	0	x	x-xx	xx	xxx
Medicine	0	X	xx	xx	xx	xxx
Economy and market dependencies…						
Guidelines / certification	-	0	x	xxx	x	x-xxx
Knowledge / Information / Education / Training	-	x	xx	xxx	xxx	x-xxx
Local / national market	-	xxx	xxx	xxx	xxx	x-xxx
International market	-	x***	0	x-xxx	x-xx	x-xxx
Fair trade	-	x***	x	xx-xxx	(x)	(x)

Legend: 0=independent; x=low; xx=moderate; xxx=high; -=not applicable; ()=in specific cases higher risks / dependency
Conventional agriculture: if international market oriented, assessment is mainly "xxx"
* A positive assessment of environmental friendly land use systems is only possible, if the methods are well transferred into practise
** free of pesticides
*** traditional products

6 Organic agriculture under pressure – weaknesses and omissions in practice

The comparison of the different farming systems emphasizes the potentials of organic farming, but it also points at threats, which can be expected in the case of inappropriate land use. Organic farming thus can turn into a non-sustainable agricultural practice. Most of the transfer deficiencies we can find on organic farms can be seen as a result of an underdeveloped natural resource management:

- Non or incompletely established agroforestry concept

- Insufficient soil cover (lack of plants / soil cover, lack of water, insufficient water harvesting, storing and irrigation techniques)
- No use of various cropping system approaches (crop rotation, inter cropping, mixed cropping, improved fallow systems, hedge systems)
- Low diversity of plants and animals
- Open nutrient cycles (lack of nutrients, or high nutrient input on market crops)
- Lack of biomass compost, farmyard manure preparation and use

Exploitation of forest and other on farm trees for fuel wood due to lack of alternative energy systems/sources

These obstacles never appear concurrently, on each plot and rarely on the whole farm, because control organizations would intervene in case the farm is certified. Nevertheless, there are cases (the so-called “organic farming by default”), where organic farming is done using neither pesticides nor fertilizers, and without practicing anything against the guidelines, but where at the same time some important things (which makes organic farming sustainable) simply are being left out.

We can identify five driving forces, out of which the most are not very specifically for the organic farming system but more general, which led to unsustainable land use:

- Lack of techniques, which are not primarily linked to a specific land use system (e.g. none / obsolete irrigation systems; no water harvesting systems).
- High labour input for the daily organisation of firewood and water.
- Lack of education, information, knowledge.
- Lack of financial resources for
  - basic investments in the natural resource management,
  - basic inputs in the production.
- Limited land resources: The more a farm is market oriented (certified organic farms) the more there is a riskto use all land capacities for the
  market production, while at the same time neglecting the natural resource management,
  - to intensify the production in an environmentally unfriendly way.

Of course, if a farm generates additional income by selling products on the international market, there is a chance to invest the money into the natural resource management. It is actually an open question whether this is the case and if yes, in which resources they do invest (Pali, 2006, personal communication). Often the economic situation of a smallholder farm is extremely limited, that the money earned in the morning is spend until the evening for covering everyday needs. Often the money must be given to other family members or friends that at the end of the day there is no additional income available for any investment into natural resource management.

Additional to these environmental-economic weaknesses in the farming system, there is a breakage between a healthy environment, a healthy production and a healthy and manifold human nutrition. This means that if the diversity of the plants cultivated on the farm is limited, one important potential of the organic farming system, namely its contribution to the healthiness of the people, gets lost.

Complications linked to the farm controls are both in the frame and core system, the crucial factor for the development of organic agriculture. For example, in order to import tropical organic products into the European markets, smallholders have to consider numerous issues concerning the compliance with the EEC 2092/91:

- high costs and excessive paperwork (Hadid et al., 2004),
- differing local conditions which require comprehensive knowledge (Twarog and Vossenaar, 2003),
- various social issues (Vanderhoff-Boersma, 2000),
- extensive inspection requirements (Herrmann and Heid, 2000) and
- a conflict with the organic principles (Singh, 2000).

A reduction of certification costs, any adjustment of the so called international guidelines to (sub) tropical environmental, economic as well as societal conditions, which were basically developed by European countries and thus have a 'colonial' character from the small-holder farmers' point of view (Naturland, 2002) (Rundgren, 1997) or the establishment of local certification branches or indigenous certification bodies (FAO, 2006) (e.g. the Internal Control Systems, ICS) are possible options which could help to increase the application of organic agriculture.

To a certain degree some of the described deficiencies are similar to what is called "*Conventionalisation of Organic Agriculture*" in the western hemisphere (e.g. Guthman, 2004), but the picture is different. At the level of production this means that the farmers simplify the cropping system, the management of manure and the biodiversity of the landscape.

7 Organic agriculture as an integrated framework for a modern land use system in (sub) tropical environments

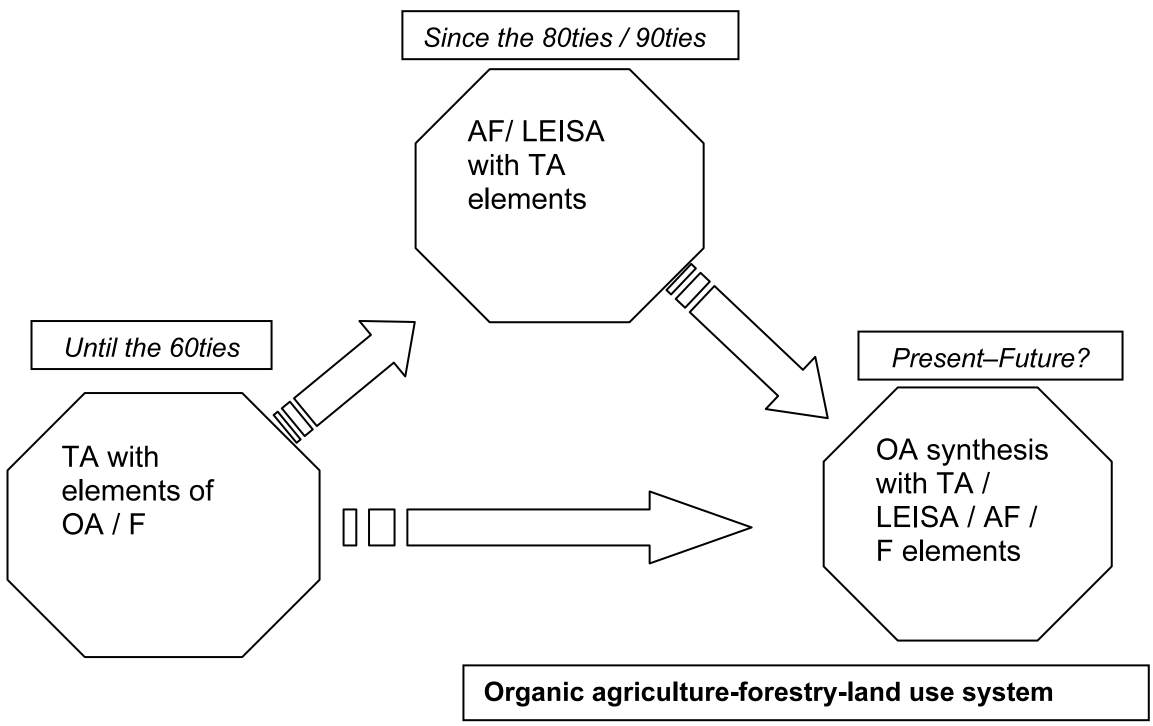
Having compared different land use systems and shown their characteristics from different perspectives, the question arises: how could a synthesis of the traditional and organic farming as well as other approaches look like?[4] Within this synthesis, elements from other land use systems, which stand in accordance with organic farming guidelines, should also be taken into consideration. Organic agriculture offers a becomes a guiding function under all mentioned systems because with its system approach it:

- offers space for the integration of traditional and modern elements of "close-to-nature" methods from different land use systems,
- contributes highly to the self-sufficiency and to a healthy nutrition,

[4] The idea of such a synthesis is not new. One example is the Center of Indian Knowledge Systems, where research, training and publications about indigenous knowledge and organic farming are being offered (http://www.ciks.org/projects.htm).

- shows to be socio-culturally near to the traditional agriculture, with a high degree of innovation at the same time,
- protects natural resources,
- disposes over internationally accepted instruments and structures (guidelines, control, counselling, information material, research),
- strives for economic justice between the trade partners (see Kledal, 2003) and is already integrated into Fair Trade with its many products,
- offers internationally recognized and demanded products.

Traditional knowledge serves as a starting point for agriculture in the (sub) tropical conditions, which is suitable for the future. This knowledge is being taken over, modified, and it is also being replaced by the innovations of organic farming. Agro-forestry systems, forestry systems and elements of the LEISA or conservation agriculture system, all based on biodiversity, are being incorporated into the ecological land use system, as far as they correspond to the basic guidelines of IFOAM.



AF=Agroforestry; F = Forestry; OA=Organic Agriculture; TA=Traditional Agriculture

Figure 2. Organic agriculture-forestry-land use system

Organic agriculture is a mixture of many techniques. Its central elements are the conservation of soil fertility, site adapted livestock units and a large degree of independency from external agricultural products, as well as the perception of the farm and its surrounding as an organic whole. Traditional methods such as for example a high plant diversity, the keeping of animals and breeding goals adapted to the climate or the use of local plants for medicine or pesticides, stand in accordance with organic farming perceptions. The proportionally high consumption of water and energy, which is necessary for the production of animal calories (Pearce, 2006), emphasizes the significance of those traditional diets, which are mainly based on plants. The human diet has to be brought into line with the diversity of plants and animals. Biological pest control, as it was developed by the LEISA approach, corresponds in most cases to the guidelines of organic farming as well as low tillage systems from conservation agriculture. The integration of agroforestry plays a central role. Little has been discussed so far, but also indispensable, is – besides agroforestry – the systematic integration of forestry elements into the organic farming system. The result of a consolidation of the methods mentioned above would be a so-called “Organic agriculture-forestry-land use system”.

Efficient water usage and the application of alternative energy systems, as well as hygienic measures for diseases prevention, play a crucial role in the self-sufficiency approach. Sustainable changes of land use systems are unthinkable without investments in those sectors.

Extra work required in organic agriculture will be worth the effort once its positive effects on the security of the yield and on the quality of the products will be realized. The tasks, which are most labour-intensive, are not so much the manual work in the agriculture itself, but, in many cases, the (hard work of) obtaining of water and fuel.[5] Without innovations in those sectors, any extra work required for organic agriculture will not be well-accepted and also will come up against real limiting factors. Decisive is the advantageous integration of organic farming into the livelihood framework.

From a farm-economical perspective, organic farming does not require the common inputs but there is a need for investments into soil fertility mainly at the beginning of the conversion. Organic farming hence achieves better results even before selling the products compared to any reduced form of conventional farming defined by low biodiversity, no agroforestry, natural fallow instead of legume-based fallow, certain input of mineral fertilizers and pesticides instead of mulching, composting etc.

Seen from the socio-economic perspective the implementation of the system presented here is certainly a big challenge:

- “In the South too, the young generations do not like to spend the whole day toiling in the fields if there are no attractive alternatives. Increasing leisure-time by using pesticides instead of weeding is very common e.g. among many of the Maya maize farmers in southern Mexico. In Africa, the almost magic reliance on pesticides in “plant medicine” is very widespread” (Johannsen, 2005: 18). Manual work is less respected than the application of pesticides.
- “Additional distortion of market prices by government subsidies being provided for external inputs hinders the farmers to renounce of chemical inputs (sometimes chemical inputs is used as an election bribe by governments)” (Johannsen, 2005: 18).

[5] In fact, a general statement about labour is not possible: a lack of labour is obvious in some societies, in others less or not at all (Johannsen, 2005: 14).

- From an internal perspective of the profit makers from the agro-chemical industry, organic farming will only be accepted if farmers buy their products. But this will only rarely be the case.
- The social status of those employed in agriculture is decreasing. Even the students in the low-income countries prefer to study subjects such as economics and business studies or communication technologies. Agricultural studies and research are predominantly oriented towards conventional land use systems.

Those who give the organic agriculture system a chance only if an appropriate market exists, miss out that there is neither an attractive market for the conventional nor for the traditional products. National and international trade demands for organized, standardized production, require specific pre-requested quantities of products, transportation logistics etc. This is challenging for agriculture in general, not only for organic agriculture. A key approach for the international market is a production and marketing concept strict oriented according to Fair Trade rules.

The driving forces behind the development of organic farming should not be in the interest of internationally acting food traders and wealthy consumers of the North only, but rather in the interest of the farmers in a sustainable management of their own resources, in self-sufficiency as well as in the supply of the local and national markets with healthy food. That means it should be an internally driven bottom up development, to be more independent from the international development and better laid down in the local society.

The reflections have shown, that the establishment of organic agriculture is closely linked to overall societal developments and the societal value system. The role which organic farming will play mainly depends on how one communicates this system and if the same is supported by (locally or internationally) relevant stakeholders and organizations. The education and research sector have a key function here. Organic farming will not be able to establish itself without huge investment in all mentioned sectors.

8 Conclusions

On the one hand, organic farming serves to conserve indigenous knowledge. On the other hand organic agricultural systems are adapted to local conditions, as a from of modernization of the traditional land use system. An organic agriculture-forestry land use system will only work properly if the farmers perceive the system as advantageous for them and if they adjust it to the environment while taking into consideration their own socio-cultural traditions. Even without selling the products on the international market, this system is advantageous for the peasants because it contributes to an increase in the yield and in the fertility of soil, not mainly through external inputs but through a purposeful application of various plants, legumes, cropping methods and compost. Apart from all those advantages, many questions are still left open, that is, (1) how a conversion of farms and regions to organic farming could be nationally and internationally communicated, financed and realized as a development based on the interests of the stakeholders and the community and (2) how does a systematically approach looks like to serve traditional knowledge in the organic agriculture system?

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How organic agriculture contributes to sustainable development

Lukas Kilcher *

Abstract

Organic agriculture can contribute to meaningful socio-economic and ecologically sustainable development, especially in poorer countries. This is due on the one hand to the application of organic principles, which means efficient management of local resources (e.g. local seed varieties, manure, etc.) and therefore cost-effectiveness. On the other hand, the market for organic products – at local and international level – has tremendous growth prospects and offers creative producers and exporters in the South excellent opportunities to improve their income and living conditions. Establishing whether organic agriculture is a viable alternative for a particular holding needs to be carried out on a case-by-case basis. What potential does organic agriculture have for solving the problems of hunger and poverty? What can organic agriculture contribute to achieving socially and ecologically sustainable development in poor countries? Central to organic agriculture are promotion of soil fertility, biodiversity conservation (e.g. native flora and fauna), production methods adapted to the locality and avoidance of chemical inputs. These methods, together with cultivation of a diverse range of crops, stabilize the delicate ecosystems in the tropics and reduce drought sensitivity and pest infestation. Organic agriculture reduces the risk of yield failure, stabilizes returns and improves the quality of life of small farmers' families. To date, no systematic attempt has been made to evaluate the benefits and effects of each system. In 2006, FiBL therefore launched a network of long-term system comparisons in the tropics that aims at examining the contribution of organic agriculture to food security, poverty alleviation and environmental conservation. The article presents this discussion based on experience gained in practice and encompasses the following hypotheses:

1. Organic agriculture is sustainable and diverse;
2. Organic farmers conserve resources;
3. Organic farmers produce more, better-quality products and achieve higher incomes;

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4. Organic products provide market access and create added value;
5. Organic agriculture increases self-confidence and mobilizes new partnerships.

Keywords

farming systems comparison in the tropics, organic agriculture in developing countries, sustainable development

1 A wealth of experience, but so far no systematic evaluation

The concept of organic agriculture builds on the efficient use of locally available resources, and on the use of adapted technologies (e.g. soil fertility management, closing of nutrient cycles, control of pests and diseases by means of natural antagonists). This concept opens up new ways of achieving sustainable development in the South and has therefore developed dynamically over the past decade (Willer and Yussefi 2006). Organic agriculture has the potential (Kilcher 2005):

1. to improve soil fertility, biodiversity and sustainability of agricultural production;
2. to conserve natural resources;
3. to improve agronomic and economic performance; to make yields more stable, especially in risk-prone tropical ecosystems; to achieve better food quality and food security;
4. to provide access to attractive markets through certified products;
5. to create new partnerships within the whole value chain as well as to strengthen self-confidence and autonomy of the farmers.

Organic farming is the subject of extensive research in northern countries, especially in Europe. A wide range of studies (Mäder et al. 2002, Offermann and Nieberg 2000, Stolze et al. 2000) have demonstrated the advantageous aspects of this system in terms of ecosystem functioning, soil fertility conservation and economic impact. NGOs and farmers' groups are increasingly adopting organic techniques as a method of improving productivity and food security in these systems. However, no systematic attempt has hitherto been made to track the extent to which these approaches are being employed, or their effectiveness compared to other approaches, in meeting economic, social and environmental objectives (Parrott and Kalibwani, in: Willer and Yussefi 2006).

What and how organic farming can contribute to food security and sustainable development in tropical countries is of particular interest for research and development, for stakeholders in the whole value chain, and for national authorities, as well as for national and international cooperation agencies concerned with policy development: in view of the diminishing financial resources available for agricultural research in development, it is important to invest in the most sustainable and cost-efficient strategies. The interest in secured data based on a sound evaluation of organic farming vis-à-vis conventional solutions is therefore very high.

2 Long-term farming systems comparisons in the tropics

Based on this demand, in 2006 FiBL launched a network of long-term farming system comparisons in the tropics (Kenya, India and a site in Latin America that has yet to be defined). The aim of this project is to examine the contribution of organic agriculture to food security, poverty alleviation and environmental conservation. It covers cash crop-oriented systems as well as subsistence crop-based systems under a wide range of agro-ecological and socio-economic conditions.

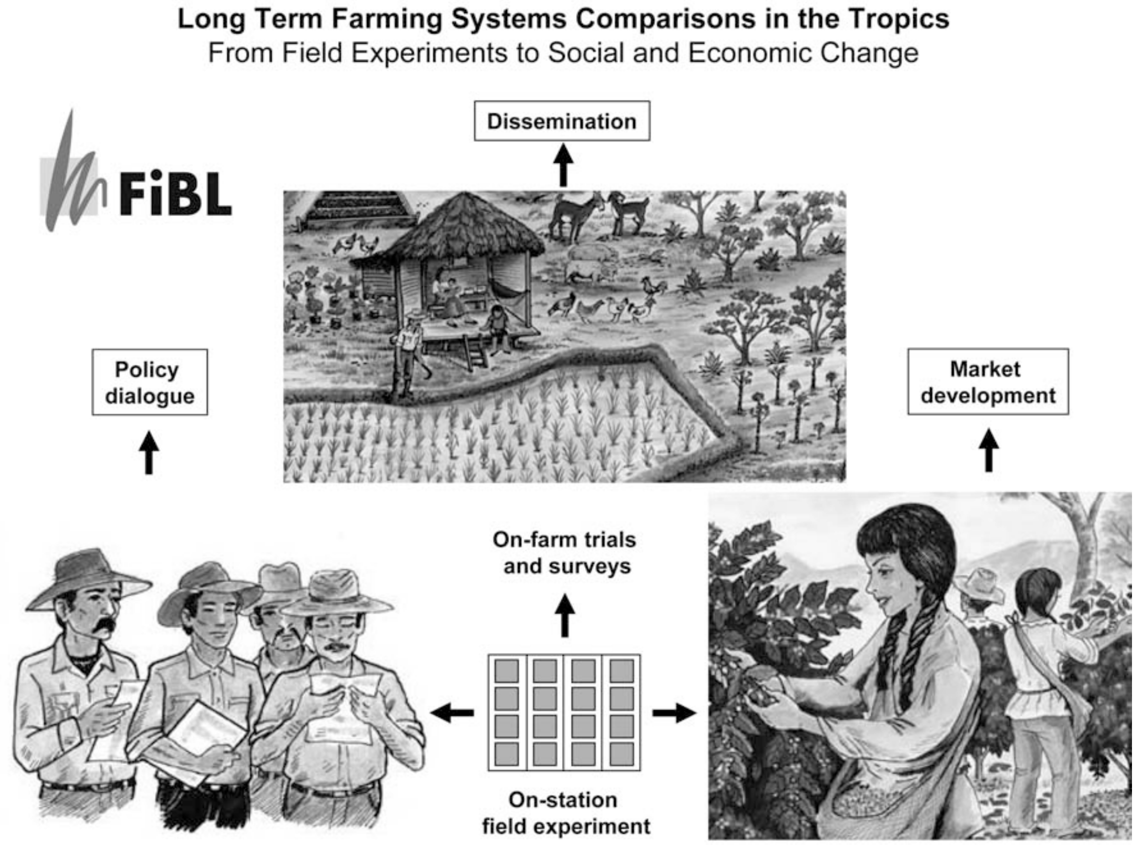

Chart 1: Approach and research methodology of the FiBL long-term farming systems comparisons in the tropics.

The core components of the project are long-term comparative field experiments on randomised plots with exact statistical profiles. Crop portfolio and management practices reflect current local practice for the system in question. This experimental design will allow for a precise comparison of agronomic and ecological parameters. To ensure that the plot experiments are run in a manner that closely reflects practice, farmers' groups are involved in defining the systems and managing the field plots.

In addition, data from existing farms and their field crops will be collected and analysed. For this, FiBL and its partners in the tropics will analyse a representative number of organic and nearby conventional farmers in the regions of interest. Strong emphasis will be placed on ensuring a statistically valid selection of farms. It will be ensured that the farms under comparison are subject to the same soil and climatic conditions and are typical for farming systems in the relevant regions. Here, the main focus will be on economic and social parameters, but agronomic and ecological aspects will also be studied.

Taking into account the different types of organic agriculture that prevail, FiBL intends to investigate (a) traditional farming (mostly small-scale, for home consumption and local markets, traditional methods), and (b) agricultural production for export markets (often medium to large-scale, improved methods). The systems will be evaluated in terms of food security, poverty alleviation and environmental conservation. Accordingly, the physical yields of the organic and conventional systems will be measured, and inputs and outputs will be recorded. This will allow input-output analysis of both farming systems and the systems will be characterized by their efficiency. A set of indicators for environment conservation will be assessed, relating to soil, water, landscape and biodiversity. A socio-economic study will be carried out based on farmers' records and on data assessed in the field plots. Semi-structured interviews will cover social issues.

Further, we aim successively to integrate innovation packages into the long-term system comparison trials (e.g. improved crop rotations, soil management, cover crops, biodynamic preparations). For this purpose, new agro-ecological technologies developed both by local farmers and/or international/national agricultural research institutes will be tested under local conditions, adapted if necessary, and introduced into the system comparison experiments at pre-defined intervals (e.g. every five years).

Picture 1: Organic farmers from Karatinga (Kenya) discussing their experiences with organic farming in a pepper nursery. These pioneers in organic farming in Africa are important partners of the FiBL network of long-term farming systems comparisons in the tropics. Participatory on-station and on-farm research generates new knowledge that is shared with other farmers. Such learning processes lead to sustainable innovation.

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The results of the system comparison trials will show benefits of and challenges for organic agriculture. These results will be communicated through appropriate channels to all relevant stakeholders and interested parties. The results will support farmers' organizations, research, extension, development cooperation, trade and national authorities in their strategic orientation, and in developing action plans for organic farming. The outcomes of the system comparisons can also be utilized as a basis to develop and disseminate organic farming technologies further according to the specific requirements of the farmers.

Initial results of the long-term farming system comparisons in the tropics will be available within a few years. Even now, a wealth of experience is available from farmers and farmers' groups in the South that have already adopted organic farming methods. The following discussion is based on this experience, which has been gained especially through international cooperation projects of FiBL and its partners in the arid and humid subtropics and tropics.

3 Organic agriculture is sustainable and diverse

Humid tropical conditions such as hot temperatures, high annual rainfall and poor soil properties require appropriate agricultural practices. The tropical rain forest as an original ecosystem with its closed nutrient cycles and biodiversity serves as an ideal model concerning nutrient management and cropping patterns. The diversity of the production system is therefore of special importance in the tropics: simplified systems and monocropping harm soil fertility and the ecological balance to a much greater extent than in temperate climates because soil oxidation and pest population dynamics run permanently and more rapidly in the tropics. Heavy rainfall and high temperatures accelerate mineralisation of the nutrients and retard accumulation of soil organic matter. Tropical farming can only be sustainable if the primary rules of this natural system are respected.

Central to organic agriculture are promotion of soil fertility, conservation of biodiversity (e.g. native flora and fauna), production methods that are adapted to the locality and avoidance of chemical inputs. Use of such methods and cultivation of a diverse range of crops stabilize the delicate ecosystems in the tropics and reduce drought sensitivity and pest infestations. Organic production reduces the risk of yield failure, stabilizes returns and therefore enhances food security for small farmers' families. Organic farmers do not fight against the natural dynamics; on the contrary, they use them to their advantage. The perennial vegetation in the tropics offers excellent alternatives to simplified production systems:

1. Agroforestry: agricultural production in forestry systems and under shade trees.
2. Intercropping: a combination of two or more crops on the same plot and at the same time.
3. Rotation: one crop is followed by another crop, preferably from a different botanical family.

In 1997, the Cuban Ministry of Agriculture started a project in cooperation with FiBL, local traders and investors (ASI, Agricultural Services and Investments) with the objective of developing the production and marketing of organic citrus products, tropical fruit, coconuts, sugar, coffee and cocoa. FiBL and the Cuban Institute for Tropical Fruit Production (IIFT) coach the farmers and agricultural employees during the conversion process. Nine years on since its launch, this project now has more than 2000 participating farmers and covers more than 6000 ha of land. Most farmers are located in the eastern and central provinces. The large-scale cooperatives in the central provinces have specialized in a few products, while the small mountain farmers' cooperatives produce a range of agricultural goods in agroforestry systems.

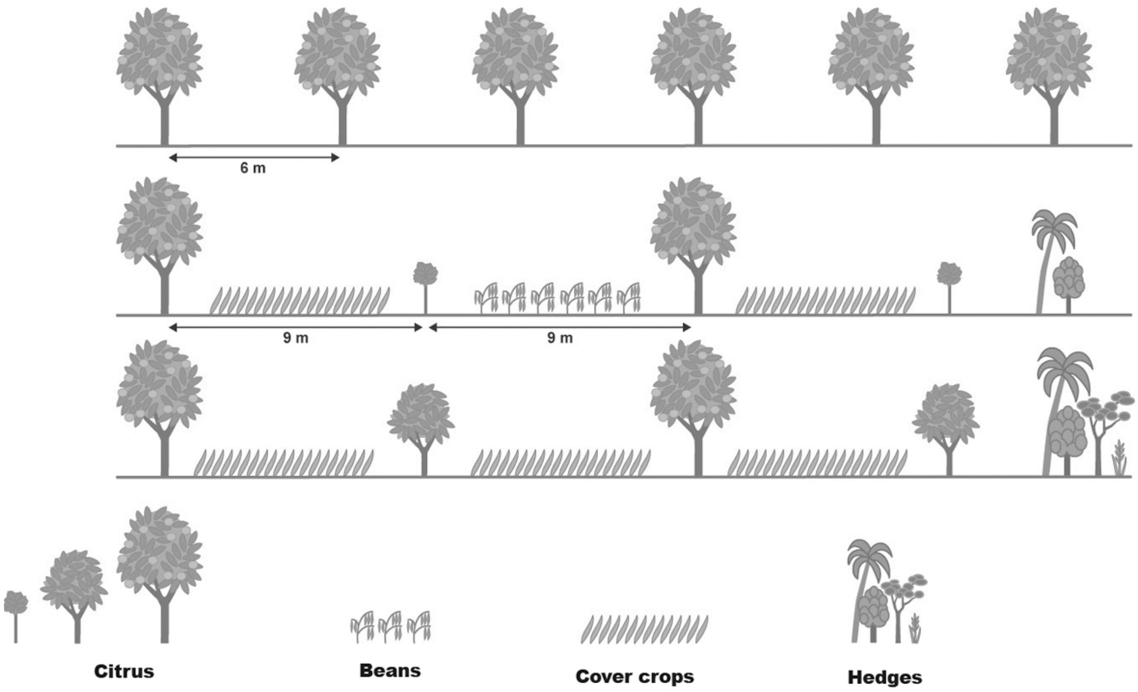

Chart 2: Conversion of an existing citrus orchard into an intercropping system

Picture 2: Agroforestry is a centrepiece of organic agriculture in the tropics. The cooperative “El Jobo” in Cuba applies this system with success: besides the cash crops coffee, cocoa and grapefruit, the farmers of El Jobo plant a large number of shading trees (Inga, Erythrina, Leucaena, etc.) and self-sufficiency crops (banana, beans, potatoes etc.). Agroforestry systems result in greater stability in the agro-ecological system, improve soil fertility, add nitrogen to the soil (N-fixation), protect the soils against erosion and weeds, add large amounts of organic matter by distributing leaf litter, and keep the soil humid by providing the area with shade and covering it with mulch. Agroforestry creates a high diversity of plants and micro-climatic effects; it is a very sustainable production system.

One of the most important tasks on the road to organic production is to identify strategies to increase the diversity of the production system. Organic farmers in the tropics therefore combine the systems referred to above to achieve an optimal mixture of diversity in space and diversity in time. The Cuban example shows how the diversity and sustainability of the system can be increased step by step in the conversion process of citrus plantations (see chart 2):

1. Increase the distance between the rows of citrus trees from 6 to 9 metres, cutting down several rows of citrus trees. Lower-density plantings are better adapted to the organic production system; they increase ventilation and light interception and thus decrease disease pressure. Lower tree density gives space for crops in the alleyway between rows.
2. Plant young trees between the rows. At the same time, intercrop beans for self-sufficiency and leguminous crops for fodder, or just cover crops, such as *Neonotonia wightii*.
3. Create a diverse mosaic of citrus units and other crops from an existing plantation: divide large plots (over 100 ha) into smaller plots of about 1-2 ha and plant hedges or other fruit trees along the plot borders.
4. Between the rows (in the alleyway) it may be possible to intercrop permanently with pasture (sheep), beans or other crops. However, this may be difficult in the case of older plantations where the trees are adapted to a certain type of management; in such cases, a step-by-step procedure is recommended (introduction of new crops and elements at yearly intervals), to allow the root systems of the citrus trees to adapt to new competition in the soil. For larger, mechanized organic farms it may be difficult to continue intercropping as soon as the newly planted citrus trees are in production. In such cases, cover crops may be more appropriate in order to avoid disturbances in citrus management.

4 Organic farmers conserve resources

The soils that are most predominant in many humid tropical regions are weathered ferralitic soils such as oxisols and ultisols. These soils are comparatively infertile, in other words, they are low in organic matter and have a low water-holding capacity. This causes drought stress and hinders crop growth between the rainy seasons, although the yearly rainfall amount is actually abundant. Large amounts of rainfall are often lost as run-off. This is especially the case in hilly areas and is the main cause of erosion and landslides. Soil and water conservation technologies therefore play an essential role in the tropics.

Organic farmers protect their soil from erosion by soil bunds and terraces, minimum tillage and contour cultivation. Planting cover crops, mulching, intercropping and agroforestry play an important role in protection against erosion and landslides, because their rooting system stabilizes the soil. Further, these technologies increase the organic matter content of the soil, which also has positive effects on water-holding capacity. Additionally, the vegetation cover conserves humidity by protecting the soil from direct solar radiation.

The fertility of tropical soils is highly influenced by their organic matter content. In the natural ecosystem of the rain forest, plant growth is vigorous and biomass is rapidly decomposed into humus and organic matter by soil organisms. Due to hot temperatures and high air humidity, organic matter is mineralised very quickly. To maintain the balance in the soil and to increase the organic matter content, organic farmers in the tropics cover their soils with dead or living vegetation. This covering biomass not only delivers organic material, but also protects the soil structure.

Organic matter also plays an important role in water-holding capacity, neutralizing acidity and enhancing workability of tropical soils.

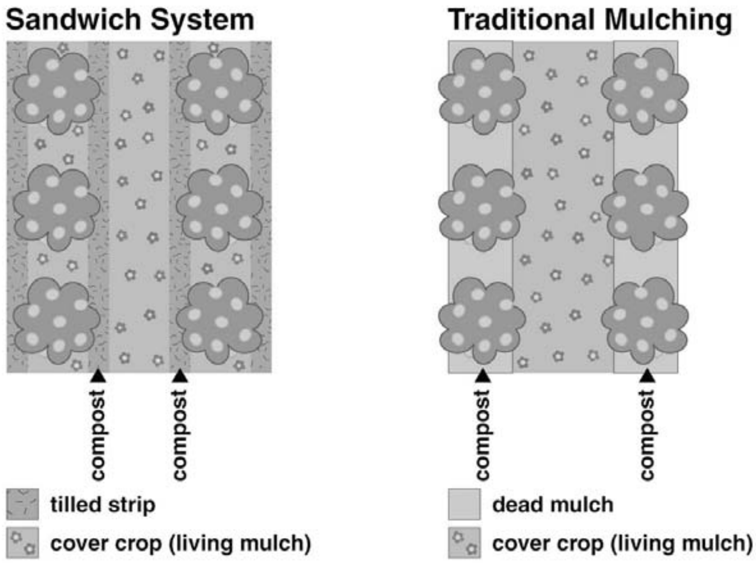

Chart 3: The FiBL sandwich system

The sandwich system (right; compared to traditional mulching on the left) consists of a small strip with cover crops directly under the tree strip and softly tilled strips to the left and the right of the cover strip. This system supports an efficient application of compost on tilled strips. The alleyway is planted with a leguminous cover crop. In dry areas, it is often not possible to have a permanent cover crop. In these areas, it is therefore recommended to plant a green cover crop during the rainy season, supplemented with dead mulch. This system achieves several aims of organic agriculture: soil cover with selected valuable crops, avoidance of erosion, target-oriented organic fertilization and avoidance of competition for water in the area of the fine roots.

Fortunately, in the humid tropics, it is not only decomposition processes that are rapid, but also composition processes. Animal manure, green manure and compost favour the composition processes and can replenish nutrients required by crops and supply the soil with essential organic matter. Additionally, legume plants are a highly valuable source of nitrogen. Closed nutrient cycles and efficient use of local resources – for example compost, dung or seeds – are especially important for subsistence farmers depending on few and limited assets. For this reason, organic agriculture means adapted technologies, e.g. for the farmers of the village Tekelioglu (near Izmir, Turkey).


Picture 3 and 4: The 32 organic farmers of Tekelioglu (near Izmir, Turkey), together with Rapunzel Turkey, initiated a project to improve soil fertility through production and application of high-quality compost. At the start of the project, farmers regarded animal manure as waste (picture on the left), and most nutrients were lost. FiBL, together with the organic producers of Tekelioglu, developed a 2 ha compost plate (picture on the right), calculated the mixture of locally available raw material (manure, straw, green material), trained and coached a local person to be responsible for compost production. Today, high-quality compost is produced on this plate for all the farmers of the village, and valuable local resources are used in an optimal way. In parallel, imports of organic fertilizers have been reduced and soil fertility improved.

Organic farming helps to conserve resources not only in the humid tropics, but also in the arid tropics: soils in the arid tropics vary widely according to the climatic and geological conditions. Predominant are aridisols, which are mostly dry mineral soils with a high pH, and may be calcic, sodic or saline. In spite of their morphological differences, all soils in the tropical drylands are profoundly influenced by two factors: little yearly rainfall and high temperatures. On one hand, high temperatures promote rapid soil organic matter oxidation. This, together with a low nutrient content, is one important reason for the soil's vulnerability to overexploitation. On the other hand, hot temperatures promote soil crusting, especially on bare land, which leads to impermeable soil surfaces. As a consequence, a large part of the rainfall is lost by run-off.

Organically managed dryland soils have a high potential to counter soil degradation and desertification as they are more resilient both to water stress and to nutrient loss. Water and nutrient retention capacity is increased due to a higher level of organic matter and permanent soil cover. Micro-organisms have a good feeding base and create a stable soil structure. Due to the resulting higher moisture retention capacity, the amount of water needed for irrigation can be reduced substantially. Several practical examples of organic agricultural systems in arid areas show how organic agriculture can help restore degraded lands to fertility.

Picture 5: Organic farmers in the tropics promote the balance between growth, decomposition and mineralisation. Organically managed soils have a high potential to counteract soil degradation as they are more resilient both to water stress and to nutrient loss. In the picture: organic farmers from Hazoua (Tunisia) discussing strategies to reduce water evaporation of the soil during a visit by FiBL in 2004.

Water collecting, water saving and soil moisture conservation strategies have highest priority in semi-arid and arid regions. As water is the limiting factor for crop yields, every drop of rain or irrigation water needs to be retained in the agricultural field. The following strategies are applied by organic farmers in Tunisia, for example, to improve water use efficiency:

1. **Increasing water infiltration:** Maximum infiltration of rainfall water through the soil surface and top layer must be achieved. Crust formation and clogged soil pores (often a result of soil erosion) that promote water run-off should be prevented. Application of compost, incorporation of plant material and mulching are important means of building up organic matter in the topsoil layer, which increases infiltration and improves the rate of water conservation.
2. **Reducing evaporation:** Reduction of water evaporation is essential. Mulches and canopies of trees decrease evaporation by shading. Hedges slow down winds, thereby also reducing evaporation. Regular hoeing of the topsoil interrupts the soil's capillary system.
3. **Water harvesting and collection:** To avoid water losses after strong rains, surface run-off is collected using bunds and ideally brought into the proximity of the plants. To avoid run-off from the field, the water is retained with micro-catchments and by field contour cultivation. Run-off water that has left the fields is slowed down by terraces, bunds on contour lines, dams and hedges and, if possible, collected.
4. **Efficient irrigation:** The application of furrow and drip irrigation instead of flood or sprinkler irrigation contributes consistently to a more sustainable use of water and reduces potential negative impacts of overuse of water.

5 Organic farmers produce more, better-quality products and achieve higher incomes

Organic agriculture is based on a combination of traditional, indigenous knowledge and modern agro-ecological research. In traditional farming systems, organic agriculture often enables a direct increase in production. In the long run, this is even possible for high-input farming systems. Additionally, organic farms harvest more products on the same area, thus providing more food for the farmers' families and reducing the dependency on a few products in the market.

Picture 6: The farmers of the organic coconut cooperative in Baracoa (Cuba) produce more than just coconut in their agroforestry system:

- Cash crops: coconut, grapefruits, cocoa, honey;
- Self-sufficiency crops: rice, beans, maize, lettuce, yams, sweet potatoes, avocado, plantains and other vegetables;
- Creole pigs, chicken and sheep roaming freely;
- Wood from shade trees such as Inga, Erythrina, Leucaena.

Diversity in agricultural production and value added products increases income-generating opportunities and spreads the risks of failure over a wider range of crops and products.

Farmers usually experience a decline in yields after renouncing the use of synthetic inputs and converting their farm to organic production. Once the agro-ecosystem is restored and organic management systems are fully implemented, however, yields increase significantly. The development of yields varies, and depends on inherent biological factors and natural resources, the farmer's expertise and the extent to which synthetic inputs were used under previous conventional management. If conversion to organic takes place on the basis of a low-input system, which is often the case for poor farmers in developing countries, yields under organic management tend to be more stable compared to the previous management system.

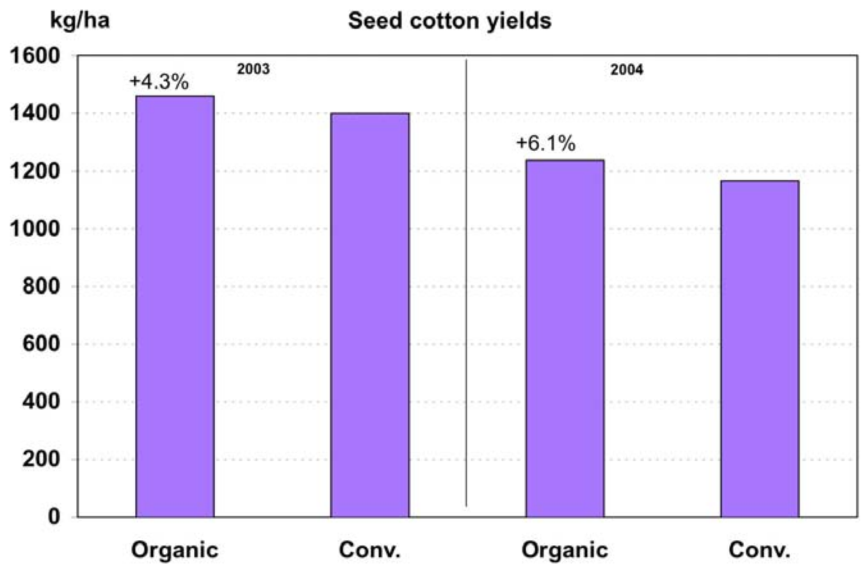

Chart 4: To investigate the economic viability of organic cotton farming and its impact on the livelihood of the involved farmers, the Swiss Agency for Development and Cooperation (SDC) and WWF Switzerland mandated FiBL to conduct a detailed study on organic cotton farming in the bioRe India project in central India. Over a period of two years, an Indo-Swiss research team collected and compared agronomic data from 60 organic and 60 conventional farms. One striking (though statistically not significant) result was that average cotton yields in organic fields were 4-6% higher in the two years of observation. The research results show that organic cotton farming does have the potential to be an economically sound business proposition even for marginal farmers.

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If conversion is from a high-input system, yield losses are frequent in the initial years due to a number of interrelated factors: soil organic matter and biological activity take time to become established; many conventional farms are on a pesticide "treadmill" (El-Hage and Hattam 2002) that does not permit the establishment of beneficial organisms for pest, weed and disease suppression; fertility problems are common until full biological activity has been restored, nitrogen fixation has improved and beneficial insects and natural predators have become established.

The productivity of organic agriculture systems varies through the different stages of management:

- In transition from conventional to organic management;
- Organic management based on input substitution;
- Complete shift to a systems approach.

The need to secure farm economic viability in the short-term results in few farms achieving a systems approach (El-Hage and Hattam 2002).

Most comparisons of the efficiency of alternative production systems focus merely on the gross yield of marketable commodities. However, yield and productivity comparisons offer a limited, narrow, and often misleading picture of the different production systems. Profitability and long-term economic viability would be a better indicator for evaluating the benefits and limitations of a production system. Moreover, the multiple environmental benefits of organic farming (see previous chapter), difficult to quantify in monetary terms, are essential ingredients in any comparison. The FiBL long-term farming system comparisons in the tropics take this issue into consideration.

Organic farmers not only produce more crops, but also achieve more sustainable yields, better quality, and in many cases even higher yields and incomes, mainly due to the following reasons:

- In developing countries where organic agriculture is not subsidized, synthetic inputs are expensive and labour is relatively cheap, market-oriented organic farmers can achieve higher returns thanks to reduced production costs and diversified production. In many cases, price premiums are not a sufficient incentive to certify and market organic products. Farmers have adopted organic practices nevertheless because the avoidance of external inputs saves on production costs while yields are more stable.
- The risk of crop failure due to drought or pest damage is lower in organic production, mainly due to higher diversity and improved overall soil fertility (soil structure, biological activity etc.).
- Efficient use of locally available resources such as manure, seeds and irrigation water contribute significantly to more stable and even higher yields, especially if highly valuable local resources (e.g. animal manure) had been lost before conversion.
- More intensive cultivation (e.g. irrigation, crop care) due to improved financial situation.
- Lower pesticide residues than conventionally grown foods (El-Hage and Hattam 2002). However, organic foods are not pesticide free, due to many factors beyond the control of the organic farmer, for example pesticide spray drift from adjacent fields or soil or irrigation water contamination.
- Organic farming can contribute significantly to improving the livelihood of smallholders, as it generates higher incomes and involves less risk. Organic farming therefore motivates farmers to invest in their future: in capacity-building, in production, processing and marketing, in manpower and in their family.

6 Organic products provide market access and create added value

Certified organic products provide access to attractive local and international markets for developing countries, while the producers generate higher incomes. In addition, due to long-term contracts, income is generated more continuously than in conventional trade: To guarantee a fair share of the international organic trade benefit to those contributing most to the production of food, trade must include social regulations. For this reason, numerous organic products in developing countries also embrace social standards in accordance with fair trade labels such as “Max Havelaar” or “Transfair”.

For example, conventional producers in Tunisia are selling most of their products as “no names” to a mass market without a label of origin. Only very few consumers in Europe know that a large share of so-called “Italian” extra virgin olive oil is actually of Tunisian origin. The Tunisian Ministry of Agriculture aims to liberate its producers from this dependency and in 2002 initiated a diversification programme in which organic agriculture plays an important role. One objective of the project is to provide Tunisian producers access to the local and international organic market and thus enable Tunisian products to create their own image. Ultimately, this strategy should provide Tunisian farmers with new income opportunities and higher added value for their products.

Picture 7: In the context of a FAO-funded project, FiBL contributed to developing a strategy and an action plan for the development of organic agriculture in Tunisia. A core issue in this action plan is promoting the local and international market for Tunisian products. The project launched organic market initiatives in several multi-stakeholder-workshops. Today, important organic products from Tunisia include: couscous and pasta for the local market from the family enterprise “Napolis”; Deglet Nour dates from Hazoua oasis for export to Europe, olives from Tabarka with the original label “Biomama”, mainly for the local market, and olive oil from Sfax, now successfully exported as “extra virgin olive oil from Tunisia”.

Picture 8: Lebanese consumers are quality-conscious and sensitive to regional provenance. The organic market initiative “Wadi El Tayim” is a women’s cooperative that produces Lebanese specialities using artisan processing techniques. Their main markets are Arab communities abroad, familiar with the much-valued Lebanese cuisine.

In spring 2005, the Swiss State Secretariat for Economic Affairs (seco) mandated FiBL to implement a project for the development of organic agriculture in Lebanon. This project pursues two main strategies: founding a Lebanese-owned certification body, Libancert, and developing the market for organic produce. For the latter strategy, a multiple-target approach was chosen. As a first step, the stakeholders in organic agriculture were brought together under the umbrella of the newly founded Association for Lebanese Organic Agriculture (ALOA). The tasks of the association are to provide market intelligence to the operators in the organic market and to foster demand for organic produce. The second step is to support several organic market initiatives that are expected to have a significant impact on the development of the market for organic produce. Despite all the setbacks of the war, the organic movement in Lebanon will fight to continue its development, with support of seco and FiBL.

Picture 9: A group of kaki producers in the region of Valandovo, southern Macedonia, has converted its production to organic methods and has formed an association. This allows the group to gain self-confidence and facilitates access to larger markets for their products; this in turn may positively influence their incomes and socio-economic conditions. They receive advice on production techniques and marketing strategies. Local consultants have been trained in the context of a FiBL project in Macedonia aimed at developing organic agriculture in the country as a whole. It is financed by the Swiss Agency for Development and Cooperation (SDC). The project offers knowledge transfer to the government and to teaching institutions as well as to farmers' organizations and market partners.

7 Organic agriculture raises self-confidence and mobilizes new partnerships

Very often, conventional agriculture puts farmers in a situation of high dependency on agro-industry and its high-tech solutions, which are difficult to understand. Organic agriculture profoundly respects indigenous knowledge, women's knowledge and local solutions. Producers thus gain control over the production cycle and increase their self-confidence. Local and international organic producers play an active role in advancing their production methods and in developing standards.

Developing organic farmers' organizations, standards, certification systems, extension services, education, research and markets brings producers together in a new manner. Stronger partnerships within the organic community enable better connections with external institutions. Such communities are in a stronger position to demand and assert their rights and to maintain or improve their economic position.

Picture 10: The development of a strategy and an action plan for organic farming in the context of the FAO project in Tunisia referred to above brings all stakeholders of the organic value chain together: farmers, processors, traders, certifiers, researchers, advisors and authorities. One of the main challenges is to develop an organic movement from rather isolated producer and trader initiatives. The project aims to create new partnerships at national and international level by empowering producer groups, developing farmer field schools, creating a national organic farming association and further developing the recently established "Centre Technique de l'Agriculture Biologique" in Sousse.

By building on local knowledge and using local services such as organic extension and certification programmes and local market development, the approaches applied in organic agriculture revitalize traditional customs and local self-reliance. Employment opportunities and higher incomes encourage farmers to remain in agriculture and to invest in rural communities. Producer cooperatives have better access to markets and can negotiate their needs as equal partners in the food supply chain. A growing number of certified organic small-scale farmers organized in democratic cooperatives meet fair trade requirements: farmers are paid adequately to cover costs of production and receive a social premium to improve the quality of life.

Picture 11: India is already exporting a range of organic products such as tea, spices, cotton, rice, etc. The Indian domestic market is promising, although still small. To gain consumers' confidence, valid certification is an essential prerequisite for marketing. In 2001, a group of organizations and corporate bodies took the initiative to set up the Indian Organic Certification Agency INDOCERT (www.indocert.org). It has become an important element of the organic movement in India and mobilizes new forces and partnerships. In 2003, together with other partners, INDOCERT created the International Competence Centre for Organic Agriculture (www.iccoa.org), a service provider for networking, capacity-building and market development in the organic sector in India. Among other activities, ICCOA implements the Indian Organic Market Development Project (2005-2007), which focuses on the following main areas: awareness-raising, market intelligence, developing organic market initiatives, and the India Organic trade fair (www.indiaorganic2006.com). Both projects are funded by the Swiss State Secretariat for Economic Affairs (seco) with technical support from FiBL.

8 Investments to overcome constraints on the road to organic farming

The above discussion provides evidence that organic agriculture is a great opportunity for poor countries and can contribute substantially to sustainable development. The target-oriented implementation of organic farming enables efficient use of locally available resources, which is a central element of adapted technologies. Organic agriculture also presents an opportunity to achieve socio-economic sustainability, because it is committed to:

1. participatory technology development
2. fair trade
3. autonomy and self-determination.

Nevertheless, there are some critical questions towards organic farming from the point of view of development policies:

1. "Brussels, Tokyo and Washington" are defining organic agriculture worldwide. Such desk-created" standards may create trade barriers for some developing countries (Vogl, Kilcher and Schmidt 2005). How can producers from poor countries increase their participation in global standards development and how can they define their own locally adapted standards in order to increase sovereignty and identification?
2. Inspection, certification and accreditation are becoming increasingly complex and thus a greater hurdle for small farmers in developing countries. The creation of local, indigenous certification programmes and smallholder group certification, which builds on the presence of an internal control system, are important solutions. How can the standard-setters in government authorities, IFOAM, UNCTAD, FAO and private labelling programmes consider this issue in their discussions on harmonization? How can they include "accreditation" in current discussions on harmonization?
3. Many small farmers in poor countries do not have access to the organic market. How can authorities and market partners from richer countries make the organic market more transparent and improve market access for small farmers from poor countries? How can they reduce especially non-tariff trade barriers such as organic certification?
4. Income and benefits for organic trade are not always equally distributed. How can organic trade guarantee a fair share of consumers' expenditure to all participants in the value chain, especially to producers? Is certified fair trade the right and only answer to this question?
5. Organic agriculture is a know-how-intensive farming method. To be competitive, organic farmers need to experiment with new techniques, and must manage land, labour, capital and innovations quite differently from conventional farmers. How can research and development improve access for small farmers to this know-how and to specific inputs, such as seeds and biological methods of pest control?
6. Does organic agriculture reach the poorest of the poor? Are other models such as "low external input systems" more appropriate for this target-group?

The greatest constraints faced by poor farmers on the road to organic agriculture are lack of knowledge, access to markets, certification, agricultural inputs, and lack of organization. Greater investment in practice-oriented research, capacity-building and extension, accessible local certification schemes and harmonized standards, organic market initiatives, fair trade relationships and inspiring partnerships within the movement can help to overcome these constraints. Developing these tools and services in such a way as to enable participatory learning processes will lead to sustainable innovation within the rural communities and thereby contribute to sustainable development.

FiBL develops organic agriculture globally

The mission of the Research Institute of Organic Agriculture (FiBL), founded in 1973, is to contribute to the development and improvement of organic and sustainable agricultural practice worldwide. FiBL does this through:

- Practice-oriented research and development to improve understanding of organic farming systems and of farming's environmental, economic and social impacts.
- High-quality extension services to make the latest organic farming methods easily accessible to farming communities, public and private-sector extension services and other education centres throughout the world.

FiBL supports partners in markets in transition and emerging markets to make organic agriculture a viable alternative. The desire to find ecologically and economically sustainable solutions must be rooted in the region or country itself. FiBL projects therefore are based on local initiatives, local ownership, local knowledge and community-based networks, promoting the refinement and dissemination of this knowledge. Major activities of the FiBL International Cooperation Department include:

1. Development and evaluation of adapted technologies and local solutions for organic farming practice;
2. Conversion planning, workshops and training sessions, training manuals and technical leaflets, curricula development and internet platforms;
3. Development of local and international markets and value chain development, linking demand and supply, quality management and processing technology.
4. Development of certification, standards, strategies and policies for organic farming.

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The potential of organic agriculture to contribute to sustainable crop production and food security in Sub-Saharan Africa

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Abstract

The ability of organic agriculture to meet the demand of growing populations for agricultural produce is a precondition of its area-wide implementation in developing countries, and a subject of controversial discussion. The challenge is most evident in Sub-Saharan Africa, where population growth has outpaced yield increases. Agricultural production in Africa is often unsustainable, mainly with regard to soil fertility, which diminishes in many regions due to lack of nutrient inputs. This review investigates whether soil fertility management based on organic inputs can stop and reverse soil nutrient mining in Africa at production levels needed to achieve food security.

Potentially available quantities and qualities of crop residue, animal manure, legumes, green manure imports, compost and human excreta were assessed and nutrient balances for different scenarios established. With a major effort, N and K exports from cropland might be balanced by organic inputs. Especially biomass ‚cut-and-carry' systems offer much potential in regions with large tracts of yet unused productive land, such as the DR Congo. The sustainability of such nutrient transfers is, however, questionable. It may also be possible to replenish soil organic matter, albeit not beyond pre-farming levels. Counterbalancing P exports is especially critical due to low contents of this element in organic materials. Strategies to improve P supply need to minimise losses through soil erosion, maximise nutrient recycling from wastes and excreta and combine organic with mineral inputs, including rock phosphate.

Organic agriculture in its present form may not render agricultural self-sufficiency in Sub-Saharan Africa possible without further nutrient mining. It does, however, have much to contribute to the sustainability of crop production when implemented judiciously at suitable locations, particularly if techniques to replenish soil P stocks and realise hygienically and environmentally safe nutrient recycling from organic wastes and excreta are adopted.

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Keywords

nitrogen, nutrient budgets, nutrient flows, nutrient mining, nutrient sources, organic farming, phosphorus, potassium, soil fertility

1 Introduction

Organic agriculture[1] is being practised on a growing share of the global agricultural land, increasingly including cropland in tropical developing countries (Willer and Yussefi, 2005). The International Federation of Organic Agriculture Movements (IFOAM) stipulates the worldwide adoption of the principles of organic agriculture (IFOAM, 2005). The feasibility of an area-wide implementation of organic agriculture in developing countries will first of all depend on its ability to meet the demands of growing human populations for food, feed and technical crops. This statement is most valid for Sub-Saharan Africa (SSA), the region with the most rapid population growth and the lowest crop yields worldwide (PRB, 2005; FAOSTAT, 2006). While achieving food security is critical in the short term, maintaining it in the long term will require agricultural production to be ecologically sustainable. Under SSA conditions, this implies the balancing of nutrient flows and the replenishment of nutrient stocks (Sanchez et al., 1997).

What are the premises of organic agriculture to achieve food security in SSA without further nutrient mining? The principles of organic agriculture extend beyond biophysical aspects to include matters of equity and stewardship (Table 1; IFOAM, 2005). Prominent features of organic crop production include an emphasis on soil fertility management and the rejection of synthetic mineral fertilisers and biocides. Nutrients are provided to plants through manure, compost and mulches, biological nitrogen fixation (BNF) by legumes and crushed minerals. In Europe and North America, yields in organic crop production on average are 10-30% lower than on conventional farms (Stanhill, 1990; Mäder et al., 2002). However, the latter are highly productive enterprises using large amounts of agrochemicals, while most African crop production is characterised by marginal use of external inputs on often nutrient-depleted soils. Under SSA conditions, the use of organic soil amendments typical for organic agriculture may improve nutrient supply, stimulate soil microbial activity and suppress disease-causing organisms and parasitic *Striga* spp. weeds (Sauerborn et al., 2003). Contrary to conversions from chemical input-intensive to organic farming in temperate regions, transitions from traditional low-input to organic agriculture may well prompt yield increases in SSA.

At any rate, boosting African crop production will require increased use of soil amendments. Natural soil fertility restoration during long fallow periods, as practised in traditional shifting cultivation systems, becomes less and less feasible with rising population pressure. Mineral fertilisers have been key components of strategies to increase crop yields and restore soil fertility (e.g. Quinones et al., 1997), yet their availability and use in SSA remain very low due to lack of production, transport and market infrastructures (Larson and Frisvold, 1996; Dudal, 2002). Nutrient imbalances have resulted in the loss of an estimated 700 kg N, 100 kg P and 450 kg K ha^{-1} from SSA cropland during the last 30 years, while

[1] In this review, the term ‚organic agriculture' exclusively refers to production systems complying with the IFOAM norms for organic production and processing (IFOAM, 2005).

commercial farms in the temperate zone added 2.000 kg N, 700 kg P and 1.000 kg K ha^{-1} (Stoorvogel and Smaling, 1990; Pieri and Steiner, 1996). Diminishing soil fertility is recognised as the primary biophysical constraint to increasing crop production in most of SSA (Sanchez et al., 1997; Bationo et al., 1998).

Table 1. The four principles of organic agriculture

The Principle of Health – Organic agriculture should sustain and enhance the health of soil, plant, animal and human as one and indivisible.
The Principle of Ecology – Organic agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.
The Principle of Fairness – Organic agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities.
The 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.

The stagnant adoption of mineral fertilisers has, along with objections related to their potential detrimental ecological effects, spurred interest in organic soil fertility management. There are claims that ‚organic agriculture can increase productivity, especially in situations where farmers are most prone to food shortages' (Rundgren, 2002), and that the broader benefits of adopting organic agriculture would include enhanced food security (Parrott and Kalibwani, 2005). Then again, it is argued that there is too few organic fertiliser to supply sufficient nutrients to the soil to satisfy the growing food demand of Africa (Quinones et al., 1997), and that, rather than a transition to organic agriculture, the best option for SSA crop production would be an investment into mineral P fertiliser and germplasm, accompanied by micro-credits for N fertiliser and hybrid seed (Sanchez et al., 1997). Since certified organic production currently occupies only 0.2% of African cropland (Parrott and Kalibwani, 2005), and few scientific studies investigated the performance of organic agriculture under SSA conditions, few evidence explicitly supports these contrasting views on the feasibility of achieving food security and sustainability by means of organic agriculture.

Our review attempts to narrow this knowledge gap by assessing the feasibility of maintaining or increasing soil fertility under the pedoclimatic conditions of SSA by relying on organic inputs. The focus is on nutrient flows in agroecosystems, problems associated with the current situation and trends, and prospects for improvement through the adoption of organic soil fertility management. We (i) draw on evidence of effects of organic soil amendments on crops and soils compiled in studies across the continent, (ii) assess the evidence on quantities and qualities of organic inputs available to farmers, and (iii) develop scenarios to estimate the feasibility of organic soil fertility management in different ecozones.

2 Setting the stage

2.1 Soil resources of SSA

The land area of SSA totals 24.2 mio km² and stretches over several ecozones, from humid tropical rainforest to subtropical desert. Across this vast and heterogeneous area, inherent low fertility and high fragility characterise many soils. Together with human-induced nutrient depletion and erosion, they act to constrain crop cultivation. Climatic constraints are mainly related to insufficient and unreliable rainfall. Neither solar radiation nor low temperature impose serious restrictions on vegetation period and crop growth in most regions (Agnew, 1998; Dudal, 2002). Eswaran et al. (1997) grouped African land in five categories based on soil potential for sustainable agricultural development (Table 2). Their categories provide an estimate of soil constraints to be kept in mind when assessing agricultural production potential:

- Prime land (10% of the land area) occupies sizable areas in western, eastern and southern Africa; much of it has tropical wet-and-dry savannah climate. Rain falls during up to six months during summer, more towards rainforest, less towards desert margins. Well-buffered, deep soils with good levels of soil organic matter (SOM), high water retention and few impermeable layers prevail. Textures are loamy to clayey with good tilth, soils have great potential for agricultural use.
- High potential land (7%) occurs in Côte d'Ivoire, Ghana, Guinea, Nigeria, DR Congo, Tanzania and Zambia (overlap with tropical savannah). Physical constraints are caused by temporary moisture stress, sandy or gravely materials or root-restricting soil phases. The land has good productive potential if SOM is maintained. Soils are prone to damage by low-input farming, as frequently observed in traditional agriculture.
- Medium potential land (12%) occupies much of Central and East Africa, Madagascar and coastal West Africa, mostly with humid climate (rainforest). Abundant rainfall, high humidity and high temperatures with little seasonality prevail. Soils are often acidic and tend to fix high amounts of P. The probability of crop failure under low-input agriculture is high due to low inherent soil fertility.
- Low potential land (16%) covers desert margins from Ethiopia to Senegal, and from Angola to Madagascar (grassland to thorn savannah) marked by seasonally intermittent rainfall. Annual rainfall is 150-500 mm, mainly incident during summer. Soil constraints include surface crusting, impenetrable layers, subsoil acidity, salinity, alkalinity and vulnerability to SOM depletion. The risk of crop failure is very high. Sparse plant cover hardly protects soils from erosion.
- Unsustainable land (55%) consists of deserts and other lands with major constraints. Climate is characterised by extreme heat and aridity. Soils are poorly buffered, SOM and water retention levels are very poor. Some cultivable land, prone to degradation, exists at desert fringes, where nutrients and water are scarce and productivity is very low.

Table 2. Land classes in Africa (including North Africa)

	Area		Major soil types	People
	mio. km²	%	(USDA)	(mio.)
Prime land	3.0	10	Mollisols, Alfisols	250
High potential land	2.1	7	Ultisols	
Medium potential land	3.6	12	Oxisols	140
Low potential land	4.8	16	Inceptisols, Entisols	200
Unsustainable land	16.7	55	Aridisols, Entisols	260

Adapted from: Eswaran et al. (1997)

2.2 Crop production in SSA

Arable and permanent crops are grown on 7.6% of the SSA land area, permanent pasture covers a further 30.4% (FAOSTAT, 2006). The major farming systems that evolved in the diversity of African environments are described below (Fig. 1) (e.g. Dixon et al., 2001):

- Forest based: farmers practice slash-and-burn agriculture, clearing a new field from the forest, cropping it for 2-5 years and then leaving it fallow for 5-20 years. Fallow periods decrease due to growing population density. Forest products and game animals are the main source of cash income. Physical isolation and lack of roads and markets obstruct development.
- Tree crop: mainly based on the production of permanent crops, e.g. cocoa, coffee, oil palm or rubber. In the establishing phase, before shade impedes annual crop growth, food crops are interplanted and grown mainly for subsistence.
- Highland perennial: based on perennial crops, e.g. banana, plantain, enset and coffee. Land use is intense, holdings are very small (<1 ha). Cattle are raised for milk, manure and social security. Major constraints are decreasing farm size, declining soil fertility and limited opportunities for off-farm activities.
- Highland temperate mixed: cereals, e.g. wheat and barley, and legumes, e.g. pea and lentil, are the main staples. Farm size is 1-2 ha. Soil productivity suffers from soil erosion and lack of inputs. Cattle are kept as draught animals, for milk, manure, savings and emergency sale. Off-farm activities are limited.
- Root crop: the area in West Africa where this farming system is mainly practiced is sandwiched between the "tree crop" and "forest based" systems in the South and the "cereal-root crop mixed" system in the North. A similar strip exists south of Central Africa.
- Maize mixed: the most important food production system in East and Southern Africa, also exists in parts of West Africa. Typically, there is a single cropping season; some areas experience a shorter second season. Farm sizes are often <2 ha. Main cash sources are small ruminants, tobacco, coffee and cotton. Cattle are kept as draught animals, for

breeding, milk, manure and savings. Market access and regional institutional conditions are comparably well developed.

- Cereal-root crop mixed: mainly found in the Guinea savannah, resembles the 'maize mixed' system. Differences are lower altitude, higher temperatures, lower population density, abundant arable land and often poorer infrastructure. Maize, sorghum and millet are widespread, but yam and cassava are equally important as staple crops. Intercropping, mainly with legumes, is common. Major constraints are drought and incidence of *Striga* spp. weeds.
- Large commercial and smallholder: mostly in South Africa and Namibia. Two distinct subtypes: smallholder farming and large-scale commercialised farming. Cattle and small ruminants are raised, the level of crop-livestock integration is moderate. Since the area is drought-prone and soils have poor quality, vulnerability is high, especially in the smallholder subsystem.
- Agro-pastoral millet/sorghum: crops, mainly sorghum and millet, and livestock are of comparable importance. Livestock farming provides subsistence (milk, milk products), transportation (camels, donkeys), draught animals (oxen, camels), and social security. Pressure on resources rises with growing human and livestock populations. Crop-related constraints include weed infestation in cereals and cowpea, pests and diseases in cowpea and groundnut, and drought and declining soil fertility. Shortage of dry-season grazing frequently weakens animal performance.
- Pastoral: pastoral systems have strong linkages to other farming systems. During the driest season, Sahelian pastoralists move south to the "cereal-root crop mixed" system areas to gain fodder from crop residues. During the rainy season, they return north. Overgrazing of rangelands presumably is a major cause of vegetation loss and land degradation throughout the region.
- Sparse (arid): includes oasis farming and scattered irrigation settlements, in many cases used by pastoralists to supplement their livelihoods. The boundary between pastoral systems and sparse farming systems is vague.
- Irrigated: irrigated farms vary in size from <1 ha to >20 ha. The advancement of drilling and pumping technologies has permitted the development of groundwater-dependent schemes. Includes high-value cash and export crops, intensive vegetable and fruit cropping. Water use varies greatly, but is often wasteful. Excessive irrigation and poor drainage can cause rising groundwater tables and soil salinisation.
- Urban-based: very heterogeneous and dynamic system that includes small-scale, capital-intensive commercial vegetable growing, dairy farming and livestock fattening. Farmers quickly respond to urban market demand for fresh produce and adopt improved technologies.

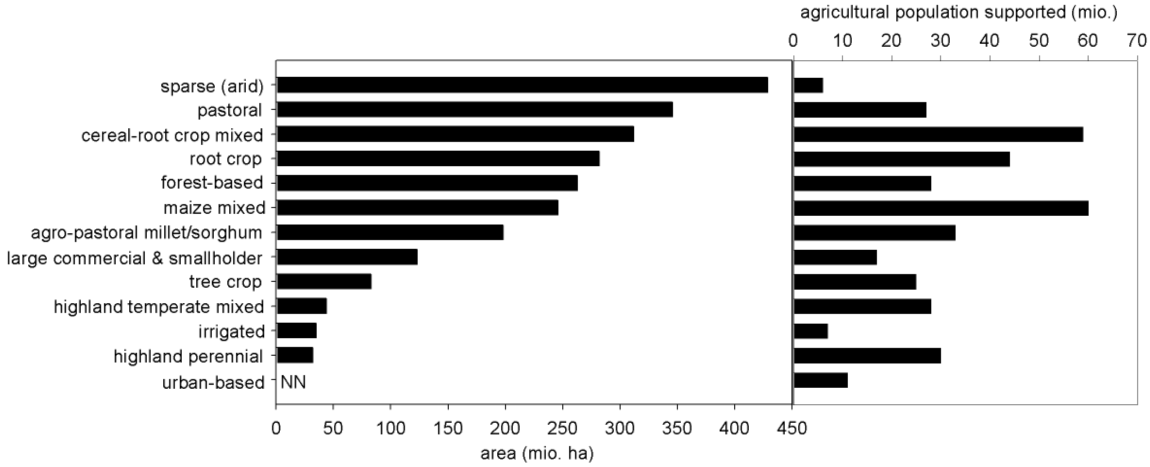

Figure 1. Areas of and agricultural population supported by the major farming systems of Sub-Saharan Africa.

2.3 Are SSA farming systems 'organic by neglect' ?

In many SSA production systems, agrochemicals are hardly or never used. Are these systems thus ‚organic by neglect' or ‚non-certified organic agriculture', as sometimes suggested (El-Hage Scialabba and Hattam, 2002)? Crop production need not be modern, highly mechanised and dependent on agrochemicals to be ecologically unsustainable. Historically, as well as in recent years, soil fertility in many parts of SSA was and is depleted by traditional low-input agriculture. To regenerate soil fertility, farmers used to clear land, raise a few crops, then move on to clear more land, leaving the land fallow. This practice is only ecologically viable where population density is low. At regional level in the past, and nowadays worldwide, population pressure forces farmers to grow crop after crop. Nutrient exports and loss of soil biological activity exhaust the soil. Although traditional farming foregoes synthetic inputs, it must not be considered organic, since it neglects soil quality, whereas enhancing soil quality lies at the heart of organic agriculture. A crop grown on a field devoid of any stimulating input should not be considered organic, since that would undermine the sustainability approach of organic agriculture. Organic farming by definition goes beyond production issues to view sustainability in a holistic sense, embracing ecological, economic and social aspects.

3 Status quo: Nutrient flows and imbalances

The population of SSA, 750 mio. people in 2005, is increasing at a rate of 2.4% yr^{-1} (world: 1.2%) (PRB, 2005). Unlike in other tropical areas, increases in agricultural production lag behind population growth. From 1999-2001 to 2005, the SSA agricultural production index grew by 8.1% in absolute terms, but decreased by 4.1% per capita (FAOSTAT, 2006). Average cereal yield was 1.0 t ha^{-1} in SSA, but 3.3 t ha^{-1} worldwide in 2005. Although agricultural growth has mostly been achieved by expanding arable land (+28% from 1961 to 1997; Dudal, 2002),, per capita arable land decreased from 0.53 to 0.35 ha during 1970 to 2000 (FAOSTAT, 2006).

The countries of SSA produced 315 mio. t of the major food crops and 27 mio. t of meat and milk in 2003. Together with stock balances and net imports, 367 mio. t of food were available (PRB, 2005; FAOSTAT, 2006). While mean national dietary energy supply was above the required minimum in all but four countries (Burundi, Eritrea, Mozambique, Somalia) during 1996-98, actual food allocation caused an average 34% of the population to be malnourished (FAO, 2000; excl. South Africa). Despite an expected population increase to more than 1 billion people (PRB, 2005), average daily caloric intake is projected to rise from 2050 kcal in 1998 to 2500 kcal in 2030, partly due to expected increases in food imports (FAO, 2000).

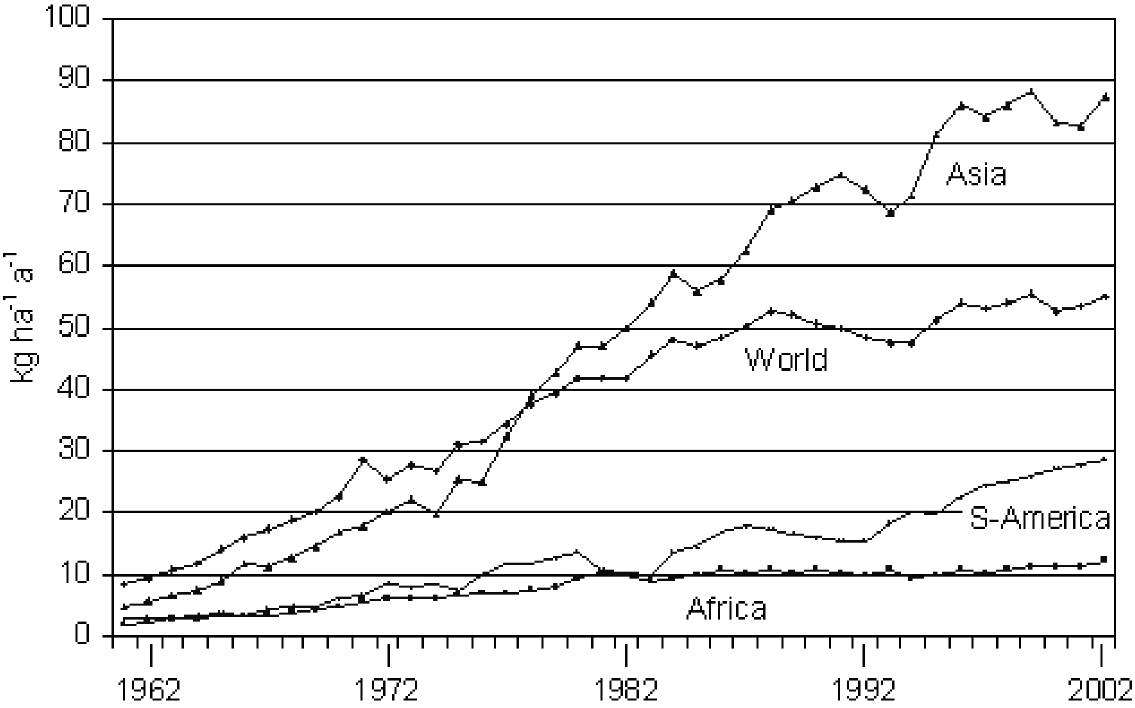

Figure 2. Trends in the use of nitrogenous fertilisers (kg ha^{-1} cropland) in different regions (FAOSTAT, 2006).

Food production and consumption drive large nutrient flows resulting in deficits in rural and excesses in urban environments. Removals of harvested produce corresponded with an estimated 17 kg N, 5 kg P and 25 kg K ha^{-1} in 2003, to which losses through erosion, leaching, volatilisation and removal of crop residues add. Average annual inputs through mineral fertiliser supply roughly 12 kg N, 5 kg P and 2 kg K per ha of SSA cropland; global averages are 55, 22 and 15 kg ha^{-1}, respectively (Fig. 2). Reasons for the low fertiliser use include (i) high prices due to lack of transport and marketing infrastructures - Sanchez (2002) reports prices of 1 t of urea of 90 US-$ free-on-board in Europe, 120 US-$ in the port of Mombasa, 400 US-$ in western Kenya and 500 US-$ in eastern Uganda -, (ii) a low proportion of irrigated land, (iii) prevalence of traditional crop varieties that are less responsive to fertilisers than modern varieties adopted across Asia and Latin America, and (iv) low population density, providing few incentive to invest in land-saving technology (Kherallal et al., 2002; as cited by Crawford et al., 2006). There are no data on rates of organic input addition at continental scale, but reports suggest that amounts are rather low.

Net nutrient losses resulting from insufficient replenishment have been estimated at 22 kg N, 2.5 kg P and 15 kg K ha^{-1} yr^{-1} in 1982-1984 across SSA (Stoorvogel et al., 1993). Henao and Baanante (2006) calculated nutrient mining rates of more than 30 kg NPK ha^{-1} yr^{-1} from 85% of African farmland during 2002-2004. According to Sheldrick and Lingard (2004), average depletion was 17.4 kg N, 3.3 kg P and 20 kg K ha^{-1} yr^{-1} in the period 1961-1998. National and continental soil mining estimates neglect the fact that at farm and village level, farmers preferably allocate soil amendments to fields close to the homestead, where no deterioration might occur (Lamers et al., 1998; Giller et al., 2006). However, it does seem plausible that imbalances exist at regional and higher scales.

At the consumer end of the food chain, approximately 3 kg N, 0.5 kg P and 2 kg K per capita and year are consumed by humans. Most of this is converted into human excreta that pollute surface and groundwater due to lack of sanitary and sewage treatment infrastructure. Associated problems of human and ecosystem health are most severe in urban areas, whose population is projected to increase from 285 mio. to 440 mio. until 2020 (UN, 1999).

4 Prospects and challenges for organic soil fertility management

Agroecosystem productivity can be increased by adding soluble nutrients to immediately boost production, or by fostering SOM build-up, which allows for higher and more stable yields in the long term. Accordingly, short-term nutrient supply to crops and long-term SOM build-up will be discussed separately here.

Organic production norms permit the application of material of microbial, plant or animal origin, with restrictions concerning the use of human excreta. Some inorganic materials, e.g. non-acidulated rock phosphate, may be used as well. When considering the effects of soil amendments, it is essential to distinguish materials from inside from those originating outside the system. Recycling of materials originating within the production system can help tighten matter and energy cycles, while lasting productivity increases require additions from outside the system.

4.1 Biomass originating on-field

Crop residue

Crop residue application can prevent erosion, reduce nutrient losses, stimulate microbial activity in the rhizosphere, improve soil structure and increase the yield of subsequent crops (Schlecht et al., 2006). It may contribute to SOM build-up, but rapid breakdown due to synchrony of high temperature and moist soil during the rainy season(s), together with termite activity, limits residual effects in savannah areas. Mulching with 2 t ha^{-1} of crop residue, the rate most frequently used on experimental plots, resulted in yield increases from less than 10% to manifold, depending on crop, management, soil and climate (e.g. Schlecht et al., 2006).

Amount and quality of crop residue available for mulching or incorporation depend on pedoclimatic conditions, crop and cultivar choice, tillage, and residue management. Since crop cultivars in SSA tend to have low harvest indices (Pieri, 1992; Briggs and Twomlow, 2002), amounts of residue are comparably high. Quantities calculated from crop yields (multipliers modified from Reed et al., 1988) are in the range of 2 to 3 t ha^{-1} yr^{-1} in cereals and 1.5 t ha^{-1} yr^{-1} in root and tuber crops (FAOSTAT, 2006). Nutrient contents are usually moderate for N (high in legumes) and K, and low for P. According to the yield-based estimate, a mean 19 kg N, 4 kg P and 30 kg K ha^{-1} (cropland) are contained in crop residues of SSA staple crops. Only part of this is available for soil application. Residue is commonly used as fuel for cooking or as housing and fencing material. In semiarid West Africa, around 50% of sorghum and millet stover are grazed by livestock (Bationo et al., 1995). Once these needs have been met, many farmers burn the remaining material.

Replacing nutrients removed at harvest of an average cereal crop would require 3 to 7 t ha^{-1} of crop residue in semiarid West Africa (Palm et al., 1997), and 5 - 10 t ha^{-1} in East Africa (Nandwa and Bekunda, 1998). Quantities of stover actually available to farmers are much lower, e.g. 0.5 to 1 t ha^{-1} in the Sudano-Sahelian zone (Bationo et al., 1995; Palm et al., 1997; Buerkert et al., 2001). Where crop residue is available, it is often preferentially applied to spots of poor crop growth, because material and labour force are insufficient for extensive mulching (Lamers et al., 1998). Applying crop residue is an important component of organic soil fertility management that involves less effort than biomass transfers from outside. The available quantities suggest potential contributions to nutrient balances to be moderate for C, N and K, and low for P.

Legumes as rotational crops, green manure, pasture and intercrops

Leguminous crops are an integral part of crop rotations in organic agriculture. They can supply N to subsequent crops through biological fixation, break pest and disease cycles and alter soil physical and biological properties (Peoples and Craswell, 1992). Haynes (1999) reported a more active microbial biomass associated with grass-legume leys compared to arable crops. An active soil microbial biomass can reduce the occurrence of organisms damaging the crop, such as the parasitic *Striga* spp. weeds (Berner et al., 1996; Sauerborn et al., 2003).

Rates of BNF depend on several factors, including strains of N-fixing bacteria and growing conditions. Galloway et al. (1995) estimate N fixation by legumes to range from 70 to 140 kg N ha^{-1} yr^{-1}. This agrees well with estimates by Harris (1998) that groundnut and cowpea fixed 0.6 and 1.7 g N per plant in a trial in northern Nigeria. At the recommended density of 80,000 plants ha^{-1} (Bationo and Ntare, 2000), this adds up to 48 and 136 kg N ha^{-1}, respectively.

Since legumes were cultivated on 29.8 mio. ha in SSA in 2005 (FAOSTAT, 2006), BNF may have added 2.1 to 4.2 mio. t N to soils, equalling 2.2 - 4.4 kg N ha^{-1} cropland. At harvest of a grain legume, 45% to 75% of the N in the aboveground legume biomass are removed with the grain (Beck et al., 1991). Legume crops with high harvest index, such as soybean, are unlikely to leave much N in the field. Depending upon climate, soil and agricultural conditions, the residual effect of legumes on yields of subsequent cereals can be equivalent to 20 - 123 kg mineral N fertiliser ha^{-1} (Rabindra et al., 2002). Across SSA, this results in a potential of 0.6 - 3.7 mio. t of residual N, or 7.1 - 43.7 kg N ha^{-1} (cereal area).

It has been recommended to grow legumes as green manure to build soil fertility. Becker and Johnson (1997) determined BNF by 50 multipurpose cover legumes in

Table 3. Nitrogen fixation[1] by selected legumes in Côte d'Ivoire

Fallow vegetation	Use	Guinea savannah	Derived savannah	Bimodal forest	Monomodal forest
		BNF-N (kg ha^{-1})			
Aeschynomene histrix	F	9.5	63.9	136.7	44.9
Arachis hypogaea	F/G	12.9	53.3	45.5	9.4
Cajanus cajan	G	27.0	88.8	187.9	9.9
Calopogonium mucunoides	GM	n/a	75.6	61.6	1.4
Canavalia ensiformis	GM	44.7	181.8	133.7	66.2
Canavalia rosea	GM	22.1	138.6	74.1	46.2
Centrosema pubescens	F	n/a	33.6	104.3	2.9
Clitoria ternata	F	n/a	51.6	12.4	6.3
Crotalaria anageroides	GM	12.0	15.2	221.4	3.6
Crotalaria juncea	GM	28.9	142.5	103.2	n/a
Crotalaria retusa	GM	9.7	52.4	93.1	4.7
Dolichos lablab	F/G	7	69.9	66.2	n/a
Macroptilium latyroides	GM	23.0	66.4	53.1	19.4
Macrotyloma geocarpum	G	5.4	13.1	10.2	n/a
Mucuna cochinchinensis	GM	52.4	103.4	172.2	32.3
Mucuna pruriens var. utilis	GM	55.9	92.5	213.3	18
Pueraria phaseoloides	GM	n/a	26.2	53.1	5.7
Stylosanthes guianensis	F	25.2	84.3	158.8	44.9
Tephrosia villosa	F	18.1	71.4	81.6	22.2
Vigna unguiculata	G/F	13.9	33.5	18.6	4.2
Voandzeia subterranea	G	10.4	18.0	17.5	5.3

[1] based on maximal dry matter during a 6-month fallow period; n/a: no data available; G = grain legume; F = forage legume; GM = green manure legume

Adapted from: Becker and Johnson (1997)

farmers' fields at four sites in Côte d'Ivoire with contrasting climate and soil conditions (Table 3). After six months, 1 - 270 kg N ha^{-1} had accumulated, 30 - 90 % of it from BNF. Legume performance was affected by site, species and management practice. Average N accumulation by green manure legumes was

100 kg N ha^{-1} (70 kg from BNF). In experiments conducted in eastern Uganda, velvet bean (*Mucuna pruriens*) grown as fallow or relay with maize for 4 to 5 months accumulated 170 kg N ha^{-1} (57% BNF) at sites with low fertility, and 220 kg N ha^{-1} (39% BNF) on fertile soil. Of the accumulated N, 7.5 - 19 % were taken up by the succeeding crop, resulting in 25 - 68% higher maize yields (Kaizzi et al., 2004).

A further option of utilising legumes is ley cropping with pasture legumes. Leys are sequences of food crops and a ley phase with forages providing feed for livestock. They were used for centuries in Europe and remain widespread in Mediterranean-climate areas. Short-term leys involving self-generating, short-lived legumes like *Centrosema* spp. and *Stylosanthes* spp., can be distinguished from long-term leys with a crop phase after several years of pasture use (Schultze-Kraft and Peters, 1997). Rates of BNF in legume/grass pastures throughout the world range from 13 to 373 kg ha^{-1} yr^{-1} (Ledgard and Steele, 1992). Legume-based pastures help build up soil organic N pools. During the crop phase, 40 - >100 kg N ha^{-1} are released to the first crop, and progressively less to succeeding crops (Haque and Jutzi, 1984). Perennial legumes can be grown as intercrops with cereals or other crops in hedgerow intercropping systems, widely known as ‘alley cropping’ (Kang et al., 1990).

Alley cropping involves the cultivation of annual crops between rows of small leguminous trees or shrubs, e.g. *Leucaena leucocephala*, *Gliricidia sepium* or *Cajanus cajan*. The legume hedge is pruned to produce mulch for the crop area between the hedges. There often is strong interspecies competition for light, nutrients and water. Additional labour cost makes these systems economically less attractive (Hairiah et al., 2000). Benefits include enhanced BNF and the ability of some deep-rooting perennials to ‘pump up’ nutrients from the subsoil, which then become available to the crops as litter or pruning (Rowe et al., 1999).

4.2 Biomass originating off-field

Plant biomass transfers

Plant biomass imported to arable land constitutes a real addition of C and mineral nutrients to arable soils. The biomass may originate from managed, semi-natural (e.g. roadsides) or natural (e.g. forest stands) areas. The principle of biomass transfers from less- to higher-valued areas is congruent with differential nutrient allocation to ‚bush’ and ‚compound rings’ in SSA villages (Manlay et al., 2002; Giller et al., 2006), whereas organic material is added to fields close to the homestead and ‘islands of fertility’ with sustained and even increased soil productivity are created. In the past, similar practices prevailed in temperate areas, where the concept of the ‚Thünen rings’ was conceptualised.

The amount of potentially transferable plant biomass depends on available area and local aboveground net primary productivity (NPP). The NPP of natural vegetation in SSA has been measured on-site, deducted from earth observation information and extrapolated to larger areas using simulation models (Olson et al., 1996; Kucharik et al., 2000; Running et al., 2004). Typical values range from 2 to 26 t ha^{-1} yr^{-1} of biomass, mainly depending on amount of rainfall and type of vegetation. The most productive regions are the humid rainforests of the Congo Basin and around the Gulf of Guinea, while desert fringes produce the least biomass (Fig. 3). Imhoff et al. (2004) calculated a continental annual NPP of 12.5 x

109 t C (16.9 t per capita), 12.4% of which are appropriated by humans (Western Europe: 0.7 x 109 t C yr^{-1}, 72.2% appropriation).

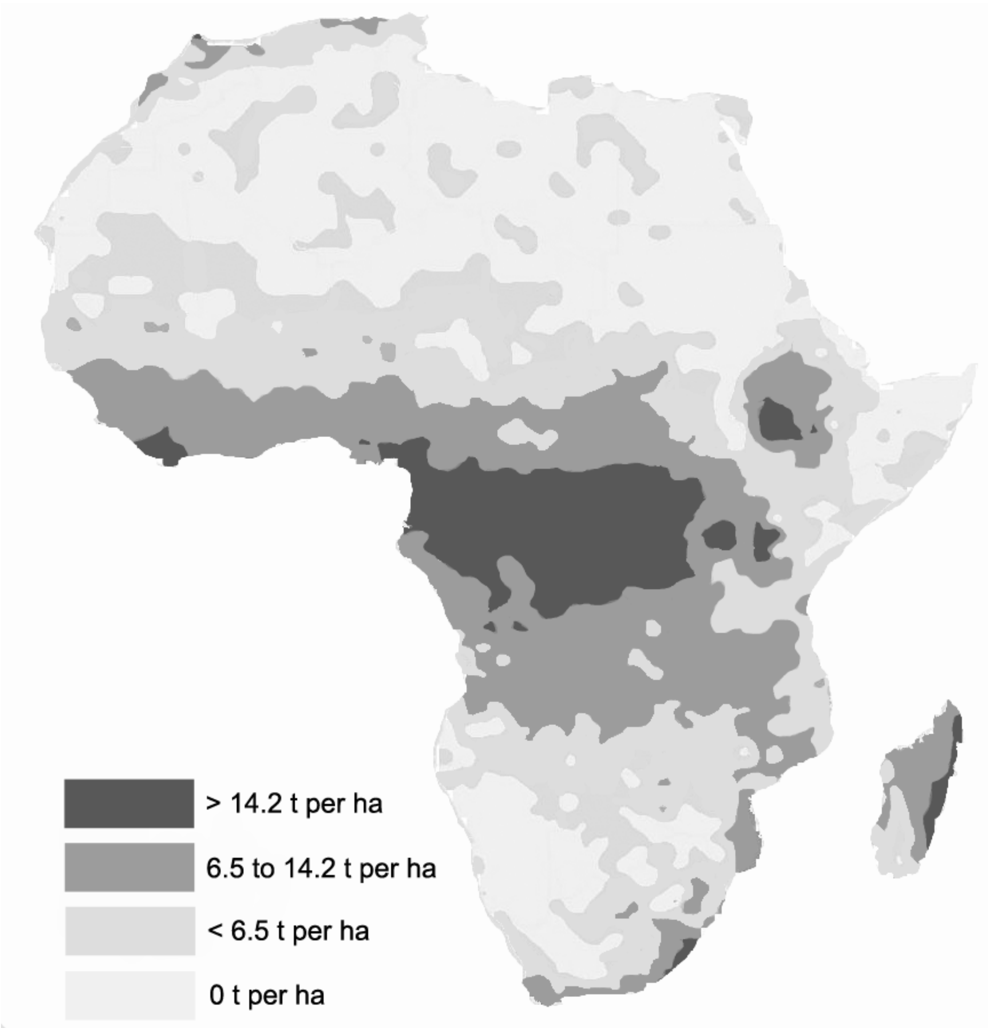

Figure 3. Mean annual net primary productivity (NPP, dry mass) in Africa. Adapted from Atlas of the Biosphere (University of Wisconsin, www.sage.wisc.edu/atlas/maps.php), figures based on data of Kucharik et al. (2000).

Numerous plant species have been tested for biomass production and nutrient uptake ability (Table 4). Particular interest has prevailed in members of the Fabaceae family, but also in Asteraceae and Euphorbiaceae (Palm et al., 2001). Stand productivity can strongly vary with species, pedoclimatic conditions, management and duration. In trials in western Kenya, Sesbania sesban produced 7.8 t ha^{-1} aboveground dry matter within six months when seeded directly, but 12.6 t ha^{-1} when planted as seedling. Within one year, 39.7 t and 46.5 t aboveground dry matter ha^{-1} accumulated in these two treatments (Niang et al., 2002). Belowground organs account for substantial amounts of biomass that are often neglected in calculations: in addition to 5.3 t ha^{-1} aboveground dry matter, Tephrosia vogelii produced 3.2 t ha^{-1} belowground biomass within six months in trials of Rutunga et al. (1999). Figures for Tithonia diversifolia were 4.4 t ha^{-1} above- and 4.2 t ha^{-1} belowground. Natural fallows are often less productive then stands of species improved through selection and breeding: 2.3 t ha^{-1} (six months; Rutunga et al., 1999) and 8.4 t ha^{-1} (12 months; Niang et al., 2002) aboveground dry matter were measured in natural fallows in the above trials.

Table 4. Nutrient contents of various materials with potential for use as green manure

Plant species	Plant family	Plant organ(s)	N%	P%	K%
Azadirachta indica	Meliaceae	leaves, twigs	2.6	0.2	1.6
Cajanus cajan	Fabaceae	leaves	3.2	0.2	0.7
Calliandra callothyrsus	Fabaceae	leaves	3.4	0.3	1.8
Chromolaena odorata	Asteraceae	leaves	3.8	0.2	1.5
Crotalaria juncea	Fabaceae	whole plant	1.9	0.5	1.3
Combretum glutinosum	Combretaceae	leaves	1.2	0.05	n/a
Combretum glutinosum	Combretaceae	twigs	0.3	0.02	n/a
Desmodium uncinatum	Fabaceae	leaves	3.2	0.3	1.8
Gliricidia sepium	Fabaceae	leaves	3.3	0.2	2.1
Grevillea robusta	Proteaceae	leaves	1.4	<0.1	0.6
Lantana camara	Verbenaceae	leaves	2.7	0.2	2.1
Leucaena leucocephala	Fabaceae	leaves	3.4	0.2	2.1
Mucuna pruriens	Fabaceae	whole plant	2.0	0.4	1.2
Parkia biglobosa	Fabaceae	leaves, twigs	1.8	0.1	0.7
Senna spectabilis	Fabaceae	leaves	3.3	0.2	1.6
Sesbania sesban	Fabaceae	leaves	3.4	0.2	1.2
Stylosanthes spec.	Fabaceae	whole plant	2.1	0.6	1.9
Tephrosia vogelii	Fabaceae	leaves	3.1	0.2	1.1
Terminalia macroptera	Combretaceae	leaves	1.2	0.07	n/a
Terminalia macroptera	Combretaceae	twigs	0.2	0.02	n/a
Tithonia diversifolia	Asteraceae	leaves	3.6	0.3	4.3

n/a: no data available
From: Palm et al. (1997), Steinmaier and Ngoliya (2001), Vanlauwe et al. (2001), Niang et al. (2002), Manlay et al. (2002).

The quality of plant material, mainly defined via its N, P, lignin and polyphenol contents, which decide on its value as a soil amendment, varies not only among plant species, but also among organs. Data collected by Chikowo et al. (2004) in Zimbabwe illustrate biomass allocation to plant organs. Of the total aboveground dry matter of a two-year old Acacia angustissima fallow of 26.1 t ha^{-1}, 62% were woody biomass and twigs, 36% litter and 2% fresh leaves. Respective ratios were 48%, 47% and 2% in 10.8 t ha^{-1} of Cajanus cajan, while in annual cowpea, 74% of 3.4 t ha^{-1} of biomass were litter and 26% were pods (Chikowo et al., 2004). Leaves usually contain 2-3% N, around 0.2% P and 1-2% K; contents in litter, stems, roots and twigs are lower, particularly for N (Palm, 2001; Manlay et al., 2002; Niang et al., 2002; Fening et al., 2005). Applying materials with a wide C:N ratio can result in N immobilisation and thus cause yield reductions. Palm et al. (1997) only recommend materials for direct use that contain >2.5% N, <15% lignin and <4% polyphenols. Species with unfavourably high lignin content include Gliricidia sepium, Leucaena leucocephala, Senna spectabilis and Ficus spp., while high levels of polyphenols characterise the genus Calliandra (Palm et al., 2001). Stands of Pueraria trifolia, Tephrosia vogelii, Tithonia diversifolia and Chromolaena odorata have been reported to contain around 150-200 kg N, 5-10 kg P and 100-270 kg K ha^{-1} (Rutunga et al., 1999; Tian et al., 2005). Assuming an NPP of 5 - 15 t ha^{-1} yr^{-1}, and N, P and K contents of 1%, 0.1% and 1%, respectively, we can expect the produced biomass to contain 50-150 kg N, 5-15 kg P and 50-150 kg K ha^{-1} yr^{-1}.

In regions with large tracts of productive yet unused land, plant biomass transfers implemented in 'cut-and-carry' systems may in the long term account for substantial proportions of crop N and K, but not of P requirements. Short-term benefits are moderate, since decomposition and mineralisation processes can lead to a time course of nutrient release not in synchrony with crop needs (Giller et al., 2006). Not all nutrients contained in the biomass are taken up by crops, also in the long term. Even for high-quality leguminous green manure and crop residues, nutrient recovery by crops is rarely >20% (Giller and Cadisch, 1995). Palm et al. (1997) conclude that many plant materials, when applied in amounts of <5 t ha^{-1}, contain sufficient N for a 2-t crop of maize, but cannot meet P requirements. Even Tithonia diversifolia, a plant known for its P-scavenging abilities, accumulates just 0.3 to 0.5% P in its leaves (Gachengo et al., 1999; Kimetu et al., 2004). However, organic materials may positively interact with e.g. rock phosphate by reducing P sorption capacity of the soil and hence increasing availability of soil P to the crop (Palm et al., 1997).

The potential of plant biomass transfers to contribute to soil fertility and crop nutrient supply will ultimately not only depend on land availability and vegetative productivity, but also on the availability of labour and capital for collection, transport and mulching. When considering issues of sustainability, it must be kept in mind that concentrating nutrients from a large area on a smaller area deprives most of the land of its fertility.

Animal manure

Depending on where and how animals are fed, inputs of manure to fields may be regarded as nutrient additions from outside (e.g. communal pastures or savannah) or as recycling within the farming system. In integrated crop-livestock systems, nutrients may be recycled, while in regions where livestock and crops are produced by distinct groups, net transfers are likely to prevail. Farm animal stocks in SSA amounted to 207 mio. tropical livestock units (TLU, equalling 250 kg live weight) in 2005, with 210 mio. cattle (1 cattle = 0.7 TLU) accounting for 70% of the total. Livestock populations are concentrated in arid and semi-arid regions: Sudan, Ethiopia, Nigeria, Tanzania and Kenya each host more than 10 mio. TLU (FAOSTAT, 2006).

Scientific trials involving applications of animal manure were implemented as early as the 1930s, e.g. in Nigeria. Experimental rates of application have varied from 2 to 5 t to as much as 60 t ha^{-1} (Swift et al., 1994; Nandwa and Bekunda, 1998; Schlecht et al., 2006). Yield effects have throughout been positive, both in short- and long-term experiments: sometimes severalfold increases in cereal yields were obtained (Pieri, 1992; Swift et al., 1994; Bekunda et al., 1997; Bationo et al., 1998; Nandwa and Bekunda, 1998).

Quantity and soil fertility effects of animal manure depend on soil, climate, animal species, amount and quality of feed sources, animal and crop husbandry, and manure collection and application practices. Rufino et al. (2006) cite stocking rates of 0-10 TLU per km² in rangeland-based systems and 5-55 TLU km-2 in rainfed mixed farming systems, those at the lower end being more common. Fernández-Rivera et al. (1995) estimated a mean 1.5 TLU to produce 679 kg manure ha^{-1} cropland yr^{-1} in the Sahelian countries. Schlecht et al. (2006) report daily N excretion in Sudano-Sahelian West Africa to be 50-420 mg kg^{-1} live weight in cattle, and 72-600 mg in sheep, thus one TLU excretes 12.5-150 g N per day. If we assume a daily excretion of 30 g N per TLU, then the potential amount of N available is 31 kg ha^{-1} cropland yr^{-1} in Ethiopia and Tanzania, 25 kg in Kenya and Sudan, and 6 kg in Nigeria. Unless animals are corralled at night, much of the manure and most of the urine will be lost for further use. Cited actual manure application rates range from 2 t in northern Nigeria, 0 - 10 t in southern Senegal and 5 t in Zimbabwe to 40 t ha^{-1} yr^{-1} in parts of semiarid Kenya (Manlay et al., 2002; Chiano and Tsuji, 2005; Rufino et al., 2006). Again, farmers tend to allocate the resource heterogeneously at the field and farm scale.

Manure nutrient concentrations are typically in the range of 0.5-1.5% N, 0.2-0.5% P and 0.5-2% K; ‚kraal' or ‚boma manure' tends to have low nutrient concentrations due to high ash contents (Palm et al., 1997; Wortmann and Kaizzi, 1998; Vanlauwe et al., 2001; Fening et al., 2005). The efficiency of nutrient cycling through animals tends to be low: N recovery efficiencies of livestock, manure collection/handling and storage are each estimated to be in the 70-80% range. The resulting overall nutrient cycling efficiency of 35-50% may be further reduced by losses during and after application (Rufino et al., 2006). Higher efficiencies may be expected for P, K and other nutrients less susceptible to leaching and volatilisation.

Nandwa and Bekunda (1998) report that in order to replace the nutrients removed by a 2-t crop of maize, 1 - 2 t of poultry manure or 7 t of low-quality ruminant manure need to be applied per ha. Depending on manure quality, 2 - 8 cattle are needed to supply the necessary amount. In the miombo woodlands of southern Africa, 14 - 42 ha of grazing land are needed to source 10 t of low-quality manure containing 96 kg N (Nandwa and Bekunda, 1998). Sandford (1989) accordingly estimates that in semiarid West Africa, 16 - 47 ha of grazing land may be required to sustain one ha of a maize crop producing 1 - 3 t grain yield ha^{-1}.

Nutrient recycling through animals is an essential element of soil fertility management in mixed crop-livestock systems. In dry areas, where only a fraction of land can be used for crop production, herding ruminants can be the only suitable land use and can facilitate substantial nutrient transfers to cropland. Granted effective systems for transport and trade of animal manure are in place, nutrient inputs from this source can regionally be highly important. The complete replacement of nutrients removed by crops through 'crop-livestock recycling' would most likely require the grazing of animals on non-agricultural land or the purchasing of manure from herders.

Compost and organic wastes

Substantial amounts of organic matter and nutrients accrue in the form of wastes of the agriculture, household and industry sectors, including agro-industrial wastes and by-products - bagasse, coffee, banana husks and citrus pulp, filter mud, market wastes and city composts (Nandwa and Bekunda, 1998). Urban wastes tend to contain more organic materials in developing than in industrialised countries: organic contents of 55 to 87% are cited for Accra (Ghana) wastes, compared to 3 to 16% in a northern European city (Drechsel and Kunze, 2001). The cities of Dar-es-Salam (Tanzania, 3 mio. inhabitants) and Kano (Nigeria, 1.4 mio.) are estimated to generate 740 t and 450 t of organic wastes per day, respectively (Harris et al., 2001). Assuming an N content of 0.5%, 1350 t and 820 t of N, respectively, accumulate in these two cities' organic wastes each year. So far, the bulk of the urban organic waste is dumped, while in villages, the material is rather used as a soil amendment, either directly or as compost.

Beneficial effects of compost addition to soil include increased pH and cation exchange capacity (CEC), higher N and P availability and improved soil structure. Applications of 5-10 t ha^{-1} of compost prepared from household refuses, farmyard manure, crop residues and ashes increased pH and CEC in the topsoil and boosted sorghum yields by factors of 1.5 to 3 in Burkina Faso (Ouédraogo et al., 2001). Results obtained from an on-farm assessment showed the use of compost to be more effective than a combination of manure and mineral fertiliser in low-potential areas, but less effective in high-potential areas of Kenya (Onduru et al., 2002). Since compost preparation and application involve substantial amounts of unused organic material and water, as well as labour input, it is primarily an option for lands close to homesteads and in peri-urban areas (Drechsel and Kunze, 2001; Schlecht et al., 2006). Preparing 1 t of compost, involving digging a pit, collecting materials, setting up and turning the heap, took 2.1 - 2.2 labour days in Kenya (Onduru et al., 2002). The cost of compost production was 838 to 1614 Kenyan Shillings (10.8 to 20.8 €; 2002), making the cost of this input per unit N, P and K comparable to that of animal manure or mineral fertiliser.

Quality can be very variable in compost and organic wastes because the materials originate from a variety of sources and are processed differently. They are in general poorer in C than crop residues or animal manure and hence less appropriate for SOM build-up (de Ridder and van Keulen, 1990). Instead, compost can contain higher nutrient concentrations in more readily available form. Compost from high- and low-potential rural areas of Kenya analysed by Onduru et al. (2002) contained 0.4 - 0.8% N, 0.1 - 0.2% P and 0.5 - 0.6% K. Urban compost from Ghana was found to contain 0.5 - 1.3% N, 0.3 - 2.2% P and 0.3 - 0.4% K (Etuah-Jackson et al., 2001).

Compost and organic wastes are potentially important sources of comparably high-quality biomass. At present this section of the nutrient cycle is rather a sink, since most of the material is disposed of at dumpsites. Improving the situation requires tackling several constraints related to transport, labour demand, health and environmental issues and acceptability of sometimes offensive material.

Human excreta

While part of the agricultural produce of SSA is exported, turned into waste during processing, or used for non-food purposes, the bulk of the crop and animal products, 261 mio. t in 2003, is for domestic food consumption (FAOSTAT, 2006). Per capita human nutrient intake from food is in the range of 2 - 3 kg N, 0.3 - 0.5 kg P and 1 - 2 kg K yr^{-1}. Most of this is excreted with the roughly 500 l urine and 50 l faeces produced per person and year (Ganrot, 2005). Human urine, which is sterile in persons with healthy renal function, contains 80% of all N, 50 - 80% of all P and 80 - 90% of all K excreted (Maurer et al., 2003). Given the mean daily supply in SSA of 53.6 g protein (FAOSTAT, 2006) with an average N concentration of 16%, 6 g N per person and day, or 2.2 kg N yr^{-1}, can be expected to be excreted in urine.

Pure human urine has a fertiliser value similar to NPK 18:2:5; it can be diluted with water or processed into solid substances such as struvite (Ganrot, 2005). Similarly to organic wastes, human excreta are commonly perceived merely as a disposal problem (Refsgaard et al., 2006). Consequently, they are a sink rather than a part of nutrient cycles. Considering the fact that P and K are non-renewable resources and that P contents of most organic materials are low, one wonders whether permanent and increasing losses of these nutrients from agroecosystems can be afforded. The IFOAM Basic Standards (2005) permit the application of human faeces or urine to soil not cropped for the next six months provided the material is free of human pathogens. Use on crops for human consumption is handled very restrictively due to hygienic considerations. The hygienic aspects of using human excreta do require thorough consideration, since faeces can be a source of pathogens that may also contaminate urine in conventional toilets. However, sanitisation of urine can be achieved through 1 to 6 months storage, while containment, alkaline treatment (e.g. with ash or lime), composting and sufficient storage are necessary to sanitise faeces. The mixing of faeces and urine can be prevented by the installation of 'no-mix' or separating toilets, possibly in the context of an ecological sanitation concept.

4.3 Alleviating P limitation by rock phosphate application

Low availability of P is a major constraint to agricultural productivity in large areas of SSA, particularly Sudano-Sahelian regions with 300-600 mm rainfall and pH between 4.1 and 4.5 (Buerkert et al., 2000). While N may be supplied in sufficient quantities through BNF, plant biomass transfers or animal manure, P removed in agricultural produce needs to be replaced from other sources. One alternative to the use of soluble P fertilisers is the application of rock phosphate (RP). Schlecht et al. (2006) cite yield-boosting effects of RP application to cereals and legumes in West Africa ranging from 0 to 203% for rates of 39 to 130 kg RP ha^{-1} yr^{-1}. Much research has been dedicated to quantifying effects and optimising application strategies of RP, e.g. by placed application of limited amounts to planting holes instead of broadcasting (Renard et al., 1998).

The availability of P from RP mainly depends on the reactivity of the material and on soil pH. Combined applications of RP and organic materials may foster P solubility (Sanchez et al., 1997). Organic farming principles permit the use of RP only in non-acidulated form, which implies that highly reactive RP should be used. High- to medium-reactive RP deposits exist in Angola, Burkina Faso, Mali, Niger, Senegal, Togo, Tanzania and Madagascar (Sanchez et al., 1997). A further intricacy stems from the fact that only small fractions of the P present in acid soils, e.g. Nitisols, clayey Ferralsols and Acrisols, are available for crop uptake due to P adsorption to Fe and Al oxides. Soils with high P-fixing capacity cover >25% of tropical SSA. The desorption of applied mineral P takes 5 to 10 years in these soils. Sanchez et al. (1997) suggest that P sorption might even be an asset if it were used to turn soils into P capital stocks - which would require large initial applications of P fertiliser.

After extensive experimentation in West Africa, Buerkert et al. (2001) concluded that locally available RP can be a viable option only if (i) it is much cheaper than more soluble mineral sources of P, (ii) it is properly conditioned and (iii) its application is restricted to well-defined zones with low pH and high rainfall. In the absence of mineral fertiliser, RP is an important source of much-needed P. While Africa is well endowed with RP deposits of varying quality, it seems doubtable whether a supply with sufficiently reactive RP at low price can be guaranteed, all the more if only non-acidulated material is used. The difficulties of achieving sufficient P supply highlight the paramount importance of optimising P recycling.

4.4 Implementation of organic soil fertility management in SSA

The diversity of organic soil fertility management techniques suggests that there should be scope for biological intensification, particularly in regions with high biomass availability. Organic soil amendments are indeed used by a substantial fraction of SSA farmers, but adoption and rates of input application often fell short of scientists' expectations.

Place et al. (2003) reviewed the practice of soil fertility management in SSA. In semiarid and subhumid Kenya, manure was applied by 90% of farmers, compost by 40% at favourable and by less farmers at dry sites, while 20% practiced forms of improved tree fallows and biomass transfer. In dry areas, 37% of farmers combined organic and mineral fertilisation, 10% used more than one organic source of nutrients. In Rwanda, 49% of fields received some kind of organic input, while only 2% were treated with mineral fertiliser. In Zimbabwe, 48% of farmers had adopted legume rotations and 23% green manure systems. In the Guinea and Sudan savannahs of Nigeria, Chianu and Tsuji (2005) found that 23% of households applied crop residues as surface mulch, mostly to high-value crops, 68% planted legumes, 49% applied mineral fertiliser and 56% used animal manure, while 40% of the interviewed farmers applied no inputs at all. A wealth of indigenous techniques have evolved, including 'tassa' and 'zaï' planting pits, half moons, compost mounds, grass strips, terraces and agroforestry (Reij et al., 1996). The 'chitemene' and 'fundikila' systems of Zambia are examples of indigenous biomass transfer techniques. In the first, tree branches are gathered in heaps, burnt and the ash is used as fertiliser. 'Fundikila' involves burying herbaceous natural vegetation in mounds that are planted with beans in the first and spread in the second year (Lungu, 1999). Harris et al. (1998) confirm that isolated ‚organic' techniques are practised in Africa, but state that an integrated approach to soil fertility management is lacking.

Many investigations into the reasons of adoption or rejection of soil fertility management highlight the importance of socio-economic circumstances. Schlecht et al. (2006) cite low product prices for agricultural commodities, immediate cash needs, risk aversion and labour shortage as major reasons for limited adoption of soil fertility management techniques; issues of land tenure may add to an unwillingness to invest into long-term soil fertility. The existence of functioning input and output markets seems to be a prerequisite of intensified soil fertility management. This consideration is supported by the finding of Place et al. (2003) that farmers preferentially use animal manure on high-value commodities, e.g. potato, coffee and vegetables. Hence, some of the obstacles to increased use of mineral fertilisers - lack of an enabling policy environment in rural areas, deficient road and market infrastructures (Sanchez et al., 1997) - can affect organic inputs as well. Accordingly, it is mainly high-value cash crops in which both mineral fertiliser application (Drechsel et al., 2001) and intensive organic soil fertility management are most widespread. Adoption is also related to farmers' material and financial endowments. While rich farmers who can afford mineral fertiliser may have no interest in labour-demanding soil improvement technologies, poor farmers are often labour-constricted and hardly able to invest workforce in long-term soil fertility improvement (Giller et al., 2006). This may impede the use of organic inputs, which require few capital, but much labour, sometimes at times when the labour force is involved in other activities (Schlecht et al., 2006).

Where soil amendments are available, they are often not spread over an entire area, but preferentially allocated to gardens and compound fields close to the homestead (Manlay et al., 2002; Sauerborn et al., 2003; de Ridder et al., 2004; Giller et al., 2006). This spatial allocation problem particularly affects organic inputs, which need to be collected and often processed in several steps and are bulky and inconvenient to transport (Giller et al., 2006). Farmers do not willingly and permanently neglect 'bush fields', but rather optimise input allocation. In the words of a farmer interviewed by Enyong et al. (1999): 'with the limited amounts of manure and compost that we can generate, we cannot fertilise the entire field. So we rotate the application of the manure. We start with the areas that need it the most and rotate application each year until the whole field has been covered.'

Added benefits of techniques, such as food and fodder from grain legumes or weed-smothering effects of velvet bean can foster adoption. The success of the latter in Benin and Cameroon has been attributed to its perceived ability to suppress spear grass (Imperata cylindrica) rather than its contribution to improved soil fertility (Place et al., 2003; Giller et al., 2006). Reasons for not adopting soil fertility management techniques brought forward by West African farmers include: (i) crop residues are available in limited amounts, there are competing uses, application is labour-demanding and incorporation is difficult; (ii) animal manure is not always supplied in adequate quantity and quality, transport is difficult and labour for application is lacking, partly because of out-migration; (iii) mineral fertiliser can often not be accessed, cash and credit facilities for purchasing it are lacking; (iv) powdery rock phosphate is cumbersome and inconvenient to use and its effects are not immediately seen (Enyong et al., 1999).

4.5 Long-term management of SOM

The long-term view on soil fertility management with its emphasis on the enhancement of SOM is a major case for organic farming. This holds all the more true in SSA, where SOM largely determines soil CEC, pH and Al toxicity in many regions (Schlecht et al., 2006). SOM contains practically all N and 20-80% of all P in the surface horizons of tropical African soils (Bationo et al., 1998), and it positively affects infiltration rate, water holding capacity and soil microbial activity.

Inherent SOM levels of tropical soils are not throughout lower than in temperate areas (IGBP-DIS, 1998). Windmeijer and Andriesse (1993) reported topsoil soil organic carbon (SOC, on average 58% of SOM) contents of 2.5%, 1.7% and 0.3% under West African equatorial forest, Guinea savannah and Sudan savannah, respectively. In most humid and subhumid regions of SSA, SOC contents are in the 1-2% range, in dry areas of the Sahel and southern Africa they are lower (IGBP-DIS, 1998). Evidence from all across SSA shows arable farming to induce drastic SOM reductions following land reclamation (Bationo et al., 1998; Nandwa and Bekunda, 1998; de Ridder et al., 2004). In the long run, the typical negative exponential course tends to level out at about one third of the pre-reclamation level (Ridder and van Keulen, 1990; Weight and Kelly, 1999).

Sustainably replenishing SOM in African soils is difficult because organic amendments are often rapidly decomposed where there is a synchrony of temperature and soil moisture optima (Schlecht et al., 2006). For instance, in a litterbag study in Ghana, 70 - 100% of various plant materials were decomposed within 80 days after burial (Fening et al., 2005).

The SOM storage capacity of soils is positively linked to their clay and silt contents; on sandy soils, e.g. Arenosols, a build-up is particularly difficult (Giller et al., 2006). In many regions dominated by coarse-textured soils, low rainfall associated with poor plant growth and low biomass availability further complicates SOM management. Sanchez et al. (1997) reason that while sandy soils may allow a gradual SOM replenishment to pre-disturbance levels, levels of clayey soils can never be reached. Enhancing SOM is thus most difficult precisely in those areas where higher organic matter levels would have the most to contribute to soil fertility (Diels et al., 2002).

In a trial conducted at Kabete (Kenya), application of 10 t ha^{-1} yr^{-1} cattle manure (dry matter with 20.5% C), combined with stover retention and mineral fertiliser (120 kg N + 52 kg P ha^{-1} yr^{-1}) could not prevent SOC from decreasing by 16% within 18 years of a maize-bean rotation. Without inputs, the decrease was 35% (Kapkiyai et al., 1999). At Saria (Burkina Faso), application of 60 t ha^{-1} yr^{-1} animal manure, together with mineral fertiliser, during 18 years only increased SOC from 0.26% to 0.71% (de Ridder and van Keulen, 1990). Rufino et al. (2006) estimate that maintaining SOM close to levels of undisturbed West African savannah soil would require additions of 5 - 10 t animal manure ha^{-1} yr^{-1}. Under conditions of that region, one can expect SOC increases of approximately 0.9 t ha^{-1} after 10, and of 1.05 t ha^{-1} after 20 years per ton ha^{-1} yr^{-1} of organic matter applied (dry matter with 50% C) (Diels et al., 2002). The same authors forecasted SOC build-up in southern Benin with the help of a simulation model and found an absolute increase of SOC by 0.33% to be the maximum achievable under intensive relay cropping systems including legumes and complete return of crop residues. De Ridder and van Keulen (1990) calculated that to raise SOC in the West African semiarid tropics by 0.1% (top 20 cm of soil), 14.7 t ha^{-1} of cereal stover, 31.4 t of animal manure or 55 t of compost would be required. To maintain the achieved soil C level, applications of 3 t, 6.4 t or 11.3 t ha^{-1} yr^{-1}, respectively, would then be necessary.

Evidence suggests that while replenishing SOM to pre-farming levels is desirable, major efforts will be needed to supply the required amounts of organic inputs. Enhancement beyond the original levels seems out of scope. Given the comparable SOM levels in humid and subhumid regions of SSA and of Europe, there might be prospects for successful SOM management in the more fertile regions of Africa. In semiarid and arid regions, other options should be explored.

5 Scenario calculations

There have been studies assessing potential agricultural carrying capacities at different levels of production intensity (e.g. Penning de Vries et al., 1997). Penning de Vries et al. (1997) concluded that an 'environment-oriented' production system could deliver a food supply outstripping demand in Africa by a factor of 1.5 to 7 (depending on region) in the year 2040. However, their scenarios are based on very optimistic assumptions including production on all potential arable land, absence of pests and diseases and return of nutrients from consumers to farmers.

In order to approach the question whether self-sufficiency in SSA food production could be achieved by means of organic farming, we attempted to establish nutrient balances for N, P and K at national level for three scenarios and in three countries with different natural endowments and agricultural infrastructure, namely the Democratic Republic of Congo, Mali and Kenya (Table 5). Outflows from arable land considered included harvested produce, crop residue used elsewhere, erosion, leaching and volatilisation. Inputs stemmed from atmospheric deposition, remaining crop residue, animal manure, green manure imports from non-agricultural land and, in 'high-input' scenarios, human urine and composted solid organic wastes (Table 6). Amounts of matter removed or added to arable land were calculated on a per ha basis and then multiplied by the respective average nutrient content to obtain flows of N, P and K.

Table 5. Population and land use in the DR Congo, Kenya and Mali

	DR Congo	**Kenya**	**Mali**	**based on**
Population, 2005	60.7 mio.	33.8 mio.	13.5 mio.	PRB (2005)
Population, 2025	108.0 mio.	49.4 mio.	24.0 mio.	PRB (2005)
Arable land, 2003	6.7 mio. ha	4.7 mio. ha	4.7 mio. ha	FAOSTAT (2006)
Potential arable land	167.8 mio. ha	15.9 mio. ha	26.5 mio. ha	FAO-AGL (2003)
Crop production, 2003[1]	19.7 mio. t	7.7 mio. t	3.0 mio. t	FAOSTAT (2006)
Livestock, 2005[2]	1.2 mio. TLU	11.7 mio. TLU	8.7 mio. TLU	FAOSTAT (2006)
Food insecurity, 1996-98[3]	61%	43%	32%	FAO (2000)

[1] Sum of cereals, roots, tubers, vegetables and fruits; [2] TLU = tropical livestock unit, 250 kg live weight; [3] Share of undernourished in total population.

The scenarios included (A) the current low-input situation, with input levels of organic matter considered realistic in the literature (a maximum 500 kg crop residue and 5 t green manure ha^{-1}); (B) outputs reduced due to higher crop residue retention, plus higher amounts of organic inputs; (C) a projection of scenario B to the year 2025, with improved per capita food supply, higher yields and expanded cropland (Table 7). The basic question was: can nutrient flows, today and in the future, be balanced purely by organic means? In order to differentiate short- and long-term effects of organic matter additions, gross and net nutrient balances were calculated for each scenario and country, the first recognising all quantities entering the field as inputs, the latter only considering the fraction of imported nutrients expected to be actually available to crops within the following season.

Table 6. Annual quantities and associated qualities used to calculate nutrient balances

Category	**Amounts**	**N**	**P**	**K**	**net as % of gross**
atmospheric deposits[1]	see right	2.5 - 5 kg ha^{-1}	1 - 2.5 kg ha^{-1}	3 - 5 kg ha^{-1}	100
crop residue[2]	0.2 - 4 x produce	0.14 - 1.2%	0.03 - 0.4%	0.1 - 2%	15
animal manure[3]	450 kg TLU^{-1} yr^{-1}	2%	0.6%	2.2%	30
green manure[4]	3 - 15 t ha^{-1}	2%	0.1%	2%	20
human urine[5]	500 l per capita	0.26%	0.02%	0.08%	30
solid organic wastes[6]	110 kg per capita	0.7%	0.4%	0.9%	30
harvested produce[7]	see Table 4	0.16 - 1.8%	0.02 - 0.3%	0.3 - 0.65%	---
erosion, leaching,...[8]	see right	23 - 40 kg ha^{-1}	1 - 3.5 kg ha^{-1}	9 - 20 kg ha^{-1}	---

Based on: [1] Henao and Baanante (1999), Galloway et al. (2004); [2] Reed et al. (1988), Henao and Baanante (1999), FAOSTAT (2006); [3] Fernandez-Rivera et al. (1995), Probert et al. (1995); [4] Kucharik et al. (2000), Palm et al. (1997, 2001); [5] Maurer et al. (2003), Ganrot (2005); [6] Wortmann and Kaizzi (1998), Harris et al. (2001), Fening et al. (2005); [7] Wortmann and Kaizzi (1998), Henao and Baanante (1999), FAOSTAT (2006); [8] Henao and Baanante (1999).

Table 7. Scenarios of nutrient demand and supply by agriculture in SSA in 2005 and 2025. Values in % refer to shares of the respective total amounts available in each country (as calculated using Tables 5 and 6). Production in 2025 was assumed to be sufficient to meet domestic demand. Land reclamation was expected to contribute 15% of the increase, the remainder resulting from yield increases.

Inputs and outputs	Scenarios		
	A (2005, low-input)	**B (2005, high-input)**	**C (2025, high-input)**
Inputs			
atmospheric deposition	100%	100%	100%
crop residue	500 kg ha^{-1} cropland	50%	50%
animal manure	50%	100%	100%
off-field green manure	10% of suitable natural areas, max. 5 t ha^{-1}	20% of suitable natural areas, max. 5 t ha^{-1}	20% of suitable natural areas, max. 5 t ha^{-1}
human urine	---	50%	50%
organic waste	---	30%	30%
Outputs			
harvested produce	country-specific	country-specific	country-specific
removed residue	total - 500 kg	50%	50%
erosion, leaching etc.	country-specific	country-specific	country-specific

In scenario A, balances of N, P and K were positive – albeit marginally for P – only in the DR Congo, where there is ample scope for green manure imports from biologically productive non-agricultural land (Fig. 4, 5). Inputs from crop residue and animal manure alone would not even offset losses from erosion in all countries. With more generous inputs of organic matter (scenario B), positive balances could be established for all nutrients and in all countries. Green manure inputs would dominate on the N and K input side, while animal manure could substantially contribute to the P balance in Mali and Kenya. Tapping the nutrient potentials of human urine and composted organic wastes may not seem worthwhile from an agricultural point of view, however, it must be taken into account that this approach would help tackle sanitation problems. Also, contributions may regionally be significant in periurban areas. In scenario C, demand-driven increases of agricultural production and associated nutrient removals would result in negative balances for P in the DR Congo and Kenya and for N in Kenya by the year 2025 (Fig. 4, 5). These preliminary calculations corroborate the fact that among the major nutrients, it is often P whose replacement is most critical in the strive for balanced nutrient flows.

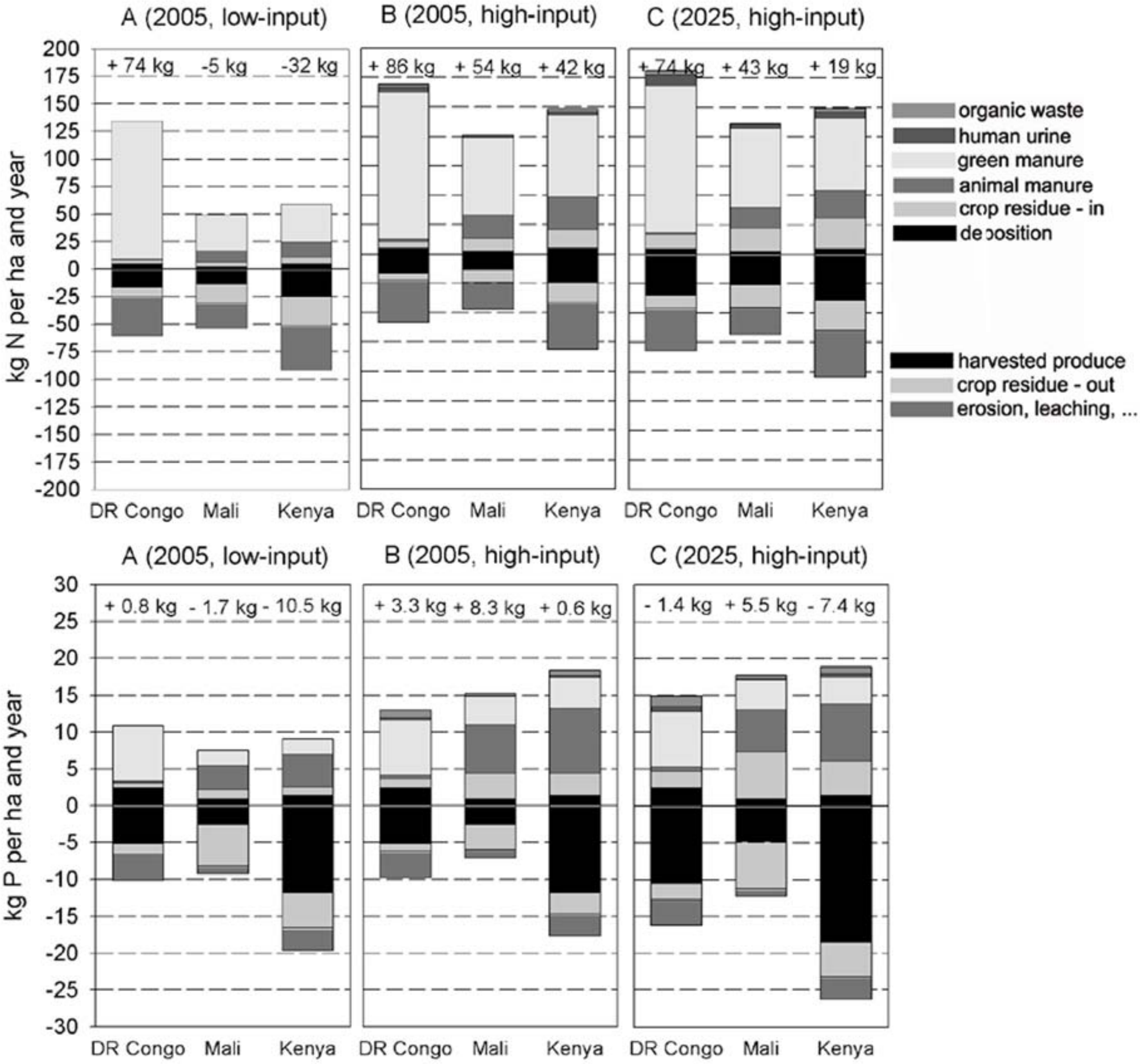

Figure 4. Gross N and P balances in the DR Congo, Kenya and Mali for three nutrient demand and supply scenarios (defined in Table 7). All nutrients contained in applied materials are accounted for as inputs.

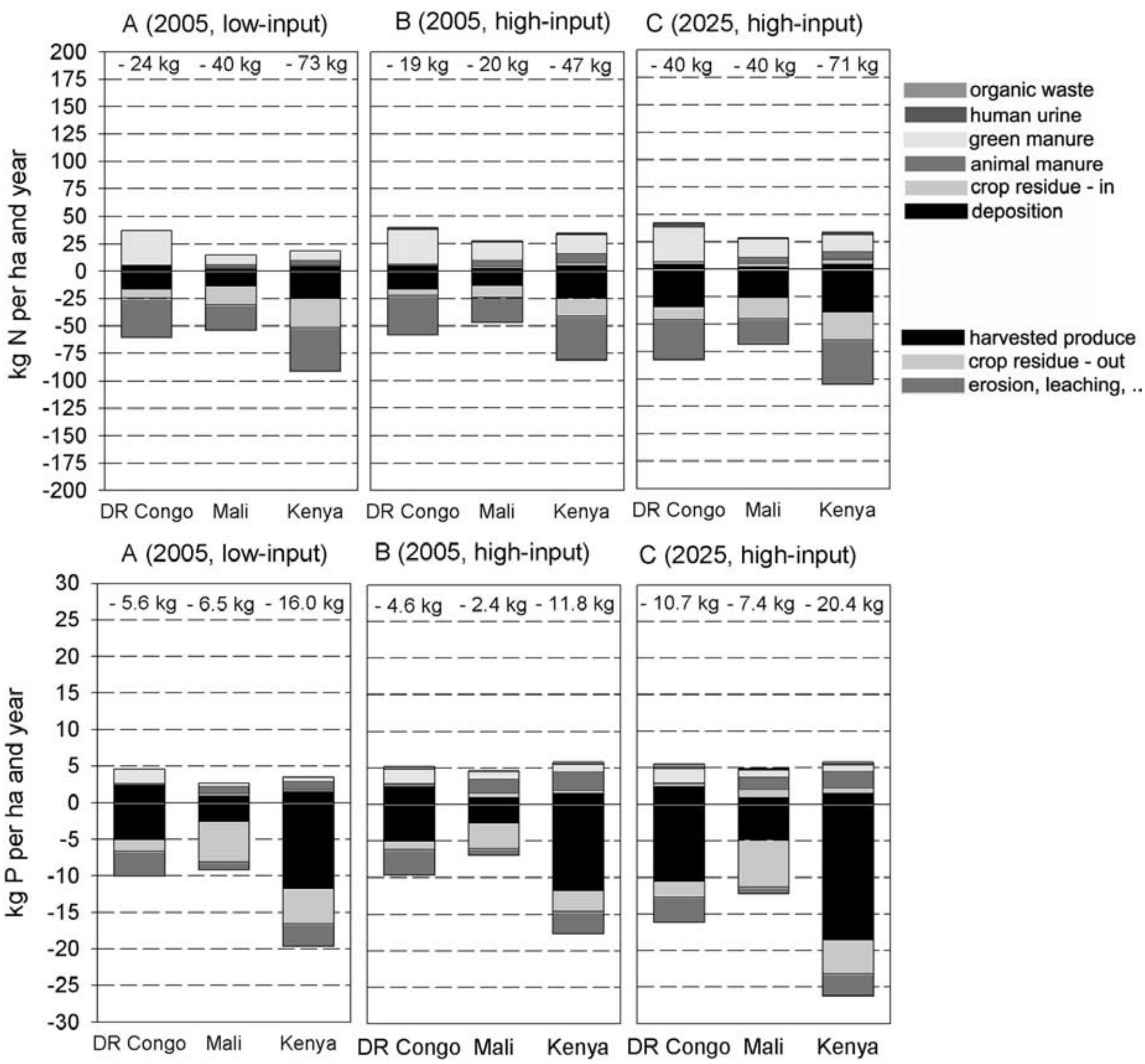

Figure 5. Net N and P balances in the DR Congo, Kenya and Mali for three nutrient demand and supply scenarios. Only nutrients available to crops within the season following application (conversion factors, see Table 6) are accounted for as inputs.

6 Discussion and conclusions

Managing soil fertility is a cornerstone both of organic agriculture and of strategies to boost crop production in Africa. Organic soil fertility management, which involves the use of a variety of materials and techniques, has the potential to substantially contribute to restoring soil nutrient balances and maintaining soil organic matter levels. Namely the use of green manure originating from outside the cropland may facilitate large nutrient and biomass additions to arable soils. The largest untapped source of green manure are the vast biologically productive tracts of land not yet reclaimed for agricultural use, namely in the DR Congo.

However, the results of our scenario calculations suggest that if food self-sufficiency in SSA is to be achieved, strategies for counterbalancing nutrient outflows from cropland by purely using organic inputs will require huge logistic and labour efforts, and yet be insufficient in the long term. Two major intricacies are the unlikeliness of organic amendments to provide timely nutrient availability to crops (short term) and the difficulty of sustainably increasing SOM content (long term), particularly on coarse-textured soils and in dry regions. Biomass transfers, granted they are economically feasible, would translate into a mere relocation of nutrient mining and degradation problems from cropland to other areas. Such exploitative practice would arguably comply with neither the principles of organic agriculture nor those of sustainability. Also, securing sufficient P supply would be highly difficult even if soil fertility management strategies were to integrate major biomass transfers and applications of non-acidulated rock phosphate.

To effectively close nutrient cycles is an unaccomplished task not limited to Africa or to organic farming. Meeting the food demands of growing populations invariably involves the removal of increasing amounts of biomass and nutrients from arable land. The capacity of agroecosystems to recover from these withdrawals set the limits to preindustrial arable farming, which fed at most five people per ha of high-potential farmland (Smil, 1997). Precise estimates of today's 'organic carrying capacity' in SSA and worldwide are required to quantify how many people could be fed by means of organic agriculture. Calculations must not be limited to farm gate balances, but at the least consider the regional level. Nutrient flows at farm level may seem balanced due to transfers from outside the farm, without cycles in the entire system being closed (Pender and Mertz, 2006), an approach that would ultimately be compromised by land scarcity if population continues to grow.

Global N balance can be achieved by tapping the atmospheric reservoir of elemental N, either 'organically' through BNF or 'conventionally' through synthetic fertiliser production. Under the conditions of SSA, a combination of both may be required. Improving P supply to SSA cropland is a task that can probably only be accomplished with massive applications of rock phosphate in its natural and acidulated forms. Organic production standards provide for such practice under 'exceptional circumstances', which arguably do apply to SSA regarding soil fertility. Since P is neither renewable like N nor easily extractable from seawater like K, closing the cycle of this element will be of paramount importance to humanity (Tiessen, 1995). In crop production, P losses mainly occur through erosion and surface run-off, major amounts are also removed with produce at harvest. Tackling P deficits requires the combination of improving supply by applying inorganic and organic sources of P, preventing erosion and run-off through soil-conserving techniques, and maximising P recycling by using organic wastes and human excreta as soil amendments. Larger efforts should be directed at better integrating the latter approach into organic farming schemes.

While organic agriculture in its present form seems inappropriate as the sole basis of SSA crop production due to the above-mentioned drawbacks, it may significantly contribute to improving the sustainability of African agriculture by

- tightening nutrient cycles through optimisation of on-farm nutrient recycling, reliance on regional inputs and production for regional markets;
- fostering soil organic matter management, thereby slowing down or stopping further soil degradation (including erosion and associated loss of P), boosting soil microbial activity and increasing agroecosystem resilience;
- providing additional benefits related to biological crop protection, biodiversity conservation, adherence to social standards and stringent quality control.

Certified organic agriculture, which depends on functioning input and output markets and transport infrastructures and involves additional costs for certification, may be most adequate in regions with high production potential and access to national and possibly international markets. These criteria are often met in periurban regions congruent with areas suitable for nutrient recycling from human excreta and organic waste; these are also regions offering good prospect for high-external input agriculture. In low-potential areas, pragmatic approaches, such as low-external input agriculture and integrated soil fertility management, may provide more feasible solutions (Pender and Mertz, 2006). Pursuing the present approach of introducing organic farming locally in high-value cash crops and suitable regions may be more promising than striving for implementing organic practices in staple crops and at continental scale. With respect to the vision of worldwide adoption stipulated in the principles of organic agriculture (IFOAM, 2005), reconsideration of several production standards seems recommendable. The organic movement should consider

- permitting the temporary use of mineral fertilisers, including acidulated rock phosphate, for soil fertility replenishment in tropical and subtropical areas with nutrient-depleted soils;
- encouraging the adoption of techniques facilitating the hygienically and environmentally safe reclamation of nutrients and biomass from organic wastes and human excreta;
- promoting research facilitating the adaptation of organic methods to SSA conditions, as well as the compilation and dissemination of traditional and modern methods of soil fertility management;
- setting up regional and national nutrient balances, in addition to farm gate balances, in order to allow holistic assessments of the sustainability of soil fertility management strategies.

Such gradual shifts from existing principles might eventually turn out to substantially contribute to the flexibility, adaptability and feasibility of organic farming at a global scale.

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Organic agriculture and plant genetic resources management

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Abstract

Organic agriculture is more than a production management system, it also promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. Therefore, biodiversity plays an important role in organic farming and this makes the conservation and the sustainable use of (agro)-biodiversity an integral part of the organic farming activity. Against this background the paper briefly describes the various conservation methods and approaches and provides information on germplasm holdings of the CGIAR Centres' main crop gene pools and the kind of material that make up these collections as an illustration of sizes, diversity and responsibilities of genebanks that manage public domain material. Proper characterization and evaluation of the conserved material is an important prerequisite for its use and so is the legal and policy framework that regulate access and benefit-sharing arrangements. Underutilised and neglected species are generally under-represented in *ex situ* collections but play an important role in on-farm and home gardens' conservation programmes. As they generally are well adapted to specific local agro-ecological conditions, including resistance to pest and diseases and possess characteristics that are region-specific they form an interesting sub-set of genetic resources for organic farming. The importance of genetic variation within species for organic farming is being treated in some detail, especially from a breeding perspective. Base broadening approaches as well as participatory plant breeding, frequently combined with on-farm conservation efforts and economic development, and are briefly described as two areas that are seen as being of particular interest to organic farming. In the section that deals with enhanced germplasm management practices an analysis of routine genebank operations is being presented by listing specific actions that would lead to providing a better service by genebanks to the organic production sector. Finally the paper assesses opportunities how organic farming can contribute to biodiversity conservation before the paper draws pertinent conclusions and makes some recommendations.

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Keywords

Organic agriculture, plant genetic resources conservation, PGR management, biodiversity, neglected and underutilised species, genetic diversity, genetic variation

1 Introduction

According to the Wikipedia free encyclopaedia (http://en.wikipedia.org/wiki/organic_farming, consulted on 31.05.2006) is organic farming "a form of agriculture that relies on ecosystem management and attempts to reduce or eliminate external agricultural inputs, especially synthetic ones. It is a holistic production management system that promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity". Furthermore, the Wikipedia states that "in preference to the use of off-farm inputs, organic farming emphasizes management practices, taking into account that regional conditions require locally adapted systems. Utilizing both traditional and scientific knowledge, organic agricultural systems rely on agronomic, biological and mechanical methods as opposed to using synthetic materials to fulfil any specific function within the system. Organic farming is also associated with support for principles beyond cultural practices, such as fair trade and environmental stewardship".

The International Federation of Organic Agricultural Movements (IFOAM) defines organic agriculture as "a whole system approach based upon a set of processes resulting in a sustainable ecosystem, safe food, good nutrition, animal welfare and social justice. Organic production is therefore more than a system of production that excludes certain inputs" (IFOAM, 2002). Other definitions, including that of the Food and Agricultural Organization of the United Nations (FAO) are similar and many of the expanded descriptions of organic agriculture refer to the important role of biodiversity and thus, making the conservation of biodiversity an integral part of the organic farming activity (Scialabba et al., 2003).

Against the above background, especially the reference to the important role that biodiversity plays in organic agriculture, this paper has a clear focus on one particular aspect of biodiversity, i.e. plant genetic resources. The paper will briefly describe plant genetic resources, how they are being conserved and their use is facilitated and why genetic diversity is relevant to organic agriculture. Furthermore, the paper presents suggestions how conserved genetic resources can be made more useful to organic agriculture through specific management practices and procedures, how organic agriculture can contribute to conservation of genetic resources and, finally, some general conclusions are presented.

2 Plant genetic resources conservation

Plant genetic resources or germplasm consist of the different genetic forms that one can find in domesticated species, i.e. traditional varieties, landraces, modern varieties, genetic stocks and breeding lines as well as genetic material that belongs to weedy forms as well as the wild relatives of the domesticated species. Since the first half of last century more systematic efforts have been made to collect genetic resources, especially from farmers fields as they were needed in breeding programmes and/or their existence was threatened because of the advancements of agriculture and to conserve the material in so-called genebanks (i.e. *ex situ* conservation). In the latter part of the last century the role of people in creating and managing genetic resources was more and more recognized and programmes were initiated to conserve plant genetic resources in a targeted manner in their natural as well as in human-made habitats, i.e. in nature and on-farm (so-called *in situ* conservation). Further details of the conservation of plant genetic resources can be found in numerous publications, including in the proceedings of a global technical conference on the conservation and use of plant genetic resources (Engels *et al*., 2002).

At present, more than 6 million accessions of plant genetic resources are reported to be conserved in approximately 1500 germplasm collections or genebanks world-wide, predominantly national or institutional in nature. The Consultative Group in International Agricultural Research (CGIAR) operates 11 international genebanks, comprising more than 700,000 accessions of the major food crops, including their wild relatives (see Table 1). Most of this germplasm has been placed in the public domain, under the auspices of FAO as part of their International Network of *Ex Situ* Germplasm Collections. Table 2 provides a summary of the types of germplasm material that are being managed by the CGIAR genebanks and Table 3 provides these details for one of the biggest crop collections, i.e. rice.

Until the early 1990-ies germplasm material was regarded as an international public good that was freely available to any *bona fide* user. The advancement of biotechnology, in particular molecular genetic techniques, and the increasing importance of intellectual property rights resulted in a much more politicised situation that led to a much more restricted attitude of countries to provide access to genetic resources. By executing their sovereign rights over these resources users can only obtain genetic resources from countries legally through the designated authorities in countries by concluding either acquisition agreements when intending to collect germplasm in the respective country or through a material transfer agreement when requesting conserved germplasm from that country. The entrance into force of the International Treaty for Plant Genetic Resources for Food and Agriculture should be mentioned in this context as the Treaty has established a multilateral system for access and benefit sharing for the major food crops with the intention of facilitating access and to regulate the benefits that might arise from the use of these resources (Moore and Tymowski, 2005).

The ultimate objective of genebanks, while conserving germplasm for posterity, is to provide adequate information about the conserved material with the aim of facilitating its use. The International Plant Genetic Resources Institute (IPGRI), one of the 15 CGIAR Centres is solely concerned with the conservation and utilization of plant genetic resources and its publications are intended to provide technical guidance to its partners, i.e. genebanks curators, researchers, on-farm conservation specialists and others (http://www.ipgri.cgiar.org). One of the recommended international genebank management standards is to systematically characterize and preliminary evaluate conserved accessions, following agreed lists of descriptors and according to agreed procedures.

Table 1. Total germplasm holdings of CGIAR germplasm collections as of April 2006 (SGRP, 2006).

Centre	Crop		Total holdings
CIAT	Cassava		5,969
	Forages		22,053
	Beans		36,067
	Rice		1,000
		Total	**65,089**
CIMMYT	Maize		25,200
	Teosinte		162
	Tripsacum		152
		Sub-total	***25,514***
	Triticum aestivum		95,364
	Triticum durum		20,181
	Triticum and *Aegilops* spp.		9,725
	Triticosecale spp.		20,785
	Hordeum vulgare		16,264
	Secale cereale		772
	Synthetic hexaploid *T. aestivum*		356
		Sub-total	***163,447***
		Total	**188,961**
CIP	Andean roots and tubers		1,785
	Sweet potato		7,567
	Potato		10,351
		Total	**19,703**
ICARDA	Barley		26,138
	Chickpea		12,448
	Faba bean		10,801
	Wheat		38,149
	Forages		34,118
	Lentil		10,580
		Total	**132,234**
ICRISAT	Chickpea		19,272
	Groundnut		15,419
	Pearl millet		21,594
	Pigeon pea		13,632
	Sorghum		36,774
	Minor millets		10,193
		Total	**116,884**

Table 1. (continued).

Centre	Crop		Total holdings
IITA	Bambara groundnut		2,030
	Cassava		3,368
	Cowpea		15,869
	Soybean		1,909
	Wild Vigna		1,634
	Yam		3,200
	Maize		767
	Musa		300
	African yam bean		139
	Legumes (underutilized species) [#]		250
		Total	**29,466**
ILRI	Forages		18,270
		Total	**18,270**
IPGRI	*Musa*		1,183
		Total	**1,183**
IRRI	*Oryza sativa* (Asian cultivated rice)		102,553
	Oryza glaberrima (African cultivated rice)		1,651
	Wild relatives and interspecific hybrids		4,508
		Total	**108,712**
WARDA	Rice		20,751
		Total	**20,751**
Overall Centres total			**701,253**

[#] Pigeon pea, sword bean, winged bean, jack bean, French bean, green bean, Kersting groundnut, Lima bean, Mexican bean, mung bean, rice bean, *Cassia sp*, *Lupinus sp*, *Mucuna sp*, *Pueraria sp*.

Table 2. Summary of germplasm types in the collections maintained by the CGIAR Centres (SINGER; http://singer.cgiar.org, accessed on 06.06.06).

Sample status	% of accession type
Traditional cultivar / Landrace	36.2%
Wild	12.9%
Breeding / Research material	12.9%
Other	5.0%
Advanced / Improved cultivar	0.3%
Weedy	0.3%
Unknown Sample Status	32.3%
Total	**100.0%**

Table 3. Example of the types of the available germplasm accessions from the IRRI rice collection (R. Sackville Hamilton, personal communication 2006).

Type of germplasm	*Oryza*		Wild relatives		Number of accessions
	sativa	*glaberrima*	Annex1	Not Annex1	
Unspecified	50370	1204	4487	21	56082
Breeding and inbred lines	9785				9785
Improved varieties and advanced breeding materials	3602	1			3603
Traditional varieties	38796	446			39242
Total	**102553**	**1651**	**4487**	**21**	**108712**

Characterization (i.e. using highly heritable characteristics and traits) and preliminary evaluation (i.e. evaluating germplasm for characteristics and traits that are of high agronomic interest, that do not require highly specialized tools or procedures and that are not strongly influenced by the environment) are seen as a typical genebank responsibilities, whereas the (further) evaluation of the germplasm is regarded as a typical responsibility for the plant breeders but with an active participation and support by the genebanks. In general, important traits such as vigour, seed setting and field resistance to pests and diseases are usually observed by curators of collections, but these data are not always present in germplasm catalogues, in particular if such traits are more linked to collection management. Other traits commonly determined in collections that are also of specific interest to organic production are growth habit (weed suppression) and earliness.

IPGRI has published such descriptor lists for more than 95 crops, including the last one on cañahua (*Chenopodium pallidicaule)* (IPGRI *et al*., 2005). The characterization status of the various collections varies greatly from genebank to genebank and seems to be far from comprehensive in most cases. As an example, IRRI is currently re-characterizing germplasm accessions as the recording of some characteristics was changed and they are able to characterize between 3,000 and 3,500 accessions annually (Ruaraidh Sackville Hamilton, personal communication 2006). This means that it will take up to 30 years to finalize the entire collection! In the past IRRI did take data on various agronomic traits like disease resistance. However, this process was stopped some ten years ago as it was realized that the traits were too dependent on site and year for it to be collecting single-site, single-year, single-replicate data (Ruaraidh Sackville Hamilton, personal communication 2006).

In order to ensure that the results of the aforementioned characterization and evaluation activities are readily available to potential users, genebanks usually manage this type of information in comprehensive germplasm information management systems that can be assessed through the internet. The CGIAR Centres have jointly established a system-wide genetic resources information system (SINGER; http://singer.cgiar.org) that allows easy access to the relevant information, including the provision of ordering germplasm accessions from the holding Centre. Within the context of the Collaborative European Programme Genetic Resources (ECP/GR) the countries are collaborating in a European-wide information network called EURISCO (http://eurisco.ecpgr.org). For more details on germplasm management practices reference is made to a recent guide on effective germplasm collection management (Engels and Visser, 2003).

In addition to the management of germplasm in genebanks it should be noted that possibly most of the genetic diversity continues to exist in agricultural production systems, i.e. in farmers' fields. Since the 1990-ies this situation has been recognized and concerted research efforts have been undertaken to understand and improve the management practices of the genetic resources by farmers worldwide, both from a conservation as well as a development perspective. As most of the genetic diversity deems to exist in the more marginal production areas, particularly in the tropics, it was logical to link such improved management and/or conservation efforts with economic development activities. IPGRI produced a training manual that provides detailed suggestions on how this can be achieved best, including on participatory plant breeding and research activities, on agricultural practices etc. (Jarvis *et al*., 2000).

3 Underutilised and neglected species

Underutilised plant species are generally poorly represented in *ex situ* germplasm collections; they play in general a much more important role *in situ*/on-farm management and sometimes conservation activities (Padulosi *et al.* 2002; Hammer 2004). Unfortunately, official assessments of genebank holdings with respect to number of species and accessions do not provide exact figures about underutilised species conserved in genebanks as the figures usually treat minor crops and underutilised species together (Figure 1).

From the approximately 6 million accessions of plant genetic resources for food and agriculture that are conserved today in some 1500 germplasm collections and/or genebanks around the world, about 80% of the accessions belong to major crops and their close relatives. The remaining 20% are made of other crops, including underutilised species, which are very poorly represented in terms of intra-specific variability, i.e. on average less than eight accessions per species (Padulosi *et al*. 2002). Therefore, for genetic improvement work and in case a better representation of the genetic diversity is required from underutilised plant species it will be necessary to work closely with the farming communities that still cultivate these species.

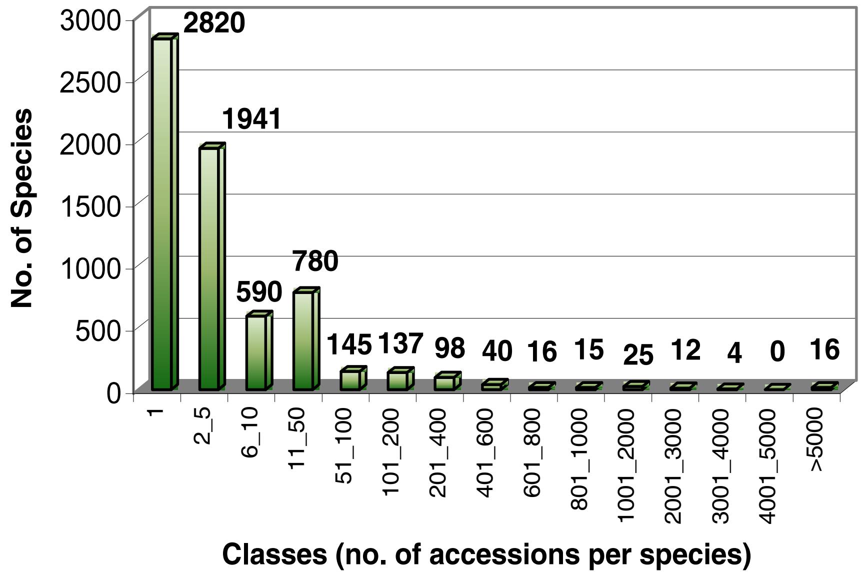

Figure 1. Representation of minor crops, including neglected and underutilised species in genebanks (Adopted from Padulosi et al., 2002)

Underutilised species have the advantage of being adapted to agro-ecological niches and marginal areas (Padulosi *et al.* 2004), thus being more resistant to pests and diseases, as well as aiming at species-specific and region-specific characteristics such as taste, colour, bouquet and shape (Lammerts van Bueren *et al.*, 1999). This makes this kind of germplasm more suitable and interesting for organic production methods per se, not requiring high external inputs such as fertilizers and pesticides. The production of underutilised species is knowledge rather than capital intensive, it provides opportunities to communities in the more marginal production areas and allows the coupling of traditional knowledge with modern technologies such as biological pest control methods (Giovannucci, personal communication, 2005). As the conservation of this traditional knowledge is one of the objectives of organic farming, these species thus, are of particular interest for the organic farming production method. In the developing countries, organic farming like production systems contribute to rural stability by decreasing the trend of migration from rural to urban areas due to its high labour requirements. In this context underutilised species fit well.

Underutilised plant species are experiencing new market opportunities as consumers want more diversity and novelty in food and other commodities. Underutilised species' products produced in the organic way, become even more attractive as their consumers tend to be more concerned with health, food safety, social, and environmental issues. Marginal and small farmers in developing countries have a comparative advantage in shifting to certified organic agriculture as the technologies they use are often very close to those of organic practices applied in Europe or North America. These farmers are also the custodians of traditional crops and the related traditional knowledge in the respective environment. Still, many farmers will face a number of obstacles to become certified organic producers due to the complexity of the certification process. They are often lacking technical knowledge, have limited storage and processing facilities, are required to attain to complex certification processes and are not linked up through organized networks (Giovannucci, personal communication, 2005). A concrete example of such limitations is that farmers dealing with underutilised species in organic production are faced with the burden of accessing organically certified seed as these species do not belong to commercial seed systems. However, to overcome this constraint the EU regulation 2092/91 foresees an exemption from this requirement upon approval by the national competent authority (EU 2003[1]).

4 The importance of genetic variation for organic agriculture

As organic farming systems refrain from high input and any chemical inputs they need to strengthen the self-regulatory ability and resilience of the farm-ecosystem, in particular through functional diversity at farm, field, crop and variety levels. Therefore, there is a need for new varieties with traits that make them flexible and robust and with an adequate buffering capacity. Functional genetic variation in varieties of self-fertilizing species, such as found in variety mixtures (i.e. frequently the case in landraces!) and multiline varieties has proven to stabilize yield and is an important tool for sustainable use of resistances. To achieve this it will be necessary to broaden the genetic basis of organic breeding programmes and to establish these newly. Furthermore, varieties should possess higher yield stability through improved adaptation to organic farming systems. Resistant traits against pests and diseases and other biotic as well as abiotic stresses are important as well as characteristics that influence plant architecture and growth dynamical aspects that render varieties suitable under organic farming conditions. An excellent treatment of the different requirements for and types of organic agricultural varieties as well as of breeding concepts can be found in Lammerts van Bueren, 2002.

Besides the within-species genetic variation that is used in breeding efforts as well as exploited in the composition of composed varieties such as multilines and line mixture varieties, the organic agricultural sector is also interested in the use of species diversity, in particular to contribute to stabilizing biological processes in the production system based on mixed cropping, intercropping and mixed varieties. Also for these situations genebanks seem to be logical sources to obtain the necessary diversity at both levels to contribute to improved production circumstances. However, the transfer of genes from related (and unrelated) species would only be acceptable if the fertilization and embryo growth occur naturally on the plant and there is no need to resort to techniques to incorporate change at the cell level (Lammerts van Bueren *et al.*, 1999)

The organic agricultural sector in Europe formulated the concept of organic plant breeding as follows “The aim to develop plants which enhance the potential of organic farming and bio-diversity. Organic plant breeding is a holistic approach that respects natural crossing-barriers and is based on fertile plants that can establish a viable relationship with the living soil” (Lammerts van Bueren and

[1] Commission Regulation (EC) No 1452/2003 of 14 August 2003 maintaining the derogation provided for in Article 6(3)(a) of Council Regulation (EEC) No 2092/91 with regard to certain species of seed and vegetative propagating material and laying down procedural rules and criteria relating to that derogation - http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32003R1452:EN:HTML

Osman, 2001). Furthermore, organic agriculture does not accept breeding methodologies that do not respect the intrinsic value and integrity of plants (Lammerts van Bueren *et al*., 2003a and 2003b). Consequently and as mentioned before, organic breeders prefer to use the genetic diversity within the primary gene pool, rather than to call upon diversity available in crop wild relatives that will require artificial means for crossing and ensuring fertility. An example of actual germplasm material being distributed for organic agriculture is provided by the genebank at Braunschweig (since a few years now merged with the genebank in Gatersleben) where in the period from 1985-2000 about 5000 samples were distributed to institutions engaged in organic agriculture worldwide. This corresponds with (only) 4% of the total germplasm distributed in that period (Frese, 2002).

Considering the foregoing, one can conclude that organic breeding efforts will be most interested in landrace material and traditional varieties that are maintained in germplasm collections as well as in germplasm that is being managed/conserved on-farm. Genetic diversity that contributes to adaptability of varieties to low-input conditions, in particular nutrient efficiency, characteristics that contribute to yield stability and to weed suppression are the most types of germplasm (Lammerts van Bueren et al., 2004). Thus, these requirements provide an opportunity to genebanks as well as to on-farm conservation projects to make a significant contribution to agriculture and horticulture as many of these specific traits and characteristics for organic agriculture and organic seed production can be found in germplasm collections and/or in farmers' fields.

Participatory plant breeding approaches that include farmers as well as plant breeders in crop improvement efforts have been suggested and are being used to obtain locally adapted varieties with desirable characteristics that respond well to specific local low-input conditions, both in developing as well as in developed countries (Buntzel, 1996; Lammerts van Bueren, 2002 and 2004; Scialabba *et al*., 2003; Jarvis *et al*., 2004; Murphy *et al*., 2004). However, participatory approaches can result in varieties that contain more within-variety genetic diversity than what is allowed by the formal plant variety protection schemes. Furthermore, multiline and other types of varieties that do not comply with the distinctness, uniformity and stability (DUS) criteria of the UPOV convention can lead to legal problems and thus, these approaches sit uncomfortably with the strict regulations of plant variety rights and performance requirements for new varieties in many countries (Beringer, 1996; Lammerts van Bueren, 2002). It is interesting to remark that this legal situation presents an analogy between the needs of organic farmers in developed countries and farmers in developing countries who want to continue using landraces as their preferred varieties as part of the traditional and/or subsistence agriculture.

IPGRI has been working closely with farmers in developing countries in the management of crop genetic diversity in agro-ecosystems, including the introduction and use of participatory breeding and research approaches. Diversity continues to be maintained and managed by farmers throughout the world as an integral part of their strategy to cope with the prevailing (uncertain) conditions. Informal seed supply systems provide important elements in the maintenance of genetic diversity and of adaptive capacity. From the IPGRI and other experiences it can be stated that the best programmes have been driven by a clear appreciation of the central role of the farmer in managing crop genetic diversity and of the importance of adopting working procedures and practices that are fully participatory and start from a desire to reflect farmers' needs and concerns in diversity management (Jarvis *et al*., 2004).

Different seed systems, both formal and informal ones, have been investigated and stimulated for access and benefit sharing of agricultural diversity, which do justice to the efforts of the breeder and his/her partners and that allow for a certain level of diversity within new varieties, needed for the resilience of a crop to withstand also adverse conditions. In the Netherlands a project was carried out to investigate the impact of farmers' involvement in a participatory project on the characterization, evaluation and selection of onion accessions to develop new and more diverse base populations for breeding purposes. The active participation of farmers resulted in additional traits for genebank characterization as well as new selection criteria for breeding and in a broader genetic base for the development of better-adapted varieties (Lammerts van Bueren *et al*., 2004).

Taking the principles of organic agriculture into consideration, it will be no surprise to conclude that organic agriculture rejects genetically modified varieties and that cross-contamination with pollen from genetically modified varieties constitutes a real concern and problem to the organic agriculture. The latter is of particular concern in centres of diversity if and when genetically modified varieties are being introduced. Specified preventive measures by genebanks under these circumstances have been suggested to avoid the unintended presence of genetically modified elements in germplasm collections (Engels *et al*., 2005). In order to achieve co-existence of conventional and organic agriculture the recent conference on organic seed concluded that transparency, fairness and respect are most important and that the dialogue on co-existence should continue (FAO, 2004).

5 Enhanced germplasm management practices and organic agriculture

The critical role genetic diversity plays in breeding organic varieties as well as in the production of organic agricultural products presents a unique opportunity to genebanks to establish a much closer relationship with the organic agricultural world and to get the conserved germplasm more intensively used by this sector. As already concluded above, organic breeders and farmers will be very interested in genetic diversity present in landraces and traditional varieties as these will possess the kind of adaptation characteristics that are of key importance. Furthermore, many of the collected germplasm accessions are genetically heterogeneous and thus will be important sources of within-variety diversity to ensure a high level of yield flexibility that organic varieties require. In addition, important tolerances and resistances against biotic and abiotic stresses might be found in genebank collections or in on-farm conservation schemes or can be obtained through the existing worldwide network of genebanks and their germplasm exchange system.

In order to achieve a good performance of genebanks while serving the organic sector with the wanted genetic resources and diversity the following management practices in routine genebank operations are suggested:

- Consult with organic breeders and farmers, especially those that are involved in participatory plant breeding and variety selection, on the kind of descriptors they would like to see used in the characterization and preliminary evaluation of germplasm accessions;

- Establish a good understanding with organic breeders (and farmers) on priorities of traits and characteristics for which germplasm collections should be evaluated and/or establish a close collaboration with them to implement this work under the environmental and cultivation conditions of the users of the germplasm. It might well be that the genebank is not always able to fulfil all expectations and that some additional funding might be needed to achieve the best result;
- Involve organic breeders and farmers in discussions if and what kind of germplasm material is missing in the collections, where that could be obtained or collected and, whenever feasible, to involve them in the actual collecting activity. Assist in searching for specific traits in germplasm collections worldwide;
- Whenever relevant and feasible, involve breeders and farmers in routine operations of the genebank (e.g. regeneration/multiplication) that will allow a better understanding of the available diversity both, between and within species;
- Facilitate linkages and collaboration between on-farm conservation or management schemes and organic breeders and farmers;
- Participate in discussions that deal with policy implications of needs and requirements of organic agriculture with respect to genetic diversity in varieties or in production systems and/or the need for changes in existing policies, including issues related to broadening the genetic base of our crops and pre-breeding efforts (see the example presented in Lammerts van Bueren et al., 2004);
- Play a more pro-active role in the deployment of genetic diversity that is well adapted to particular production areas or systems and that would increase the available genetic diversity to farmers and breeders;
- Carefully consider any steps in the routine operation of preparing seeds for storage that could lead to problems of using the germplasm at a later stage by organic farmers/breeders, e.g. dressing the seeds to be stored with fungicide/pesticide;
- Ensure that germplasm accessions that are provided to organic breeders and farmers are accompanied with any information that will facilitate their use;
- Conduct joint research activities with germplasm material of common interest;
- Consider the organic agricultural sector to be represented in the genebank steering committee or supervisory board.

More details on genebank management practices that could lead to stronger links between genebanks and plant breeders are provided in Engels (2002). Comparable considerations on how to strengthen links between on-farm conservation and (organic) plant breeding can also be found in Mar and Holly, 2000.

6 How organic agriculture can contribute to biodiversity conservation

As can be seen from the definition of organic agriculture biodiversity plays an important role in the philosophy as well as in the praxis of the holistic approach to cultivate plants (and animals) species in equilibrium with nature. This means that genetic diversity at the three levels, i.e. ecosystem, species and within-species, is an essential pillar on which the production is based and the production system’s health is maintained, including soil fertility and the prevention of pest and diseases. Organic agriculture uses the interactions between species and between different genotypes as an important factor in obtaining resilience against biotic and abiotic stresses and to use the “architecture” of the individual plants and species as a key element in the ecology of the production system. A number of authors (e.g. Beringer, 1996; Heyden, 1996; Heyden and Lammerts van Bueren, 2000; Scialabba and Hattam, 2001; Scialabba *et al*., 2003; IFOAM, 2004) see organic agriculture as an opportunity to (re-)introduce and/or maintain biological diversity into/in the production system and thus, as an important contribution to the conservation and sustainable use of biodiversity.

7 Conclusions and recommendations

1. Involving the organic agricultural sector directly and more actively in genebank work.
2. Genebanks should more actively assess the requirements and priorities of the organic agricultural breeders and farmers.
3. More targeted characterization and evaluation by genebanks should be undertaken to meet the genetic diversity expectations and needs of the organic agricultural sector.
4. Besides the distribution of germplasm material and supporting information to breeders it should be considered to also include organic farmers in the list of “clients”.
5. Organic agriculture can make a substantial contribution to the maintenance of genetic diversity on-farm (conservation through use), in particular for the so called neglected and underutilised species.
6. Organic agriculture could play a more prominent role in the “restoration” of old and forgotten crops and varieties as well as in the use of other neglected and underutilised species into the agricultural landscape.
7. Knowledge gathered and experiences made in project and field activities with the management of genetic resources and within-species genetic diversity in agricultural production systems in many tropical and sub-tropical developing countries provide very applicable approaches to organic farmers in temperate production zones.

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European perspectives of organic plant breeding and seed production in a genomics era

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Abstract

For further optimisation of organic agricultural systems, more focus is required on organically produced seeds and the development of better adapted varieties. Organic plant breeding and seed production need to comply with the concept of naturalness as applied in organic agriculture, which not only includes the non-chemical and agro-ecological approaches, but also the integrity of life approach. As organic environments are less controllable and are more variable, breeding should aim at improved yield stability and product quality by being adapted to organic soil fertility as well as sustainable weed, pest and disease management. Also the ability to produce economicacceptable seed yield avoiding seed-borne diseases should be included. On the short term, organic plant production can gain better yield stability by increasing within-crop diversity by the use of mixtures of conventionally bred varieties or crop populations. Because of expected genotype by environment interaction more research is needed to define the best selection environment for selecting organic varieties. To arrive at better adapted varieties for organic farming systems the role of practical participatory plant breeding may be crucial.

Although organic farming is clear on excluding the use of genetically modified organisms and their derivates, the use of molecular markers is still under debate. Questions arise with respect to their efficiency in selecting the most important organic traits, such as yield stability, and on the compounds and substances to produce and apply them. A major concern for a GM-free organic agriculture is an increasing contamination with genetically modified organisms in organic production and products, i.e., the problems related to co-existence of GM and non-GM agriculture. This paper discusses some important factors with regard to possible impact of co-existence on organic farming. Perspectives to a global scale of organic plant breeding and seed production are given from a European point of view.

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1 Introduction

Plant breeding for organic agriculture needs to meet the prerequisites of the sector. These are based on ecological and ethical principles. In several aspects, these prerequisites are in conflict with the direction modern plant breeding for conventional agriculture is developing. Organic management systems differ substantially from the conventional ones. This difference is largely due to refraining from high-levels and readily soluble fertilizers and from chemical pest, disease and weed management. Instead, much emphasis is put on soil fertility management and broad crop rotations. Organic farmers aim at resilience and buffering capacity in their agro-ecosystem by stimulating internal self-regulation through functional agro-biodiversity in and above the soil, instead of external regulation through chemical protectant (Mäder et al., 2002). Therefore, traits required for varieties in organic agriculture will differ from the ones for varieties in conventional systems (Lammerts van Bueren et al., 2002; Welsh et al., 2002). As the expression of a phenotype depends on the environment, varieties with the desirable traits for organic agriculture may not be found when the breeder selects under conventional management systems. Similarly, the farmer may not be able to identify the optimal varieties since an official variety testing (VCU-testing) under conventional conditions will not value the relevant traits and thus not reveal the desirable varieties (Osman and Lammerts van Bueren, 2003). Another problem arises when the organic principle of diversity is employed on crop, plant and genetic level. Modern plant breeding has aimed at pure lines and increasingly use of hybrids, resulting in a decrease of genetic diversity in conventional varieties. Also genetic diversity at the regional level is decreasing with few varieties grown over large areas. The rapid spread of GM crops in some countries (e.g. in Argentina) has contributed to this (Knudsen et al, 2006). In search for implementing more genetic diversity on different levels as a tool for improved yield stability under organic conditions, the possibilities of landraces and variety mixtures are explored. But such variety concepts do not fit easily into current official testing and certification systems (Welsh and Wolfe, 2002). And as worldwide plant breeding research is very much focused on exploring the potential of genomics and gene technology, there is alsothe concern that the modern conventional breeding and seed production techniques may not be appropriate for organic products since it does not reflect the concept of naturalness (Alföldi, 2001; Verhoog et al., 2003).

As the organic sector largely depends on varieties bred for the conventional agriculture, the organic sector needs to identify such above mentioned critical points in the conventional plant breeding process and seed production phase to guide further improvement towards better adapted varieties for organic farming systems. In this paper we will elaborate on the desired characteristics of organic plant breeding (OPB) and organic seed production (OSP) based on the concept of naturalness, and will discuss these critical points in relation to the conventional system. Therefore, we will at first discuss the required breeding aims in interaction with the organic environment and some aspects of breeding strategies, such as the role of genetic diversity in gaining better yield stability for organic varieties and the role of the organic environment in the breeding and variety testing process. Besides, the question whether and in which way OPB can benefit from the modern breeding strategies, e.g. by applying molecular markers in the selection process, will be discussed. Next to the critical points for organic plant breeding we will address the consequences of the organic principles for organic seed production. As the sector has not the means to rapidly develop appropriate varieties and seed, we will point out the strategies for a step by step transition from conventional to organic varieties. And as organic agriculture excludes the use of genetically modified organisms (or genetic modification, hereafter GM), also the question whether a GM-free organic agriculture, including GM-free breeding and seed production, has a future surrounded by GM agriculture, needs to be addressed. Although the authors mainly discuss European perspectives for OPB and OSP in a genomics era, also comments are made on relevant issues for developing and transition countries.

2 The framework of values

A clear framework of the ecological and ethical values and principles of organic agriculture should form the basis to further develop OPB and OSP. A analytical framework has been described by Verhoog et al. (2003) by means of the concept of naturalness as applied in organic agriculture. This concept of naturalness encompasses three approaches: a) the non-chemical approach, b) the agro-ecological approach, and c) the ethical approach in which the integrity of life is taken into account. In Lammerts van Bueren and Struik (2004) the consequences of naturalness for organic seed production and plant breeding have been discussed. Thenon-chemical approach requires the replacement of synthetic and chemical inputs in organic farming systems, including seed production, post-harvest seed treatments and during the breeding process. It also implies that the use of colchine is questioned. The agro-ecological approach focus on a broad rotation and a good soil fertility management, being the core of organic farming systems to keep the disease pressure at a low level and to enhance a high level of self-regulation in the organic agro-ecosystem. This approach leads to the need of producing seeds under organic farm conditions and to the question whether the breeding process for varieties better adapted to organic conditions should take place under organic conditions. The third component of naturalness, the concept of integrity of life, is expressed in the fact that organic farmers not only depart from the instrumental values of farm animals and crops, but also base their management decisions on their respect for intrinsic values being the autonomy, wholeness or completeness of living organisms, their species-specific characteristics and their being in balance with their species-specific environment. To be able to apply the integrity of life approach to assess the appropriateness of breeding techniques criteria at four levels are set: i) integrity of life, ii) plant-typic integrity, iii) genotypic integrity and iv) phenotypic integrity (Lammerts van Bueren et al., 2003b). The respect for integrity of life is one of the reasons why the organic sector rejects the use of genetic engineering and other DNA-techniques like protoplast fusion often used to obtain cytoplasmic male sterility, e.g. in cabbage hybrids.

Albeit only as a draft, OPB standards have been published since 2002 by IFOAM. According to the IFOAM draft standards for OPB, organic plant breeding should be conducted under organic conditions applying only those breeding techniques that allow crossing, pollination, fertilisation and seed formation on the whole plant itself. In 2005 IFOAM published standards for organic seed production (IFOAM, 2005).

3 Breeding aims in interaction with the organic environment

Although for many crops organic farmers profit from modern breeding efforts, concerns nevertheless remain whether modern varieties possess the right combinations of traits to ensure stable and acceptable yield and quality when grown under different organic growing conditions. Many modern varieties have been developed with the aim of combining high productivity and uniform product quality under high levels of chemical input conditions.

Refraining from chemical disease and pest management and applying a relatively low level of organic manure instead of a high level of readily soluble mineral fertilisers determines the organic environment to a large extent. And because organic farming systems cannot easily mask the variability in micro-environments with a ‘chemical umbrella’ against pest and diseases or a ‘nitrogen blanket’, the environments of organic farming systems are characterised by a large variation over years and between and within locations. In organic growing systems, biotic and abiotic stresses have to be controlled by growing appropriate varieties with good yield stability and by good, multilevel farm management practices supporting a high level of self-regulation within the organic farm ecosystem. For OPB, this implies special focus on breeding for varieties that are able to perform with a good yield level and good yield stability under organic farm management, as have been described by Lammerts van Bueren et al. (2002). The main aspects are:

- *Adaptation to organic soil fertility management*

Especially the dependence on the mineralisation dynamics of a low-input of slow-releasing organic stable or green manure makes the nutrient flow in different soils less controllable, and requires varieties adapted to such soil fertility management. Deep, intensive root architecture may contribute to a more efficient capturing of water and nutrients (Løes and Gahoonia, 2004). Experiments have also shown that varieties may differ in efficiency of nutrient uptake and use (Baresel et al., 2005). The ability to interact with beneficial soil micro-organisms can support this efficiency (Bosco et al., 2006).

- *Adaptation to organic weed management*

Rapid early growth can improve the weed competitiveness, as can good ground coverage - for instance through a prostate growth habit, high tillering capacity or through tall plants. Some crops, such as cereals and onions, can profit from selection for a good allelochemical ability to suppress weeds (Bertholdsson, 2005). Despite such characteristics mechanical weed control will still be needed and will affect the physical soil fertility. Crops should be selected as to be robust enough to allow and resist mechanical weed control without too much crop damage. Genetic variation for crop tolerance to post-emergence weed harrowing has been found to interact with yield and leaf area index (LAI) of spring barley in organically grown fields; taller and higher yielding cultivars with high LAI tended to be less tolerant than shorter and lower yielding cultivars with low LAI (Rasmussen et al., 2004).

- *Adaptation to organic pest and disease management*

Tolerance and resistance to pests and diseases may be monogenically or polygenically inherited and involve many different traits ranging from those based on specific recognition between host and pathogen to the ability of the plant to escape from severe loss by diseases through morphological or physiological traits. Examples of such traits are a long stem to enable the ear (cereal) or fruits (beans) to ripen above moist canopy, a wax layer against fungi (onion, cabbage), or trichomes against aphids (potato), a shorter crop growth period and/or early ripening to escape fungal infections such as late blight (potato).

- *Adaptation to organic seed production management*

The earlier mentioned breeding aims do not apply only to the crop production but also to organic seed production. Some pests and diseases are manifest during the seed production phase and cause unexpected problems compared to conventional seed production. Consequently, breeders will have to take into account the ability to produce an economic seed yield under organic conditions especially avoiding seed-borne diseases. Also seed quality in terms of fast and high germination rate and seedling vigour is important characteristics, because without chemical seed coatings seedlings may also be vulnerable under cold and wet conditions.

- *Adaptation to organic quality requirements*

Consumers of organic products expect good quality and taste. Therefore varieties need to be selected for a good taste and for instance for good baking quality under low input conditions (Kunz et al., 1995). Because organic farmers refrain from chemical sprouting inhibitors on onions and potatoes a high storage potential is essential.

4 Genetic diversity within the crop

As organic farmers have few tools to interfere during crop growth, an important strategy to improve yield stability is to enhance diversity at all levels and thus to facilitate an optimal use of natural regulation mechanisms, including biodiversity at the field level and genetic diversity at the crop level. Therefore, it is important to explore the role of genetic diversity in the variety concept for organic farming systems as also discussed in a recent workshop (Østergård and Fontaine, 2006). Breeding within the last 50 years has focused on developing genetically uniform crops/varieties for farmers to be able to produce a homogeneous product for the market. The principles of organic farming do not support this thinking. Therefore, especially for selfing crops like wheat and barley, where nearly all plants in a field are genetically identical, specific tools have to be applied to ensure the availability of genetically diverse crops. One suggestion has been to use older less intensively selected varieties or landraces where some variation is generated by mutations and rare outcrossing and maintained by a combination of natural selection and breeders/farmers selection (e.g. Horneburg, 2003, Murphy et al., 2005) More variation may be introduced by production of composite cross populations from a base population where many varieties are forced to outcross (Phillips and Wolfe, 2005). Finally, a more controlled way of generating variation is to combine a few selected varieties in a variety mixture which have been used at varying extent in wheat and barley for many years (Finckh et al., 2000). As an example, certified variety mixtures of spring barley have been grown in Denmark since 1979;

recently this also includes certified seed for organic production (Østergård and Jensen, 2005).

Growing variety mixtures has the potential of increasing grain yield more than 20 % compared to the average of the component varieties as well as of increasing stability in yield over environments (for a review see Smithson and Lenné, 1996). The importance of variety mixtures for reducing development of foliar diseases like cereal powdery mildews is well known (for a review see Mundt, 2002). However, variety mixtures have so far been studied mostly under conventional farming conditions and with focus on reducing disease severity by combining varieties with different disease resistance genes. Therefore, we do not have the final solution for how to combine varieties when also other biotic and abiotic factors are largely uncontrolled, i.e., we need more information on the ability of different varieties to complement and compensate for each other under the range of different environmental conditions as found in organic farming. Different conclusions as to yield stability and mixing effects has been observed in organic field trials of spring barley (Østergård et al, 2005) and winter wheat (Clarke et al, 2006). Also quality traits are important for organic production and an investigation of bread wheat concluded that the different bread qualities did not differ between mixtures and the average of the components (Osman 2006). Data from many published and unpublished trials for small grain cereals are being collected to summarise, by meta-analysis methods, associations between mixing effects, component varieties and environments aiming at clarifying principles for how to combine varieties in variety mixtures in the best way (Kiær et al, 2006).

A strategy for crop improvements based on mixtures has been suggested for subsistence agriculture (Smithson and Lenné, 1996). This strategy is based on selecting appropriate mixture components (disease and pest resistance, superior competitors) to enhance mixture yield and stability. In the long term perspective, this includes making backcrosses of sources of disease and pest resistance into local germplasm that have been evaluated for competitive ability.

5 Plant genetic resources

As mentioned above, there is a need to identify appropriate genetic resources among the older varieties or landraces either for direct use or as potential parental lines in breeding programmes for better adapted varieties (Hammer and Gladis, 2001; Lammerts van Bueren *et al.*, 2005). Evaluating and exploiting accessions from genebanks can be of use because required characteristics for organic, low-input farming might have disappeared by selection under modern, high input conditions, such as low-input tolerance and deep or intensive root architecture. Many non-profit organisations dealing with in-situ conservation of genetic resources maintain their populations under organic conditions (Negri et al., 2000).

6 Breeding and testing under organic growing conditions

To arrive at better adapted varieties for organic farming systems, an important question is the choice of selection environment for organic plant breeding programs, but little research has been done on this issue. In general, the issue of defining the optimum environment for selection during the breeding process has been much discussed by plant breeders (Hill et al., 1998), i.e. choosing an environment with optimal conditions for the crop or choosing the target environment (e.g. an organic environment or a stressed environment) for the crop, or even an alternation of these two. More than fifty years ago, theoretical considerations by Falconer (1952) established that direct selection, i.e. in the target environment, is almost always more efficient than indirect selection.

Experiments set up to analyse response to selection for yield in stressed environments are scarce; an example is selection for yield of barley under water stress (Ceccarelli et al. 1998). Selection experiments comparing selection results in conventional and organic systems have rarely been conducted. Some conventional breeding companies are interested in this question and a few experiments are under progress, such as for onions in the Netherlands (Tiemens-Hulscher et al., 2006) and for barley in Latvia (A. Kokare, pers. comm.). Some breeding companies look for a compromise and include selection under organic conditions in a later stage of the breeding process, e.g. F6, after selecting first under their 'regular' conventional conditions (Löschenberger and Lafferty, 2005).

The important factor in the discussion of selection in targeted environments is the interactions between genotype and environment (Fig 1).

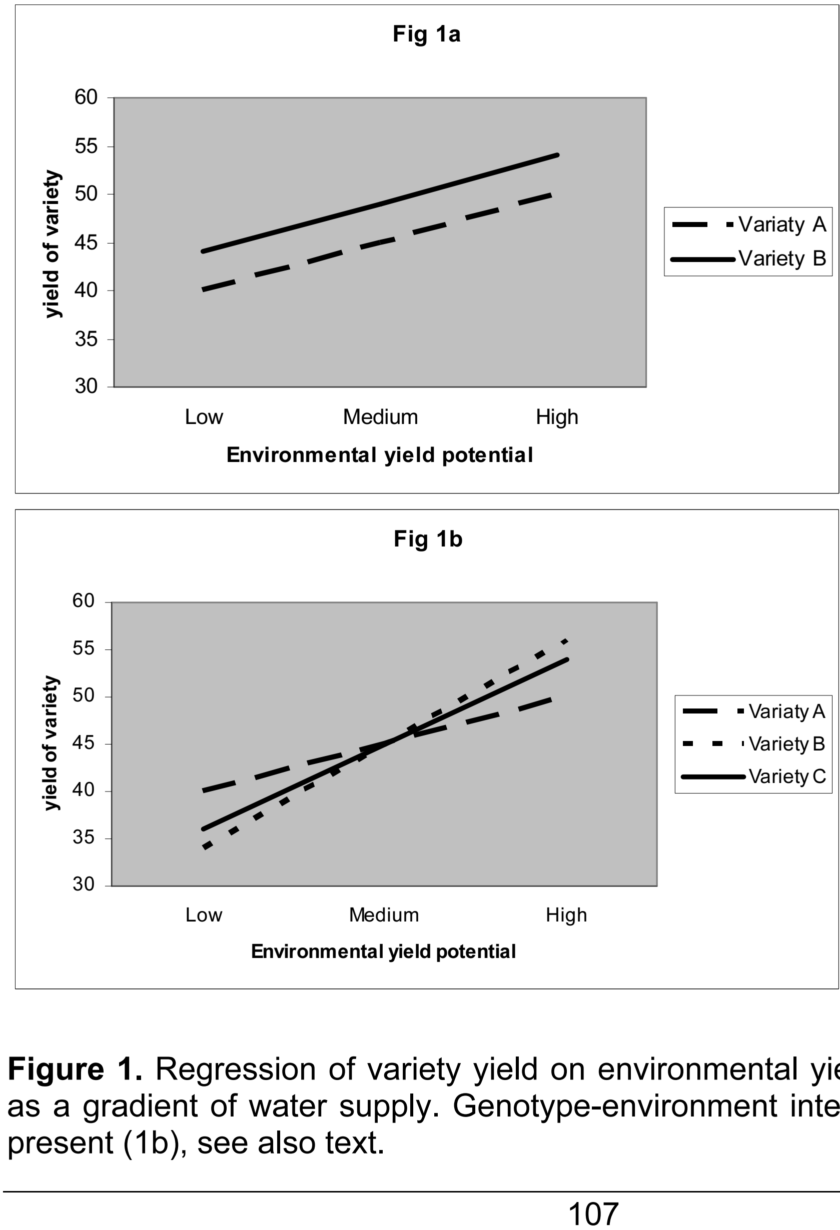

Figure 1. Regression of variety yield on environmental yield potential, e.g., given as a gradient of water supply. Genotype-environment interaction absent (1a) and present (1b), see also text.

When varieties respond equally to changes in the yield potential of environments (e.g. varying stress factors like drought or nutrient shortage), there is no genotype-environment interaction (Fig 1a). However, if varieties interact differently with the environment there will be crossover points where the ranking of the variety changes (Fig 1b). Depending on the range of environments considered in a specific breeding or testing situation, crossover points may not be recognised and one variety will always be evaluated to be the best, e.g. Variety B in medium to high yielding environments. Breeding during the last 40 years has to a large extent aimed at varieties which perform on average good over a large range of environments (Variety C) instead of targeting the varieties to different environments (negative versus positive use of genotype environment interactions (Ceccarelli, 1996)).

With respect to organic environments in industrialised countries, it remains unclear to date whether the differences in levels of input between conventional and organic growing systems are large enough to economically justify breeding and official variety testing in both environments, or rather just to include additional characteristics, of relevance only for organic farmers, into conventional breeding and tests. As demonstrated, genotype-environment interaction very much depends on the varieties and systems chosen (Fig 1). In several countries of Europe, research projects have been conducted to gain more insights into whether it is important to evaluate characteristics of varieties under organic conditions compared to the performance under conventional conditions. These data are being collected for a combined statistical analysis of potential differences between ranging of varieties in conventional and organic growing systems in a European Network on sustainable low-input cereal production: required varietal characteristics and crop diversity (SUSVAR, 2004). One example is a study of a large number of German variety trials under high input, low input and organic growing conditions. Here, substantial differences in ranking of the varieties were found (Baresel and Reents, 2006).

In a Danish study of genotype-environment interactions for grain yield involving conventional and organic farming systems including 72 spring barley varieties and 17 combinations of location, growing system and year, choice of variety was found to be as important a factor for grain yield as other factors in the management (Østergård et al., 2006). Within a group of ten organic environments, nearly 40% of the total variation in grain yields was explained by varieties or by their interaction with environment. Within a group of four conventional environments, the variation among varieties was similar to that in the former group but the variation in yield among environments was less. In both groups the genotype-environment interaction contributed with about 35% of the total variation among varieties. In another group of organic environments without application of manure, only the 24 best varieties were grown. For these extreme environments, the average variation among varieties was very little, and the variation in yield among environments was large. Furthermore, the genotype-environment variation contributed under these low-input conditions the most to the total variation among varieties (about 80 %). This supports the idea that genotype-environment interactions are most important in extreme environments, e.g. marginal conditions in developing countries.

7 The use of molecular markers in organic selection programmes

As pointed out earlier, the concept of naturalness will have consequences for the applicability of conventional breeding techniques and substances in certified OPB (Lammerts van Bueren and Struik, 2004). Although the standards for organic agriculture are clear on excluding GM for organic production, there is much discussion on the applicability of DNA-based molecular markers. Molecular markers are often suggested as a diagnostic tool in breeding programmes to supplement phenotypic trait selection methods in the field (e.g. Collard et al., 2005). However, their potential for organic agriculture has yet to be proven.

In the organic sector, the question about molecular markers concerns the production methods for molecular markers as well as the application of molecular markers as elucidated at a recent workshop (Lammerts van Bueren et al., 2005). With respect to the production methods of markers problems arise in cases where components may be applied that are not permitted according to the organic standards, such as the use of radioactive isotopes and (cancer-inducing) chemicals. Conflict with the principles also arises in the process of marker development when genes may be silenced by genetical modification to learn more about traits at the molecular level. Also the use of double haploid plants, often produced with the help of in-vitro techniques, brings problems. In conclusion, these techniques are very much the subject of debate within the organic sector with respect to the violation of plant integrity.

With respect to the possibility and usefulness of applying molecular markers in organic breeding programmes, the question is whether DNA markers can be developed for those traits that are desirable for organic varieties. This would concern for instance yield stability, broad disease resistance, nutrient uptake and use efficiency and weed competitiveness. These characteristics are quantitative - and thus complex and difficult to select for, as more genes on different chromosomes may be involved. Further, the QTL by environment interaction is expected to be larger under organic growing conditions. Therefore, in the short term, it is expected that molecular markers cannot be of value in the search for traits in practical organic agriculture breeding programmes (Lammerts van Bueren et al., 2005). This may be different in conventional agriculture where the environment can be controlled to a further extent than in organic agriculture and the effect of QTLs are expected to be more consistent.

A more obvious area for application within OPB could be in backcross programmes to include certain monogenetic disease resistances from wild relatives avoiding undesired linkage drag as this is done in conventional breeding. Such resistance genes may also be important in organic agriculture. However, in many cases organic agriculture is not primarily aiming at absolute resistance but at a broader disease tolerance combining morphological and physiological traits.

Next to operative use, molecular markers may be of importance in fundamental research aiming at understanding underlying mechanisms. It could be of interest to study ‘micro-evolution’ of composite crosses or variety mixtures (Fraj et al., 2003; Østergård and Backes, 2006) or to analyse breeding progress retrospectively in order to learn from the past.

8 Seed production

The IFOAM Basic Standards as well as many regulations on organic farming make the use of organic seed obligatory to organic farmers and growers. Organic seed is usually defined as seed which is derived from mother plants that have been grown under organic conditions for at least one generation for annual plants or in the case of perennials for two growing seasons. Derogation for the use of conventional seed will only be granted for those species of which the assortment of seed from organically propagated varieties is still not adequate or the quantities of seed not yet sufficiently available. Organic and non-organic seed used in organic growing can only be treated with substances not listed in the organic production rules.

In the European Union Regulation (EC) 1452/2003 obliges EU Member States to set up data bases in which the available organic seed in the respective territory shall be listed. Farmers and growers may only get permission by the inspection authority to use non-organic seed if no appropriate variety for their use is listed in the respective national data base. On the other hand, farmers and growers cannot be compelled to use organic seed that is not listed in the data base even if it is the very variety they request. Those data bases have been introduced as a tool to stimulate both the organic seed producers to produce organic seed and the farmers and growers to use the organically produced seed (Wilbois, 2005).

To date organic seed production faces more problems when compared to conventional (Lammerts van Bueren et al., 2003a). As a rule the degree of the difficulties depends on the respective crop and is usually more distinct in perennials (e.g. carrot, onion, sugar beet) than in annuals. The major difficulties in organic seed production are i) production costs, ii) seed health and vigour and in the future possibly iii) the seed impurities due to the presence of GMO (cf. see below). While in most annual arable crops (e.g. cereals) the costs for organic seed are not much higher compared to untreated non-organic seed the price difference due to higher productions costs can be considerably higher for certain organic vegetable seed (a multiple for certain crops), especially for hybrid varieties of biannual crops such as onion, carrots etc. This fact may negatively affect the market for organic seed of those crops (Van der Zeijden, 2004).

Since organic seed cannot be treated with chemical seed sanitation products seed borne diseases deserve special attention in the organic seed production. Therefore, seed tests for diseases and in inevitable cases also direct treatment measures, play an important role in organic seed production. For direct seed treatment only physical methods like hot water, hot air treatment, electron treatment etc. and allowed substances like natural compounds, plant extracts and micro-organism preparations (e.g. essential oils, Pseudomonas chloraphis, Bacillus subtilis) may be used for seed sanitation in organic farming (e.g. Groot et al., 2006, Jahn et al., 2006). While for some important seed borne diseases like for instance common bunt of wheat (*Tilletia caries* (DC) Tul.) treatments with hot water, hot air or with yellow mustard-powder are highly effective (Wilbois et al., 2005) there are still seed borne diseases which cannot be adequately treated (e.g. loose smut of wheat (*Ustilago tritici* (Pers.) Rostr.).

9 Strategies for transition from conventional to organic varieties

On a short-term basis, the organic sector still largely depends on conventional varieties and seeds. So the varieties available to organic farmers may be categorised in three groups: i) conventionally bred varieties which may be suitable for organic production, ii) conventionally bred varieties which have been developed specifically for low-input environments and iii) organically bred varieties. The development towards organically bred varieties suited for organic farming conditions will have to be taken in steps (Table 1).

Table 1. A time schedule for steps and results towards organic varieties and seed production (adapted after Lammerts van Bueren and Verhoog, 2006).

Time	Activity	Product
Short term	Defining desired traits per crop; organic variety trials; development of organic seed production and non-chemical seed treatments; no use of GM	Conventionally produced varieties and seeds, but post-harvest not chemically treated, next to organically produced seeds of conventionally bred varieties
Longer term	Development of organic VCU-testing protocols; conventional plant breeding programmes including low-input selection criteria	Varieties bred for low-input conditions and organically produced seeds
Long term	Organically certified breeding, maintenance and seed production programmes	Organically bred varieties and organically produced seeds

As a first step, defining organic crop-specific ideotypes (i.e. specific combinations of desirable traits for different organic growing conditions) and conducting variety trials under organic farming conditions may help to select the best varieties available in the pool of existing (conventional) varieties so as to be propagated organically. On a slightly longer-term basis, adaptation of protocols to test varieties on their value for cultivation and use (VCU) for organic farming conditions may enlarge the chances that new varieties will be released from conventional breeding programmes that match the requirements of low-input farming systems to a better extent. On the basis of experiences in several European countries, a handbook for adapting organic variety testing has been described for cereals (Donner and Osman, 2006). On a long-term basis, the organic sector will head for a true and maybe even certified OPB chain, including selection, maintenance and seed production of varieties under organic conditions.

Currently, only a small number of breeding programmes are specifically focused on organic production (for an overview see Legzdina and Skrabule, 2005). Some are conducted by (co-operations of) farmer-breeders and some by commercial breeding companies, or in combination with established and farmer-breeders.

Due to the fact that the organic sector still has limited acreage, many commercial breeding companies are reluctant to start breeding programmes specifically for this sector. Farmers are therefore looking for alternative options to enhance availability of a broad spectrum of varieties. Specifically in this respect we may learn from the decentralised and farmers' participatory approaches already applied in developing countries for areas with small and subsistence farmers neglected by the green revolution (e.g. Kudadjie et al., 2004, Zannou et al., 2004). Such approaches offer an opportunity to combine a farmer's knowledge, daily experience and developed intuition (farmer's eye) with knowledge, experience and developed breeder's eye of formal breeders (Ceccarelli, 2000; Desclaux et al., 2006). Morris and Bellon (2004) have described four breeding models in which farmers are to a smaller or larger extent involved in the different steps of a breeding process. In contrast to the traditional model adhered by the formal breeding sector of industrialised countries, a complete participatory breeding model involves farmers in all activities relating to the selection of source germplasm, to trait identification (pre-breeding), to cultivar development, and finally to varietal evaluation. In an efficient participatory breeding model, formal breeders involve farmers in the phase of selecting parent lines and in the end phase of evaluating potential varieties. In the participatory varietal selection model, farmers only deal with varietal evaluation at the end.

Benefits derived from new varieties bred by farmers require a legal system of common ownership that allows equitable access and benefits sharing. In many countries, examples may be found of networks including organic farmers and breeders that provide such a system (Henatsch, 2002; Rios Labrada et al., 2002; Ramos Garcia et al., 2004).

10 Current situation and legal framework regarding the use of GM in European agriculture

A major problem for the future development of organic agriculture and organic seed production is the co-existence with GM-agriculture, as the organic sector does not want contamination with GMOs in any product or process on the farm (cf. e.g. IFOAM 2005, Regulation (EEC) No 2092/91). The difficulties involved with the avoidance of GM contamination are due to i) that GM-plants disperse their genes in time and space through pollen flow by wind and insects as well as through seed dispersal), ii) impurities in seed lots and iii) contamination during sowing, harvesting, transportation, storage etc. In practice, co-existence becomes a highly complex issue under the prevailing conditions of a rather small-scale European farming structure (cf. Tolstrup et al., 2003, Devos et al. 2004; Van de Wiel and Lotz, 2006). Compared to countries such as the USA, Canada and Argentina, the use of GM in European farming is relatively marginal and in most countries present only on the level of field trails.

Nevertheless, more and more genetically modified varieties (mainly insect- and herbicide-resistant crops) become listed in the Common EU Catalogue of varieties, indicating that the cultivation of those GM varieties could accelerate in the near future. GM varieties need to be authorised in accordance with Directive 2001/18/EC (former: 90/220/EEC) before they are included in this Common Catalogue and potentially marketed in the EU. By doing so, this directive intends to provide a freedom of choice between GM and non-GM products, not only for consumers but also for the food and feed producers. ‘Co-existence’ refers to the farmer’s ability to choose between conventional, organic and GM production, in compliance with relevant legislation on labelling rules and purity standards. Subsequently, regulation (EC) No 1829/2003 on GM food and feed provided the legal basis for the national and regional implementation of rules on co-existence in the EU, and came into force in April 2004 (Anonymous, 2006a). Various countries have since then implemented measures to be taken to ensure co-existence. As an example, in Denmark based on this regulation, more elaborate education of potential GM farmers into measures of how to control spread of genes and seeds is enforced (Tolstrup et al., 2003).

Furthermore, regulation (EC) No 1829/2003 defines a threshold level for GM labelling for GM contamination in food of 0.9%. Above that threshold level products need to be labelled as consisting of, containing or produced by GM. The threshold level has been determined irrespective of the food production systems (organic or conventional). However, as yet, there is no threshold level in place in the EU for traces of GM in seeds. As a consequence, any seed lot containing a traceable proportion of GM seeds has to be labelled as containing GMOs in order to be authorized for cultivation and subsequent marketing in the EU. (Anonymous, 2003). The de-facto seed threshold for GM contamination in seed lots is, therefore, the detection level, which is at the moment 0.1 %. The organic sector advocates taking the current detection level as the basis to determine the legislative threshold level for GM impurities for either conventional or organic seed.

As a conclusion we could state that the whole co-existence legislation is still surrounded by many practical problems for the organic sector which still need to be solved (Anonymous 2005 and 2006b).

11 Organic farming and co-existence

The measures to be taken to ensure co-existence of GM and non GM farming - in order not to exceed the maximum level of GM contamination in food and feed – are by definition rather complex and more or less expensive depending on the respective crop, the relative share of GM plants in the region and specific farming situations. Therefore, for organic producers especially these measures are often perceived as economical threats for the following reasons:

- In general the market value of organic farming goods is higher than in conventional farming and thus the economic damage caused by contamination is usually greater.
- Since consumers of organic products expect organic food to be without any GM contamination, organic food processors demand agricultural commodities without any detectable GM-contamination in private contracts. Therefore, beyond the legal framework, in practice there often are de-facto threshold levels that are much lower, mostly at the detection level, for GM contamination of agricultural commodities. These levels have to be met by organic farmers.
- Organic farmers, unlike conventional farmers who may use herbicides, are unable to control volunteer plants from contaminated plants in the field (e.g. in oilseed rape) or volunteers which may originate from field-to-field transfer by machinery (e.g. combine, harvester).

These aspects only refer to the organic production of food and feed. Much more vulnerable activities in terms of GM contamination - like seed production including farm saved seed and plant breeding - are found in organic agriculture, too. Some organic farmers consider the repeated use of farm saved seed to be the only way to obtain varieties adapted to their site and farm-specific management. The impact of neighbouring GMOs might not be substantial in the case of pre-dominantly self-fertilizing species but could be considerable with regard to ‘vulnerable’ crop species with high rates of outcrossing, small seeds and long seed dormancy (e.g. oilseed rape). The accumulation over time may, therefore, lead to unmarketable products (Tolstrup et al., 2003).

These latter aspects of seed production and saving as well as breeding on farms contribute to the fear of organic farmers that for them difficulties - and hence costs – in the prevention of GM contamination may increase substantially in future agriculture with potentially high areas of GM plants. They also fear that this process may even render these highly vulnerable farming activities such as organic breeding and seed production next to impossible. This is a world wide problem.

12 Outlook

Summing up, what are the perspectives of organic plant breeding and seed production in a genomics era? Although organic agriculture is a growing sector, both in industrialised countries and in developing and transition countries, organic plant breeding and seed production is still conducted at a very small scale.

Plant breeding for the organic sector will need more time and substantially more money to be raised. However, even at the short term, organic plant production can take advantage of conventionally bred varieties by increasing within-crop diversity by the use of variety mixtures or crop populations. In non-industrialised countries with less seed regulation, the use of landraces may be supplemented by including such varieties into the landrace populations.

As the development of conventional agriculture moves towards a more sustainable way of farming, the conventional plant breeding industry will become more and more interested in developing varieties for lower-input such as varieties with a broader disease resistance and improved weed suppression. Such varieties need, obviously, be produced without genetical modification techniques if used for organic farming. Although policy makers tend to except that organic agriculture excludes the use of GM, they are nevertheless very eager to make the organic sector embrace DNA markers as a diagnostic tool in breeding programmes, and thus to promote genomics as a green tool. As the development and application of markers can be very costly and the benefits for the organic agriculture has not yet been proven, the organic sector is still critical when it comes to setting high priorities for these methods within the limited budgets for organic research.

To arrive at better adapted varieties for organic farming systems, not only science can play an important role, but the role of practical participatory plant breeding may be crucial. This is exclusively an area where the industrialised countries can learn from participatory approaches applied in developing countries.

As to organic seed production in Europe, the official EU Regulation has put more and more emphasis on becoming less dependent on conventional seeds.

Therefore, the conventional seed industry is (gradually) becoming interested in contributing to a larger availability of organically produced seed. Also in the US such regulations are coming into force, but harmonisation between the two parts of the worlds is needed (Sundstrom, 2004). For developing countries, such European regulations may cause problems for the development of certified organic agriculture because of a lack of harmonisation concerning private standards and official regulations (Hermoso, 2004). Many small farmers in developing countries use uncertified seeds bought on the local market or exchanged among farmers. The concern here is focused on the question when or to which extent such countries need to comply with such European or US regulation in order to be able to export their products to Europe or to the US. In all cases more research seems to be needed to support the optimisation of organic seed production and the development of effective seed treatments that comply with the organic standards.

Finally to the concerns for the future in relation to GM: For a variety of reasons, the impact of a possible GMO spread in the environment will affect organic farmers to a larger extent than conventional, non-GM farmers. Those include (i) the fact that often diverse organic practice of plant production (including continued farm saved seed, on-farm breeding etc.) is more vulnerable to GM contamination, since seed lots are not completely renewed by certified, i.e. non-contaminated, stock yearly; (ii)the risk of losing markets is greater for organic farmers since many consumers require not only the rejection of GM use by the organic sector but also the general avoidance of genetically modified material in the produce is seen as an important added value. Therefore, in the future, even with the help of suitable co-existence measures some (organic) farming activities - especially seed multiplication, continued seed saving and breeding related to ‘vulnerable species’ - could become feasible only in GM free areas or regions. For this reason the continued establishment of GM-free areas or regions merits special attention. However despite all signalled problems, the development of a GM-free plant breeding and seed production for improved varieties meeting the needs and values of organic agriculture is a challenging task for practice and science in the future.

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The need for site-specific adaptation of organic standards: The example of dryland salinity in Australia

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Abstract

Between 2000 and 2006, the proportion of organic farms and acreage lying outside Europe and the United States has expanded to about three forth of total organic farms and area. Organic standards in place often correspond closely to those applied in the traditional organic regions. For the example of dryland salinity in Australia, we investigate, how well the locally applied standards address this issue, and to what extent they reflect scientifically recommended strategies to combat the problem.

The key to controlling salinity in Australia is the reduction of groundwater recharge. The most promising strategies are forestry or agroforestry practices. We analysed six sets of organic standards (those of IFOAM, the EU, the USDA, JAS, BFA and NASAA) and investigated whether these institutions have implemented such strategies or made provisions for site-specific adaptations of organic standards.

Most of the organic standards do not adequately address the problem of dryland salinity. The Australian standards mention the issue and express the necessity to combat it. However, they do not explicitly mention the most promising strategies emerging from recent research to fight dryland salinity under Australian conditions.

We conclude that organic standards have to be adapted to “local” conditions by explicitly including means for prevention of local environmental hazards into the basic standards of certifying organizations. Furthermore, it is crucial to establish certifying agencies and recruit inspectors with fundamental knowledge about the local agricultural and environmental situations directly from tropical and subtropical countries. In accordance with the aim of the IFOAM this paper contributes to the “work in progress” of developing local organic standards for sustainable land use systems.

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Keywords

certification, organic agriculture, organic farming, salinisation, soil degradation, standards, Subtropics, Tropics

1 Introduction

Over the last few decades, many agricultural commodities from certified organic production have successfully been established on markets in several countries of the world. In Western and Central Europe, the United States and Japan, organic products have acquired substantial market shares and are on the brink of entering the mainstream. The growing demand for organic products provided economic incentives for many farmers, processors and retailers to acquire organic certification. Due to the temperate climate of most consuming countries, opportunities arose to offer organic products off-season by producing them in warmer climates, or to expand the range of products by adding crops that require tropical and subtropical growing conditions. The market situation of high demands and low established supplies provided large profit margins for growers based in warm climates and, in particular, for processors and retailers involved in the trade of products from such regions. Consequently, the organically certified area in the Tropics and Subtropics expanded rapidly.

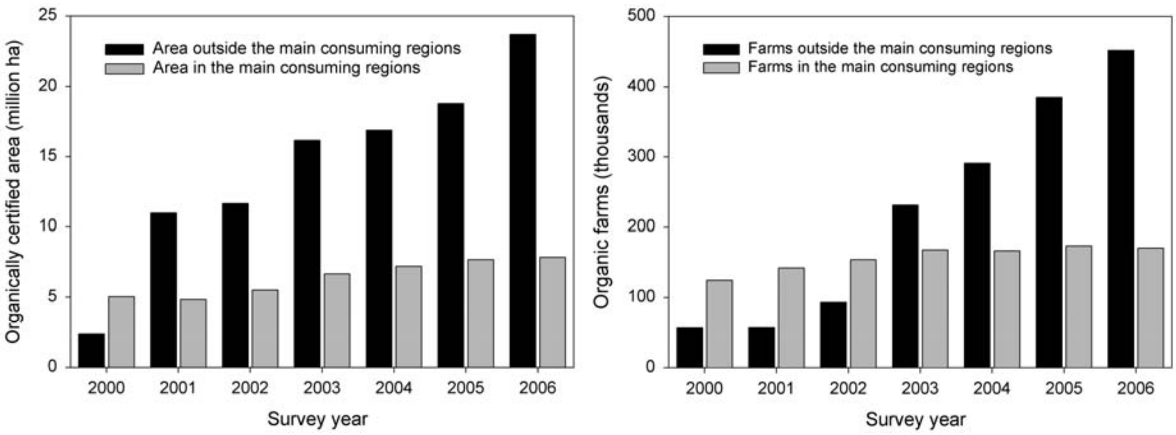

Figure 1. Development of organically certified area and number of farms in the main consuming regions (Europe, USA, Canada, Japan) and outside of those regions (Willer and Yussefi 2000, 2001, Yussefi 2003, 2004, 2005, 2006, Yussefi and Willer 2002).

The proportion of organically certified farm area lying in countries outside the traditionally consuming regions (Europe, the United States, Canada and Japan) expanded from 32% of the total certified area in 2000 to 75% in 2006 (Willer and Yussefi 2000, Yussefi 2006). At the same time, the proportion of organic farms lying outside the consuming regions rose from 31% in 2000 to 73% in 2006 (Willer and Yussefi 2000, Yussefi 2006). Over the six-year span, the number of organic growers in the non-consuming regions rose by 395,616 farms and the area expanded by 21.3 million ha. A look at the development of these figures over the last six years suggests that the proportion of organic area and farms lying in the non-consuming regions is likely to increase further in the coming years (Fig. 1).

Most of the new organic farms and hectares lie in the Tropics and Subtropics. In contrast to the temperate regions, organic agriculture in the Tropics and Subtropics is not driven by local demand, but rather by export opportunities. According to Sahota (2005), Europe, Canada and the US account for 97% of the global demand for organic products, with most of the rest originating from Japan. The trend towards the ‘development of regional markets’ identified by Sahota (2005) in the same report finds no support in these figures. It rather appears that growing demand in the temperate regions is causing a rapid expansion of organic production in the Tropics and Subtropics, even though no major markets exist in those regions.

For the organic movement, this development initiated a philosophy shift. Traditional organic farming can be seen as a reaction to the problems of intensive agricultural production in the countries that now have the highest consumption of organic products. These problems were obvious to many people living in those countries and were well documented by scientists as environmental hazards. Prominent among these problems are the eutrophication of ground and surface water, the detrimental effects of pesticide residues on natural ecosystems, the real or perceived health hazards of agrochemical residues or genetically engineered components in food, and the moral questions raised by industrial livestock enterprises. As a consequence, essential elements of organic production systems became the renouncement of most forms of mineral fertilizers and chemical pesticides and strong regulations on animal husbandry.

Organic standards, especially those of the traditional organic associations, reflect these ideals. They are the outcome of decades of discussion about the environmental and moral issues of agriculture in temperate regions, and they are thoroughly backed up by practical farming experience and scientific evidence. In addition to the production-oriented sections, however, the same standards also reflect some new, mostly consumer-driven priorities of the organic movement. Partially sparked by some recent ‘food-scares’ and the rejection of genetically engineered food, many consumers came to associate organic production with a healthy way of living. In recent consumer surveys, health and well-being rather than environmental awareness have been identified as the main reasons for buying organic products (Chryssohoidis and Krystallis 2005, Lockie et al. 2002).

When organic farming was introduced into the Tropics and Subtropics, the standards that were put in place were essentially the same as for production in temperate regions. It is unclear whether organic agriculture, as regulated by the current standards of organic production, has the capacity to solve specific agricultural problems in tropical and subtropical regions.

We therefore investigate this issue for the Australian problem of dryland salinity, an environmental hazard of an entirely different nature than those found in Europe and most parts of the United States. We start out by describing how climate conditions in the Tropics and Subtropics have shaped landscapes and influenced human-induced soil degradation. We then explore the roots and extent of the dryland salinity problem in Australia, present the most promising approaches to solve it, and finally search several sets of organic standards for implementations of these approaches.

2 Special soil conditions in the Tropics and Subtropics

The increasing world population exerts massive pressure on the often fragile ecosystems and land resources of the Tropics and Subtropics. This situation leads to resource overuse, such as excessive deforestation, overgrazing, overextraction of nutrients, and other types of agricultural mismanagement. These frequently manifest themselves in various forms of soil degradation, which are accelerated by the low ecosystem resiliency common in the Tropics and Subtropics. Responsible for this fragility are mainly the climatic conditions of past and present and the processes that dominated soil development.

Environmental conditions in the humid Tropics are characterized by high annual precipitation, intense rainfall events, and continuously high temperatures. These conditions have created highly weathered soils with low soil organic matter content and low availability of plant nutrients (e.g. phosphorus, iron). In rainforests, one of the typical biomes of this region, nutrients are stored in the above-ground biomass. Cycling of these nutrients is driven by high litter production throughout the year and high mineralisation in the topsoil, precluding the accumulation of soil organic matter. These processes are completely different to those in temperate climates, where nutrients are stored in the soil, and the accumulation of soil organic matter is a key component of sustainable land use systems.

About a third of the world's population live in drylands, with some of the semiarid and dry sub-humid areas having the highest population densities (e.g. India) in the world (WRI 2002). In Asia, 1.6 billion people or 42% of the population live in drylands. In Africa and South America, the shares are 41% (270 million) and 30% (87 million) of the population, respectively. According to their annual rainfall and evaporation rates, drylands can be categorized into hyperarid, arid, semiarid, and dry sub-humid areas, and make up 41% of the world's total land area (Ghassemi et al. 1995). Approximately 64% of the world's drylands occur in Africa (1959 Mha or 66% of the continental area) and Asia (1949 Mha or 46% of the continent). Roughly 16% of the global drylands are hyperarid deserts.

The seasonally dry Tropics and Subtropics (sub-humid to semiarid) are characterized by a pronounced change of wet and dry seasons with a net downward water movement in the soil profile.

In the arid Tropics, potential evaporation is higher than rainfall and net water movement is thus directed upwards. The water carries soluble compounds, such as carbonates, gypsum, or haloids to the topsoil or soil surface, where they accumulate and often cause salinity. This process occurs naturally in lower parts of arid areas and forms the landscape there. Human agricultural activities have resulted in additional salinity, which has become one of the most serious land use constraints in arid and semiarid regions (Qadir et al. 2000).

3 Soil degradation in the Tropics and Subtropics

Soil degradation in the Tropics and Subtropics is mostly caused by human activities such as agricultural misuse and soil mismanagement and cannot be attributed to the soil characteristics per se (Lal 2000). However, the environmental conditions in the Tropics and Subtropics and the age of the prevalent soils often aggravate negative impacts of human enterprise and accelerate anthropogenic soil degradation (Scherr 1999).

The most widespread type of soil degradation is erosion by water, which accounts for 55% of the global degraded area. It affects 440 Mha in Asia and is a particular threat to land use in the wet and semiarid Tropics (Bridges and Oldeman 1999, Ghassemi et al. 1995). The largest area affected by wind erosion, which contributes 27% worldwide, is situated in Africa and on the Arabian peninsula (332 Mha), followed by Asia with 222 Mha (Bridges and Oldeman 1999).

Another often irreversible constraint to land use is salinity (Scherr 1999), the increase of total dissolved salts in soil and water. Most of the world's saline land, approximately 955 Mha, is affected by primary salinity, a result of natural soil evolution (Ghassemi et al. 1995). Secondary salinity, however, is caused by human activities.

The most frequently mentioned type of anthropogenic salinity is caused by saline irrigation water. If the amount of applied water is insufficient to leach salts out of the soil profile, high evaporation rates may cause an upward water movement. The result is the accumulation of soluble salts in the topsoil and at the soil surface. This process is often accompanied by sodicity, an excess of monovalent ions (mostly sodium), which destroys soil structure.

Both salinity and sodicity impair plant growth and reduce agricultural yields. In severe cases, they can cause complete crop failure (Qadir et al. 2000). Plants on saline areas suffer from lack of water, because salts bind water in the soil and thus make it inaccessible to plants and microorganisms. Beside this osmotic stress situation, an excess of specific ions, such as sodium, is toxic to plants or results in an ion imbalance, which complicates the uptake of specific nutrients (Marschner 1995). Some crops have developed tolerance to salty conditions and can thus be used to a certain extent on soils affected by salinity.

Common sources of salts causing salinity are rainwater, groundwater, irrigation water, and salts in the soil profile, which are mobilized by rising water tables (Ghassemi et al. 1995). Salinity is particularly widespread in irrigated agriculture, affecting 20% of the global irrigated area of 227 Mha (Ghassemi et al. 1995). Most severely affected are Argentina (33.7% of the irrigated area), Egypt (33.0%), Iran (30.0%), and Pakistan (26.2%). The largest areas affected by irrigation salinity are found in India (7.0 Mha), China (6.7 Mha) and Pakistan (4.2 Mha) (Ghassemi et al. 1995).

Another type of secondary salinity, which has received much less scientific attention, is dryland salinity. It is a serious problem in rainfed agriculture in the warm to hot and dry zones, but it can also be found in the continental areas of North America, Central Asia, and China, where the climate is characterized by warm to hot summers and cold winters (Ghassemi et al. 1995). Dryland salinity is a threat to land and water resources in Australia, the United States, Canada, Argentina, India, Thailand, and other countries. Ghassemi et al. (1995) estimate the area affected by dryland salinity to be 31.2 Mha.

According to Bridges and Oldeman (1999), salinity accounts for 4% of global soil degradation covering 76 Mha (Table 1). However, adding up the regional values in their paper results in a much larger area than the total given. Ghassemi et al.

(1995) and Scherr (1999) also estimate that about 4% of global soil degradation are caused by salts. According to Lal (2000), however, the problem is much more alarming, with 316 Mha affected in tropical developing countries alone, occurring mainly on irrigated cropland. It seems like the extent of dryland salinity has often been underestimated in global salinity assessments. Extremely low estimates of saline land for North America conflict with information given by Ghassemi et al. (1995) for non-irrigated areas. Also for Australia (or Oceania, respectively), the assessments clearly do not take into account the severe threat posed by dryland salinity. The nature and extent of this form of soil degradation are described below.

Table 1. Distribution of land area affected by salinity in different regions of the world. Numbers for totals were taken from the references and not recalculated.

Region	**Land area affected by salinity (Mha)**			
	Ghassemi et al., 1995	Scherr, 1999	Bridges and Oldeman, 1999	Lal, 2000
Central America	2.3 †	2.0	2.0	2.0 #
South America	2.1	2.0	2.0	129.2
Africa	14.8	15.0	61.9 +	80.5
Total Asia	52.7	53.0	53.0	105.1
Southeast Asia	n.d.	n.d.	n.d.	*21.5*
South and West Asia	n.d.	n.d.	n.d.	*83.6*
Oceania/Australasia	0.9	1.0 ‡	1.0	n.d.
Europe	3.8	4.0	4.0	n.d.
North America	n.d.	negligible	n.d.	n.d.
Total	**76.6**	**77.0**	**76.0 [*123.9*]**	**316.8**

† including North America, ‡ only Australia, + including West Asia, [ ] the correct sum of the column is shown in brackets, # including Mexico, n.d. no data
Note: Data from Ghassemi et al. (1995) and Bridges and Oldeman (1999) are from tables titled with “human-induced soil degradation”.

4 Dryland salinity in Australia

To understand dryland salinity in Australia, it is necessary to first take a look at the history of the continent. The Australian land surface is among the oldest in the world. Extensive parts of the continent have been exposed to weathering and erosion since the Mid-Proterozoic, about a billion years ago (Gilkes et al. 2003). These geomorphologic processes, aided by long periods of glaciation (Eyles et al. 2006) have created a continent that is now essentially flat. The development of this landform led to changes in the continent’s drainage patterns. During most of Australia’s history, extensive river systems exported salts and eroded materials from the continent into the sea (de Broekert and Sandiford 2005). The loss of relief, however, gradually slowed this process, and the onset of drier conditions since the Eocene (Christophel and Greenwood 1989) caused almost all Australian rivers to dry out. Weathering of rocks nevertheless continued and salts were imported onto the land as oceanic aerosols (Hingston and Gailitis 1976). They were no longer washed into the sea, so most of these salts remained on the continent. The first areas to turn saline were the ancient riverbeds and other low-lying parts of the landscape. Higher areas were not affected immediately, but experienced a build-up of saline groundwater tables in the porous subsoil (Lee and Gilkes 2005).

In the dry interior of the continent, where precipitation was too low or too erratic to sustain much vegetation, the saline groundwater table eventually reached the surface leading to primary soil salinity and the formation of salt lakes. Where rainfall was higher, plants adapted to the harsh conditions. Native bush land and *Eucalyptus* forests developed dense rooting systems, deep tap roots and perennial water consumption patterns. These characteristics enabled the natural ecosystems to use up virtually all incoming water, thus reducing recharge and keeping the groundwater table below their rooting zones (Hatton and Nulsen 1999).

The fragile hydrological equilibrium was disrupted, when settlers started clearing the natural vegetation to make room for annual cereals (Eberbach 2003). Water consumption by the introduced crops was not high enough to preserve the hydrological balance. Especially during the early and late stages of crop growth, precipitation often exceeded evapotranspiration, leading to a net surplus of water that raises the saline water table. The imported crops also proved more susceptible to saline conditions, so that yields and biomass build-up declined, water consumption decreased and the advance of the ‘Silent Flood’ (Sexton 2003) in the underground was accelerated. If this process is not halted in time, the salty groundwater prevents crop growth altogether, and finally may lead to the formation of salt lakes on formerly productive farm land.

In addition to groundwater-induced salinity, stagnant saline water can also render the land unproductive, manifesting itself in a process called ’transient salinity’ (Rengasamy 2002). This situation is common due to the prevalence of subsoil constraints in many soils throughout Australia (Rengasamy et al. 2003). Such constraints can be duplex soils, which have a sandy topsoil with a clay layer underneath (Passioura 1992), sodic or compacted subsoil, or concretions of minerals, such as ferricretes, calcretes or silcretes (Gilkes et al. 2003). All these constraints can constitute water flow barriers creating shallow saline aquifers, even where the groundwater table is deep. Soil compaction or other disturbances caused by land cultivation often exacerbate this problem (Rengasamy 2002).

The mechanisms underlying dryland salinity were understood soon after the first clearings (Wood 1924), but only recently a study by the National Land and Water Resources Audit (2001) has put the problem on the national agenda. This report was the first to identify the extent of the saline area and to predict its further development (Table 2).

A recent survey-based assessment by the Australian Bureau of Statistics found that 20,000 farms already had salinity on their land, and of the 20,000 km^2 already affected, 8,000 km^2 had become unsuitable for agriculture (Trewin 2002).

To date, government studies have only documented the risk of groundwater-induced salinity. If transient salinity and other subsoil constraints are included into the assessment, up to 67% of the Australian agricultural area may be at risk of severe degradation (Rengasamy 2002).

Table 2. Australian agricultural, water, infrastructure and biodiversity assets at risk from shallow water tables or with a high salinity hazard in 2000, 2020 and 2050 (National Land and Water Resources Audit 2001).

Asset	**2000**	**2020**	**2050**
Agricultural land (ha)	4,650,000	6,371,000	13,660,000
Remnant and planted perennial vegetation (ha)	631,000	777,000	2,020,000
Length of streams and lake perimeter (km)	11,800	20,000	41,300
Rail (km)	1,600	2,060	5,100
Roads (km)	19,900	26,600	67,400
Towns (number)	68	125	219
Important wetlands (number)	80	81	130

Besides its effects on agricultural systems, dryland salinity is also a serious threat to natural ecosystems. The threat is particularly serious in Southwestern Australia, which is considered a biodiversity hot spot, where species diversity is high and particularly endangered (Myers et al. 2000). McKenzie et al. (2003) found that salinity had a devastating effect on the diversity of small ground-dwelling mammals in the Western Australian Wheatbelt, with only few species surviving on salt-affected areas. Negative effects on wetlands have been discussed by James et al. (2003), Nielsen et al. (2003) and Goss (2003), all of whom found salinity to be detrimental to species diversity and ecosystem health. On the whole, Halse et al. (2003) expect that the twenty-fold increase in salinity following clearing, which was observed in some Australian rivers, will lead to the disappearance of up to one-third of wetland and river invertebrate species, numerous plants and a large proportion of water birds.

5 Strategies against dryland salinity

As outlined before, environmental conditions in Australia are very specific and quite unlike those encountered in all regions, where agriculture has been practiced traditionally (Ewel 1999). Consequently, there are no proven solutions to the salinity problem and strategies from other continents cannot easily be transferred.

The only available example of sustainable land cover is the natural vegetation (Hatton and Nulsen 1999, Hatton et al. 2003). Many strategies against salinity thus include elements that mimic the functions of natural ecosystems (Main 1999). Characteristics of natural systems are dense rooting systems, deep tap-roots, and perennial water use, with some plants being most active during the summer (Lefroy and Stirzaker 1999, Pate and Bell 1999). Passioura (1999) identified tight nutrient cycling, adequate biodiversity, and the mosaic nature of ecosystems, which always adapt to the conditions at their specific site, as additional characteristics that ensure sustainability of natural systems. Mostly derived from these considerations, several management suggestions have been put forth.

Some of these suggested strategies, such as breeding for salt tolerant species or varieties (Colmer et al. 2005, McDonald et al. 2005) or controlling aquifer depth by using pumps or other engineering solutions (Clarke et al. 2002), have some potential to alleviate the symptoms of salinity. They do not seem promising, however, to address the causes of the salinity problem and will therefore not be discussed here.

5.1 Afforestation of strategic locations within a catchment

Some potential lies in the plantation of trees at strategic landscape positions, such as at the bottom of slopes or near natural drainage channels. In practice, however, choice of the right location is often difficult due to insufficient knowledge about local hydrology, geology or soil conditions. The most effective plantation sites for recharge control often lie on higher grounds with relatively deep groundwater table, where it is difficult to establish perennial tree stands. Finally, estimates of the proportion of a hydrological catchment that has to be revegetated to effectively fight salinity reach up to 70-80% (George et al. 1999). Under particularly complicated hydrological conditions, the prospects of controlling salinity by reforestation may be slim (Dawes et al. 2002). However, in many cases, tree plantations may contribute to reducing groundwater recharge and restore a balanced hydrology.

5.2 Agroforestry practices

Rather than strictly segregating forests and crop land, agroforestry practices strive to combine the two elements on the same area. Constituting a mixture of annual and perennial plants, many forms of agroforestry can be considered functional mimics of natural ecosystems.

In mechanized agriculture, the form of agroforestry normally preferred by farmers is alley cropping, where rows of trees alternate with rows of crops. Alley cropping has been shown to use significantly more soil water than conventional cropping and reduce recharge of underground aquifers (Lefroy and Stirzaker 1999). Even though some researchers found that the effect of the tree lines did not extend very far between the rows (Lefroy and Stirzaker 1999), this approach can probably be refined to yield good results. Water uptake by most trees tested so far was mostly confined to the immediate surroundings of the trees (Lefroy and Stirzaker 1999), suggesting that suitable alley cropping trees, which provide salinity protection and generate economic income, have not been identified yet.

Another approach to integrate woody elements into the agricultural landscape is the rotation of trees with agricultural land, also known as phase farming (Mueller et al. 1999, Ward 2006). Modelling exercises by Ward (2006) showed that phase farming, if implemented properly, has a large potential to alleviate salinity under low-rainfall conditions on non-sandy soils. For the wetter regions, and for very permeable soils, the success of phase farming seems more dubious.

The last form of agroforestry that might help fight salinity is that of dispersed woodland, where trees are established at more or less equal distances over the whole field with annual crops in between the trees. While such a system would be a close imitation of the natural environment, it is unlikely to be applicable on mechanized Australian farms.

So far, agroforestry appears to be the most promising approach to reduce groundwater recharge. It is critical, however, to identify trees with sufficient economic potential to justify their cultivation. Much potential has been identified in a group of native *Eucalyptus* species, known as Oil Mallees. Species of this group have high leaf oil contents (Bell et al. 2001) and are suitable for making solvents, ethanol and methanol as transportation fuel (Beresford et al. 2001b), high value edible oil and activated carbon (Bell et al. 2001). To date, the economics of Oil Mallee production remain doubtful. However, if oil prices continue to rise and recent innovations such as mobile oil extraction units are developed further, this endeavour could become profitable for Wheatbelt farmers (Bell et al. 2001).

5.3 Adaptation of conventional cultivation practices

Less extravagant practices can also contribute to alleviating salinity. Introducing herbaceous perennials, mainly lucerne (*Medicago sativa* L.) into crop rotations has been shown to decrease soil water contents more effectively than traditional fallows of spontaneous vegetation (e.g. Angus et al. 2001, Bee and Laslett 2002).

It is also beneficial to prolong the period of vegetation cover each season to intercept more of the precipitation that falls on the land. Especially at the beginning and at the end of the growing season, vegetation cover is insufficient to effectively regulate groundwater recharge. The seasonality of rainfall in the Australian farming areas, however, makes it difficult to maintain year-round vegetation.

Finally, it is possible to reduce recharge by storing additional water in the soil. This can be achieved by providing a favourable soil structure and enhance soil organic matter contents. Empirical studies on this strategy are not yet available, but it is likely that build-up of organic matter under Australian climatic conditions is very difficult because of high breakdown rates.

The effectiveness of all these measures, with the exception of lucerne cultivation, has not been proven. They are often impaired by climatic and geographical constraints and by adverse soil conditions, which, for example, preclude lucerne growth in many places. As stand-alone measures, such slight modifications of conventional growing practices are certainly not sufficient to control salinity.

6 References to salinity in organic production standards

6.1 IFOAM (International Federation of Organic Agriculture Movements)

Each chapter in the “IFOAM Norms for Organic Production and Processing – Basic Standards” (IFOAM 2002) is subdivided into a section containing general principles to be applied in organic agriculture, a section with recommendations for sustainable management, and finally a section with the actual basic standards, the minimum requirements that an organic producer or processor must meet.

In the *general principles* of the chapter on soil and water conservation, the standards state that “organic farming methods conserve […] soil, maintain water quality and use water efficiently and responsibly.”. The *recommendations* on this topic suggest that measures shall be taken “to prevent erosion, compaction, salin[is]ation, and other forms of soil degradation.” The basic standards require farmers to take “relevant measures […] to prevent or remedy soil and water salinisation.”

These standards have to be complied with by every farm or enterprise to be certified (IFOAM 2002). IFOAM's standards also encourage site-specific adaptations by requiring that organic standards ”take into account specific local conditions and provide more specific requirements” (IFOAM 2002). Furthermore, IFOAM explicitly states in its principles that any agricultural “operation is site-specific” and that “organic management must be adapted to local conditions, ecology, culture and scale.” Regardless of where it is practiced, organic agriculture “should attain ecological balance through the design of farming systems, establishment of habitats and maintenance of genetic and agricultural diversity” and “sustain and enhance the health of ecosystems” (IFOAM 2005).

6.2 European Union (EU)

EU Council Regulation No 2092/91 (EEC 2004) does not contain any references to salinity and other agricultural problems specific to the Tropics and Subtropics. Some researchers have argued that organic management counteracts salinity by promoting organic matter build-up and thus water holding capacity (Conacher and Conacher 1998). Assuming this stance, one might argue that the use of legumes or deep rooting plants in crop rotations and the incorporation of livestock manure (EEC 2004, Annex I, Section 2.1) may have some effects against dryland salinity. However, the more promising strategies discussed by scientists working on dryland salinity are of entirely different nature. Overall, the EU regulations show no awareness of the salinity problem or other soil constraints specific to the Tropics and Subtropics. the EU's import regulations even state that rules of production in third countries must be equivalent to those used in the EU. There are no provisions for site-specific adaptations.

6.3 United States Department of Agriculture (USDA)

The underlying philosophy of USDA's Organic Standards (Merrigan 2000) is essentially the same as conveyed in the EU regulations. Its regulatory framework focuses strongly on consumer protection and market organization, while displaying a lesser attention on sustainability of production. However, they contain some promising approaches.

In paragraph § 205.200 they state that production practices must “maintain or improve the natural resources of the operation, including soil and water quality.” However, detailed prescriptions on how this goal can be achieved are absent from the document.

Every producer or handler is required to submit an “organic production and handling system plan”, which has to be approved by the certification bodies (§205.201). In the plan, each farm has to ensure that all requirements of the standards are fulfilled. Strictly speaking, this would mean that sustainability is achieved, as required according to the introductory paragraph quoted above. The priority issues mentioned in this context, however, are rather the avoidance of product contamination and the restriction of substances used in production, and it seems unlikely that salinity control is enforced.

The document sections referring to soil fertility management (§205.203) and crop rotation practices (§205.205) run along the same lines as those in the EU's standards. Neither section displays a particular awareness of salinity.

We see a lot of potential in the specifications on State Organic Programs laid out in §§205.620 through 205.622. These programs should contain region-specific adaptations of the basic standards, because "environmental conditions or the necessity of specific production or handling practices particular to the State or region of the United States" may make "more restrictive requirements" necessary. Such adaptation is not required, but the standards emphasize it as a possibility. However, the regulation only refers to states or regions of the United States. It seems doubtful whether regions in different countries can also set up such programs. Surprisingly, the import of organic goods and the compliance with organic regulations is not treated in detail in the standards.

6.4 Japanese Agricultural Standards (JAS) for Organic Agricultural Products

Salinity is not mentioned in the very brief Japanese Agricultural Standards for Organic Agricultural Products (JAS 2000). Following the IFOAM guidelines, they state that agricultural products should be generated by "adopting such cultivation management method as reducing the load derived from the agricultural production on the environment as much as possible." (JAS 2000). Furthermore, under the topic "manuring practice in fields, etc.", the standards require that the "productivity of the farmland shall be preserved". These comments are very vague and cannot be regarded as precise guidelines to reduce soil degradation such as salinity or erosion.

6.5 BFA (Biological Farmers of Australia)

In the Standards of the Biological Farmers of Australia (BFA 2006), salinity is mentioned several times. The "Organic Farming Plan" that needs to be set up prior to certification must contain a "Record Keeping system including monitoring practices (e.g. for soil fertility, salinity, etc.)" (Section 3.1.7). The Organic Management Plan (OMP) required by the BFA is to be accompanied by a map identifying "all relevant environmental aspects" on the farm (Section 3.4.1), and outline strategies for soil and fertility management.

The only section in the regulations that concretely deals with salinity (section 4.1.11) states that "Soil salinity, acidity and sodicity levels, where relevant, shall be actively managed so as to prevent long term soil degradation. Management priority shall be such as to include reparation and regeneration of lands so affected. Details of plans and actions shall be outlined in the OMP where such issues are noted as of concern." Details as to how this can be achieved are not given and overall the issue seems of low priority.

There are, however, some additional guidelines that may help control salinity. They restrict the clearing of native vegetation and demand that 5% of any farm bigger than 4 ha be set aside for biodiversity conservation (Section 4.7). Also, the "enhancement of water holding capacity of the soil via progressive humus build up" (Section 4.4) may help reduce groundwater recharge.

6.6 NASAA (National Association for Sustainable Agriculture Australia)

The organic regulations of NASAA, the National Association for Sustainable Agriculture, Australia (NASAA 2004), clearly show that they originate from a region affected by dryland salinity. The claimed objective of the standards is to “promote wise use of land, water and vegetation” (Section 1.4). To achieve this goal, NASAA gives much better guidance for sustainable production than the other regulatory texts by making recommendations and prescriptions on three levels, following the structure of general principles, recommendations and requirements used by IFOAM. The third part is the only truly binding section of the regulations, but farmers can go beyond these by following the recommendations as well. They might also feel a certain obligation to do so, as these recommendations are directed towards more sustainable agriculture.

As in the standards of USDA and BFA, a central element of the regulations is the Organic Management Plan (Section 2.4), which requires a thorough documentation of several site-specific constraints and the presentation of management strategies to alleviate these constraints. Salinity is not mentioned here explicitly, but with soil erosion, biodiversity and water management several points have been included that may not be addressed sufficiently by other sets of standards. However, the inclusion of salinity in the Organic Management Plan is demanded in a later section, which deals with landscape and environment issues (Section 3.5). The recommendations in this paragraph include “watertable management in relation to dryland salinity”. This section also requires 5% of the farm area (on farms bigger than 4 ha) to be set aside for conservation purposes, which might preserve some natural vegetation, which is generally more effective in lowering watertables than agricultural crops. Furthermore, the rules require that farmers “must identify risks of environmental degradation (such as […] salinity […]) and signal remedial actions to be taken.” Clearing of native vegetation is prohibited (except on special application) and clearing during the last 5 years prior to conversion to organic may preclude certification. More than any of the other standards, the NASAA guidelines explicitly accept and encourage the “role of science in establishing ecosystem principles”. As in the other standards, soil management for organic matter build-up is emphasized (Section 3.6), but not for salinity prevention purposes.

The recommendations on water management (Section 3.9) contain some very valuable approaches. The site-specific management requirements of local climate and geography are clearly recognized, as well as the necessity to address salinity on a catchment and community scale. While the standards do not take up the requirement of a watershed-scale approach, they do mention that measures of groundwater recharge and discharge control must be implemented, if salinity is present.

7 Organic standards do not adequately address the problem of dryland salinity in Australia

Most of the organic standards analysed fail to recognize salinity as a problem worth addressing specifically. The regulations of the European Union, the United States Department of Agriculture and the Japanese Agricultural Standards for Organic Agricultural Products do not mention salinity at all, nor do they require production methods that are likely to alleviate or prevent salinity. The reason for this omission is clearly that salinity is not a big problem in the regions, where the standards were developed, or, in the case of the United States, that salinity has not been identified as a priority sustainability concern.

In Australia, however, secondary and in particular dryland salinity is a substantial hazard to food production throughout the country. It is therefore surprising, how little emphasis the regional organic standards place on this issue. The BFA standards, except for an occasional remark, mostly ignore salinity, and, along the lines of the aforementioned sets of regulations, focus more on food safety concerns than on the solution of soil degradation problems. According to an essay by BFA's Chief Executive Officer, delivered to the Fertilizer Industry Federation of Australia, the biggest challenges to organic farming in Australia are the development of new organically acceptable fertilizers and the prevention of sanitary hazards arising from organic smallholder farms (Monk 2001). In contrast to that, NASAA regulations are clearly more targeted towards preventing salinity. In addition to the mandatory standards, they give recommendations, how salinity can be prevented. They also require the assessment of site-specific hazards to sustainability, and the implementation of remedial action. In this respect, NASAA's standards display a greater awareness of the salinity problem and seem promising for alleviating the problem.

None of the analysed standards requires the adoption of any of the unconventional salinity control methods that are emerging from recent research, such as phase farming, Oil Mallee plantations, and other agroforestry practices. While NASAA explicitly accepts and encourages contributions from science to overcome sustainability issues, there is no indication that the other organizations are on the lookout for innovative strategies.

Does the failure to convincingly tackle the salinity problem constitute a failure of the organic concept? Looking closely at the IFOAM standards suggests that it does not. The regulative part of the IFOAM standards only constitutes the minimum standards that an operation must meet to be certified organic. The regulations are meant to be applicable on a global scale, and thus cannot be very site-specific. However, IFOAM also requires that national or regional standards be “adapted to local conditions, ecology, culture and scale” and “take into account specific local conditions and provide more specific requirements” (IFOAM 2002). The idea of globally applicable binding production standards, epitomized by the EU, USDA and JAS regulations, goes against this requirement, and even the Australian standards, in particular those of the BFA, do not seem appropriately adapted to local conditions.

8 Organic standards should be adapted to be suitable for tropical and subtropical conditions

In general, the principles of organic agriculture have a large potential to contribute to preventing soil and environmental degradation in the Tropics and Subtropics and to help with other critical issues of modern farming practices. It is undeniable that, throughout the Tropics and Subtropics, agriculture is often not sustainable, and that additional efforts should be undertaken to protect land resources. These efforts, however, inevitably cost money. It is pure economic necessity that often requires farmers to apply unsustainable practices for the benefit of surviving in the global marketplace. The idea behind organic farming is that extra efforts have to be rewarded by a price premium. There is no reason why this should not work as a means to slow soil degradation in the Tropics and Subtropics, and also for the Australian problem of dryland salinity, such a strategy seems like a viable option. It can, however, only be convincing if there is a label that assures the consumer that their environmental concerns are being met. Currently, with respect to dryland salinity, this is not the case for organic farming. The salinity crisis has clearly been noticed by many Australians, and there is a willingness to pay more to help resolve it.

The rise of traditional organic farming in the temperate zone was favoured by the failure of politicians to tackle the agricultural problems with resolution, so that sustainably-minded people turned to organic products in an attempt to support sustainable agricultural production in spite of government inaction. The scenario is the same for salinity in Australia, where politicians have a century-long history of ignoring warning calls (Beresford et al. 2001a). Instead of starting to address the salinity problem, they kept expanding the farming area and initiated clearing of more and more of the native bushlands. While by now, national and regional governments have recognized that there is a problem, their dealing with dryland salinity is more than unsatisfactory (Beresford et al. 2001b). For another environmental imperative, the prevention of global climate change, McDonald (2005) described the position of the Australian national government as an 'ultimate rejection of [central ethical principles]'. As more and more Australians come to interpret the political situation this way, the potential rises for non-governmental ways of solving environmental problems. Organic agriculture has traditionally fulfilled that function in other parts of the world, and we assume that it can do the same in Australia.

In its principles the IFOAM states that "organic agriculture is a living and dynamic system that responds to internal and external demands and conditions" (IFOAM 2005). This should hold true especially for the organic production standards with respect to the local environmental conditions. The IFOAM provides a good frame to incorporate farming practices that take the specific ecological conditions into account into the organic standards. However, this process needs thorough assessment of the limitations and opportunities of organic production methods under local conditions, by the organic community itself, as well as by independent researchers.

Besides dryland salinity in Australia, the organic movement must also address other types of soil degradation in the Tropics and Subtropics. Doing this would be an appropriate response to the often-expressed call for agricultural intensification to "feed the world" (Lal 2000). It is important to develop guidelines for a sufficiently intensive agriculture that provides food and fibre without degrading agricultural land or depleting other nonrenewable resources. Without such guidelines, the impacts of agricultural intensification are likely to ultimately cause productivity declines that might pose an insurmountable problem for the growing world population. Organic farming and other low-input agricultural systems are environmentally less harmful and cause less soil degradation, but are suspected to provide low crop yields resulting in low income, poverty, malnutrition and hunger (Lal 2000). The challenge for organic farming in the Tropics and Subtropics, as everywhere else, is thus to provide production guidelines that ensure sustainable resource management as well as economic survival of people involved in agriculture. In many situations, such guidelines have to include special provisions for local environmental or economic conditions.

Some of the means characteristically used in temperate organic farming systems, such as crop rotations, the use of legumes or the application of organic materials (e.g. compost, crop residues) are also valuable tools for maintaining soil quality in the Tropics and Subtropics (Subbian et al. 2000). On acidic tropical soils, for example, the application of organic residues can be effective in alleviating production constraints, such as reduced P availability due to P fixation and Al toxicity, and thereby enhance the effects of lime and fertilizers (Haynes and Mokolobate 2001). The traditional organic tools, however, may often not be sufficient to overcome specific production constraints in the Tropics and Subtropics, such as soil erosion and salinity. To control soil erosion, many 'conventional' farmers effectively apply no-till agriculture, which relies on pesticide application for weed control. The applicability of no-till farming in organic agriculture is very limited, and the organic community needs to show that it also has tools to overcome the erosion hazard. Innovative farming practices, such as phase farming, alley cropping or other forms of agroforestry, are useful for preventing soil erosion and should therefore be common practices in local organic certification standards. In terms of erosion control, these strategies measure up to conventional best management practices. Additionally, for controlling dryland salinity, these 'outside the box' strategies are superior to any techniques applied on a large scale in conventional agriculture. Including these strategies into its repertoire of farming tools would enhance the credibility of organic agriculture as a means to overcome the specific constraints of agricultural systems in the Tropics and Subtropics.

One of the purposes of organic standards is to ensure sustainability of production. If, however, sustainable production requires additional techniques that are not required by the standards, organic farming cannot claim to be sustainable. In organic and conventional farming alike, sustainability of production would depend on additional efforts, whose implementation would create an economic disadvantage for those who apply them. The only way to avoid penalizing those farmers who make important additional efforts is to have these strategies incorporated into local organic standards. Doing this will ensure that organic agriculture is truly more sustainable than conventional agriculture, while additionally ensuring an even playing field for all organic farmers. The price premium obtained from the sale of certified products would then truly be used to finance locally relevant strategies for sustainability rather than rewarding practices that are not necessarily more sustainable under local conditions than conventional practices.

Many developing countries do not have organic certifiers and thus rely on certification of organic enterprises by "fly-in" inspectors and certifiers (Parrott and van Elzakker 2003). This is truly one reason why organic standards are often not adapted to local conditions. Certifiers from the temperate regions are simply often not aware of the specific local problems in the Tropics and Subtropics (Parrott and van Elzakker 2003). It should therefore be a future aim to establish certification agencies in developing countries and implement the necessary education of local inspectors. For that, certifiers in the consuming areas have to provide additional education to those inspectors responsible for certification in the Tropics and Subtropics to raise their awareness of the specific local conditions. In order to achieve sustainability of production, it would also be desirable to change the process, from which organic standards arise. Currently, the basis for new organic regulations are always the established standards of other regions. Even if local requirements are added on top of these, the core of the rules will come from elsewhere, and the standards will be most effective for solving the problems occurring there. A better way to achieve sustainability of production in a certain region would be to undertake a thorough assessment of local sustainability constraints. From the results of this assessment, a team of scientists, land managers and members of the organic community should then develop farming strategies that preserve agricultural resources as much as possible. These expert recommendations and the traditional regulations of organic production should then be merged into a set of standards that satisfies the requirements of the organic movement. The result of this merging process will likely be a compromise. Whether this compromise is acceptable to the organic community will have to be decided on a case by case basis.

To us it seems that by changing its standard development process, the organic movement would gain credibility among land managers and scientists concerned with the preservation of farming resources in the Tropics and Subtropics. A change of proceedings as described above would be an appropriate response to the recent expansion of the organic world.

A general revision of organic standards as described above would also create an opportunity to address other critical issues of modern agricultural production in tropical and subtropical countries. Among these, equitable treatment and payment of all people involved in the production and trade of organic products is of primary importance. Additionally, the imperative to reduce the emissions of carbon dioxide and other greenhouse gases during production and transport could be included in new modernized standards. Society's willingness to pay for social justice and climate protection already manifests itself in the existence of the 'Fair Trade' label and in the trend among many people to 'buy local'. The organic movement should take on the challenges posed by region-specific production constraints, widespread exploitation of the agricultural labour force and climate change, and implement ways to counteract these problems in their standards. If it does so convincingly, organic farming may regain, and in the long run preserve, its status as a progressive and problem-oriented alternative to conventional agriculture.

9 Conclusions

The recent expansion of organic production in the Tropics and Subtropics, with the specific agricultural constraints of these regions, has not been adequately reacted to by the organic community. Organic standards applied there address the problems of agriculture in the temperate regions, so that they are insufficient to ensure sustainability of production, not taking the specific local conditions in the Tropics and Subtropics into account.

In particular, the Australian problem of dryland salinity is almost completely ignored by organic standards. The most promising strategies to fight dryland salinity involve forestry or agroforestry practices. These are not mentioned in the organic standards of all investigated agencies. IFOAM regulations call for site-specific adaptations, but this objective has often been neglected in local organic standards. It is entirely absent in the globally applied standards of the USDA, EU and JAS.

For organic agriculture to regain its credibility as a sustainable farming system, it is important to first identify the challenges to sustainability in a certain region.

Organic standards have to be developed around these challenges and the solutions provided by science and practical experience. To implement the necessary practices into the organic standards, certification agencies have to be established in the countries and inspectors have to be recruited locally. They must be educated so that the products are both produced in a locally sustainable manner and meeting the requirements of the organic movement.

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Organic agriculture in Africa: A critical review from a multidisciplinary perspective

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Abstract

Organic agriculture seems to be a profitable enterprise for small scale farmers in developing countries, also in Africa, to enter high value markets in the Northern hemisphere and overcome the crises of declining terms of trade on global agricultural produce markets. It is also seen as a way to overcome food security problems, induced by low yields and declining productivity of African smallholder agriculture.

This paper discusses the present situation on European organic markets and their potential for small scale farmers in Africa, finding that although markets in the North are still growing, they might be limited in the long run. Barriers to entry are many, including the lack of affordable certification bodies in Africa, poor infrastructure and experience in organic production and marketing, as well as regulation in European markets, and increasing risks and competition associated with the process of market saturation.

Organic agriculture has not yet proven to solve the problems of food security and declining terms of trade in Africa. It is also clear that there is a lot of inequity in the organic chains, and that so far only the relatively large scale farmers in Africa, as well as middlemen and traders along the chain, profit from commercial organic agriculture, similar to findings from conventional commercial agriculture.

Organic agriculture is being researched by international agricultural research organizations, and it is found to be less yielding and more risky than integrated approaches that combine organic and synthetic inputs. This research has to be still extended, and research gaps, especially in terms of costs and benefits, have to be closed to get a final picture on how to integrate and optimise the various approaches.

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Keywords

food security, integrated agriculture, niche market, Sub-Saharan Africa, sustainable agricultural production, terms of trade

1 Introduction

1.1 Aim of the study

Organic products are doubtlessly occupying a rapidly growing niche on the Northern hemisphere's food markets. As organic food products are earning high price premiums, they have attracted the attention of many stakeholders involved in developing countries' agriculture, as there seems to be a niche for developing countries' producers to share these price premiums and to have a market opportunity that outperforms the presently declining world market options for conventional food products.

The above statements hold especially for African smallholder farmers. Many see a niche for organic production in Africa, where input use is still low if not totally lacking, and where farmers are struggling to gain comparative advantage on highly competitive regional and global markets. Scialabba (2000) states that apart from the quest for niche markets, other concerns determine the choice to convert to organic farming. These include natural resource conservation, the need to find alternatives to low access to synthetic agricultural inputs, food self-sufficiency and the need to achieve wider and sustainable rural and social development through its potential to generate employment. This argument goes beyond the "niche market argument" and it implies that organic farming can contribute to overcoming Africa's agricultural problems, making a virtue out of the problem of lacking inputs.

However, there are many open questions as to whether organic agriculture as per its European and North American definition is feasible for African farmers in their ecological, social and economic environment, whether the potential benefits from niche markets can compensate the potential risks, and whether organic agriculture contributes to growth and equity of livelihoods in African countries and improved food security, in other words, whether organic agriculture is a concept that can be used to reach the goals of increased and sustainable agricultural production in Africa.

Questions related to the above are those on the equity of the distribution of profits along the organic food commodity chain, and last but not least, to what degree the present growth of the organic food market in developed countries will sustain and hence amortize the high investments in organic agricultural production in the long run.

This contribution tries to answer the above questions from an African perspective. The next section will discuss definitions of organic agriculture, and the implications of these definitions for the analysis of African organic vs. conventional agriculture. The third chapter gives an overview on the global organic food markets with a focus on European markets, including a brief analysis of their structure and the regulations that may affect trade and trade margins for developing countries. The subsequent section attempts a critical discussion of organic agriculture in Africa, its opportunities, challenges and risks. The last chapter concludes the contribution and gives recommendations to policy makers and researchers to efficiently address the issue of organic farming in Africa.

1.2 Definitions and perceptions of organic agriculture

Ideas on organic agriculture reach back to the first half of the twentieth century, with the concept of biodynamic farming being defined as a "sustainable, ecologically stable, self-contained unit, biologically complete and balanced—a dynamic living organic whole". This wide definition allows for an indefinite number of organic farming systems, but lacks precision (Goldberger 2005). The most widely used definition of organic agriculture today has been set up by the International Federation of Organic Agriculture Movements (IFOAM), which states (Goldberger, op.cit.):

“Organic agriculture is an agricultural production system that promotes environmentally, socially and economically sound production of food and fibres, and excludes the use of synthetically compounded fertilizers, pesticides, growth regulators, livestock feed, additives and genetically modified organisms. Utilizing both traditional and scientific knowledge, organic agricultural systems rely on practices that promote and enhance biodiversity, biological cycles and soil biological activity. It is based on minimal use of off-farm inputs and on management practices that restore, maintain or enhance ecological harmony. The purpose of organic agriculture is to optimise the health and productivity of interdependent communities of soil life, plants, animals, and people.”

Parrot and van Elzakker (2003) identified four different organic agricultural categories in Africa, according to their dependency on formal development aid and institutions:

1. Commercialised, certified organic agriculture without any significant development funding. This is generally practiced on large-scale farms and oriented towards organic markets in industrialized countries.

2. Export oriented certified organic agriculture, supported by development funding, and aimed at improving incomes of small farmers.

3. Poverty reducing and environment conservation oriented agriculture based on organic principles, assisted by development agencies. This system addresses soil degradation and water scarcity as well as food security, and usually supports local initiatives.

4. Organic agriculture initiatives developed by farming communities and local organizations without foreign assistance, as a means of addressing pressing social, economic and environmental problems.

Parrot and van Elzacker (op. cit.) also criticize the approaches in particular to non-certified and informal organic agriculture in the African context as merely being low-input, or non-chemical input based agriculture, often not being based on systematic approaches, and ready to be called a “failing form of organic farming”. Further, Parrot and van Elzakker (op.cit.) criticise the missing link between organic farming in practice and agricultural research, accusing researchers, in particular agronomists and agricultural economists, of simply optimising single crop production functions. However, a look into the vast amount of available literature on integrated farming systems, and cropping systems agronomics and economics research, in particular in West Africa but also more recently in East Africa, easily proves this wrong. In fact there is a lot of information available on the performance of agricultural systems under different traditional, conventional, integrated and organic approaches (see Schlauderer 1997, Buerkert et al. 1998, Bernard et al. 2000, Abele 2001, Forum for Organic Resource Management and Agricultural Technologies 2005) At the same time, Parrot and van Elzakker (op.cit.), admit the failure of the organic movement to provide documented and peer reviewed evidence of the achievements of organic agriculture in enhancing farm productivity, food security and the self regenerative capacity of farm ecosystems in Africa, while claiming that in fact organic agriculture by the above definition – or at least a kind of “de facto organic agriculture” – can increase food security and is therefore not only a viable way to commercialise and generate income for the export sector but also a way to overcome domestic food shortages.

Table 1. Definitions of organic agriculture as used in this paper

Term	Definition
Formal/certified organic agriculture	Organic agriculture practised in accordance with stringent principles that meet national and/or international requirements (categories 1-4)[a]
Commercial organic agriculture	Formal agriculture that aims at commercial trade and export (categories 1-2)[a]
Informal organic agriculture	Low- or no-input organic agriculture, not practised on the base of the above principles but out of lack of inputs and resources
De facto organic agriculture	Agriculture using integrated approaches, often combining organic and synthetic inputs

[a]Parrot and van Elzakker (2003) identified four different organic agricultural categories in Africa, according to their dependency on formal development aid and institutions: 1) commercialized, certified organic agriculture without any significant development funding; 2) export oriented certified organic agriculture, supported by development funding, and aimed at improving incomes of small farmers; 3) poverty and environment oriented agriculture based on organic principles, assisted by development agencies; 4) organic agriculture initiatives developed by farming communities and local organizations.

The above review again strengthens the outline given in the first section, i.e. that organic agriculture in Africa has to be analysed along two major lines: first, the commercial, Northern market oriented line and its opportunities and threats, and second, the line of the potential of organic agriculture for sustainable domestic agriculture in Africa, the latter including an assessment of recent research approaches to the viability of organic and de facto organic agriculture.

As we will look at the whole of the above systems in this paper, it is necessary to pre-define some of the terms we will use in order to have a clear picture to what the specific sections refer to (Table 1).

2 Organic agriculture from a global perspective

2.1 The world market for organic food and its development

Table 2 shows the present status and potential development of organic food markets in Europe, Japan and the US. Organic food markets are still a small niche of the total food markets in developed countries, and although growth rates are expected to be 10 – 20 % in the medium term, the resulting market share will be not more than 4 – 5 %.

Table 2. Overview of world markets for organic foods and beverages

Market	Retail sales (million USD) 2000	% of total food sales	Expected growth in the medium term (%)
Germany	2,100-2,200	1.6-1.8	10-15
U.K	1,100-1,200	1.0-2.5	15-20
Italy	1,000-1,050	0.9-1.1	10-20
France	800-850	0.8-1.0	10-15
Switzerland	450-475	2.0-2.5	10-15
Denmark	350-375	2.5-3.0	10-15
Austria	200-225	1.8-2.0	10-15
Netherlands	275-325	0.9-1.2	10-15
Sweden	175-225	1.0-1.2	15-20
Belgium	100-125	0.9-1.1	10-15
Other Europe[a]	400-600		
Total (Europe)	7,000-7,500		
U.S.A	7,500-8,000	1.5-2.0	20
Japan[b]	2,000-2,500		
Total	**17,500**		

Figures are rough estimates.
[a]Finland, Greece, Portugal, Ireland, Spain and Norway.
[b]Figures for Japan are uncertain and include non-certified products.
Source: International Trade Center 2002

After experiencing a rapid growth in the nineties which for some countries (Netherlands, France, Belgium) still persists, organic markets are now growing at a slower pace in many other countries, in particular some of the high income countries of Europe. Market growth seems to be linked to consumer preferences, in particular growing health awareness, sometimes raised by food scandals, such as the dioxin scandal in Belgium or the livestock diseases in other countries, whereas factors impeding organic market growth are lack of information on organic products, and in particular the prices that restrict consumers' purchasing power and willingness to pay. Related to that is the fact that consumers of organic products often look for produce with a long shelf life, such as cabbage or potatoes, which makes perishable and expensive tropical fruits less attractive (FAO/ITC/CTA 2001). The above observations underline the fact that the markets for organic products, especially from the tropics, remain a niche market. Nonetheless, this niche will still grow and at present, the demand still exceeds the supply.

2.2 Barriers to entry on European organic markets

EC regulation 2092/91 sets minimum standards for products to be called "organic" on the European market, but allows for more stringent national requirements. Therefore, despite the existence of this common EC regulation, there does not seem to be a uniform EC market for organic products. Although certified organic fruit and vegetables can circulate freely across EC countries, there are still differences among EC countries (UN 2000, FAO/ITC/CTA 2001).

Certified organic agriculture in Europe, more than in any other region in the world, is highly subsidized and protected through legislation and direct payments (Willer and Yussefi 2006). For example, European Union regulations and policies provide financial support to national governments for sustainable agriculture and rural development since the 80s. In the 90s, with the Common Agricultural Policy (CAP) under pressure to remove European subsidies on conventional farming, financial support was provided specifically for converting to and maintaining organic practices, in view of the environmental benefits of organic farming. In Austria, Denmark and the Netherlands, farmers receive payments based on the area under organic farming, and assistance is provided in developing marketing systems and providing producer and consumer advisory services (UN 2000). There is a question as to whether the subsidized organic market growths in Europe have a pull effect on organic products from the tropics, such as consumers buying packages of tropical fruits and European vegetables, but there is also reason to believe that in many cases European fruits and even vegetables are substitutes to tropical fruits or vegetables from the tropics, except for a few cases like cotton as a non-food item, medicinal herbs, or coffee (see also below Table 4: Organic produce from Africa).

Trade of organic produce within the EC is increasing. For example, the Netherlands, France and Italy export large amounts of fresh produce to net organic importing EC countries, including the UK, Denmark and Belgium. Again, policies and subsidies are encouraging this intra-EC trade in organic produce, fuelling increased production within the EC in the foreseeable future (UN 2000, FAO/ITC/CTA 2001). Organic consumers tend to protect their domestic market. Since the organic sector in many countries is still dominated by a few players, market transparency is far from optimal. If imports are needed, produce originating from nearby countries is favoured. An extreme case is Switzerland, where the major domestic organic label (Biosuisse) prohibits plane transport of organic products (FAO/ITC/CTA 2001), in effect giving the label a Switzerland-wide monopoly in terms of overseas imports. This makes for tough competition for non-

EC members. Furthermore, the organic consumer his/herself displays distrust towards imported organic products (FAO/ITC/CTA 2001).

3 African commercial organic agriculture

3.1 Overview on organic agriculture in Africa

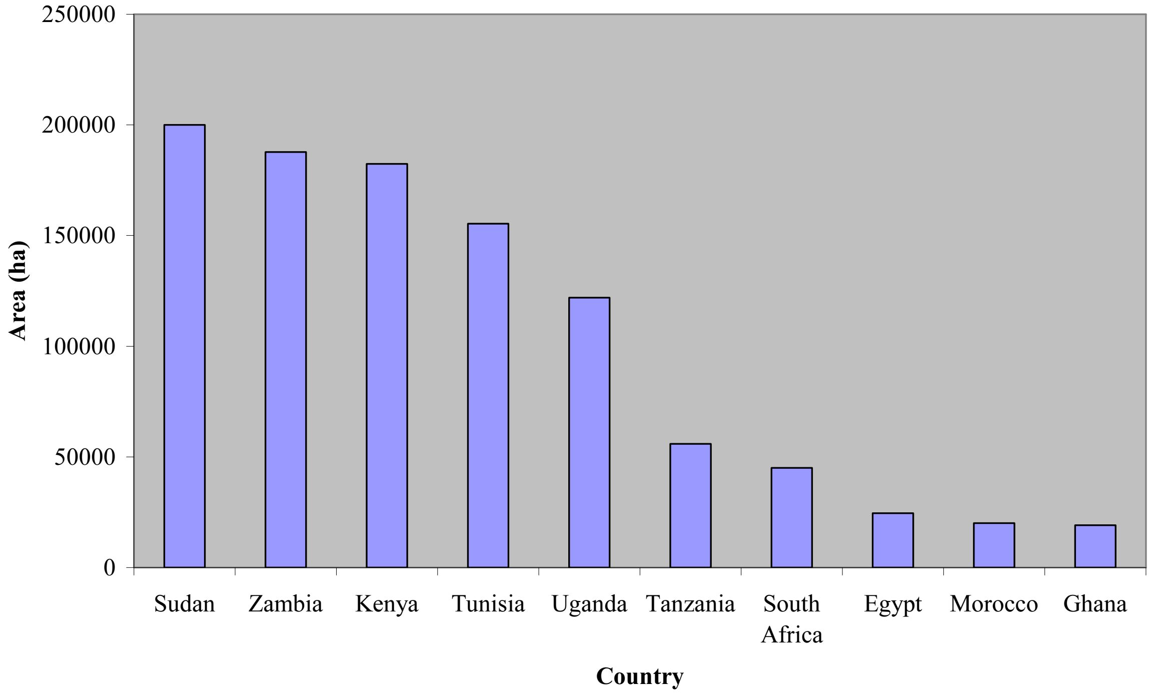
According to Yussefi (2006), 31.8 million hectares of land are currently under certified organic agriculture worldwide. Africa has the least of the shares, estimated at 1.2 million ha, equivalent to 3% of the world's total organic farmland. Regarding the number of organic farms, Africa has 19% of the world total. Table 3 compares the key statistics on organic agriculture in Africa with those of other continents.

Table 3. Key statistics on organic agriculture in Africa and other continents

Continent	Area (million ha) and share (%)	Organic farms (%)	Organic arable land (%)	Organic permanent crops (%)	Organic permanent grassland (%)	Wild collection (%)
Africa	1.2 (3)	19	2	21	0	34
Europe	6.5 (21)	27	65	33	31	3
Asia	4.1 (13)	21	13	3	31	33
S. America	6.4 (20)	31	3	41	33	30
N. America	1.4 (4)	2	17	2	5	0
Australia	12.2 (39)	0.5	0	0	0	0

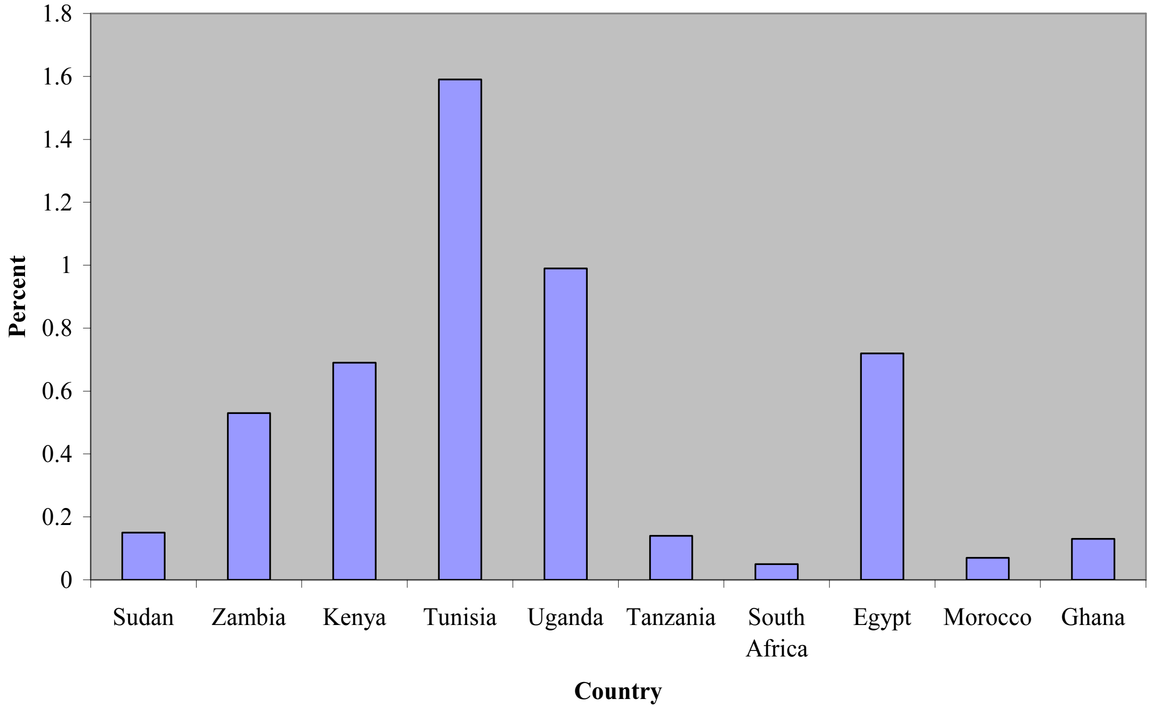
Source: Yussefi (2006). Figures in parentheses are percentages of the world total.

Figure 1: Ten countries with the largest organic land area in Africa (ha)



Source: Yussefi (2006)

Figure 2: Organic land's share of country's total agricultural area



Source: Yussefi (2006)

Table 4. Organic produce from Africa

Product	Country
Fresh vegetables	Egypt, Kenya, Madagascar, Malawi, Morocco, South Africa, Tunisia, Uganda, Zambia
Bananas	Cameroon, Ghana, Senegal, Uganda
Citrus fruits, grapes including wine	Egypt, Morocco, South Africa
Fresh fruits (avocadoes, mangoes, pineapples, papaya, etc.)	Cameroon, Egypt, Ghana, Madagascar, Senegal, South Africa, Tanzania, Uganda
Dried fruits	Algeria, Burkina Faso, Egypt, Madagascar, Morocco, Tanzania, Tunisia, Uganda
Coffee	Cameroon, Ethiopia, Kenya, Madagascar, Tanzania, Uganda
Tea	Tanzania, Uganda
Cocoa	Cameroon, Ghana, Madagascar, Tanzania
Sugar	Madagascar, Mauritius
Cotton	Benin, Egypt, Senegal, Tanzania, Uganda
Coconut oil	Mozambique
Palm oil	Ghana, Madagascar, Tanzania
Olive oil	Tunisia
Ground nut (peanuts)	Zambia
Tree nuts (cashew, shea)	Kenya, Malawi, Morocco, Tanzania
Sesame	Burkina Faso, Uganda, Zambia, Zimbabwe
Herbs (culinary)	Egypt, Ethiopia, Ghana, Kenya, Madagascar, Malawi, Morocco, Mozambique, South Africa, Tunisia, Zambia, Zimbabwe
Spices (culinary)	Cameroon, Egypt, Ethiopia, Madagascar, Malawi, Mozambique, South Africa, Tanzania, Uganda, Zimbabwe
Medicinal/therapeutical herbs and spices	Egypt, Morocco, Namibia, Tunisia, Zambia
Essential oils	Madagascar, Tanzania
Honey	Algeria, Malawi, Tanzania, Tunisia, Zambia
Other forest products	Uganda, Zambia, Zimbabwe
Cereals	Egypt

Source: Parrott and Kalibwani 2005

From Table 2, it is evident that Africa's formal organic sector is lagging behind others. In addition to having the smallest share of organic farmland, it has the second lowest share of organic arable land and does not have any organic permanent grassland. This is attributed to the fact that a large proportion of what would qualify as organic production is not certified and that the domestic market for the certified one, with the exception of South Africa and Egypt, remains small (Yussefi, op cit). Nonetheless, organic production in Africa is gradually increasing especially in the southern countries. Currently, 23 African countries are engaged in certified organic agriculture, out of which 14 have more than 900 ha of organic land. Figure 1 shows the ten countries with the largest organic land in Africa. Sudan leads with 200,000 ha, while Ghana, which is the 10th, has 19,132 ha.

However, in terms of the share of a country's agricultural area, Tunisia has the highest, with 1.59% as shown in Figure 2.

Looking at the two figures, there is no clearly discernible pattern between organic land holding and its share of agricultural land. According to Scialabba (2000), the major motivation for many developing countries (including those in Africa) to produce organic food and fibres is to tap market opportunities in developing countries. A case in point is Tunisia, whose proximity to the European organic market has triggered the Tunisian government to implement measures, including subsidies, aimed at encouraging farmers to adopt organic farming. This explains its relatively large organic land holding and the fact that its organic sector has the highest share of agricultural land. The table below shows the diversity of organic produce that is supplied by African countries. The range goes from cash crops like coffee, tea, cotton and sugar, across fruits and vegetables, up to processed fruits and vegetable oil (Table 4).

3.2 Efficiency and equity in African commercial organic value chains

The following section discusses competitiveness, equity, as well as constraints and risks along the certified organic value chains. The problem in this field is the lack of quantitative and comparable data across value chains and regions, so that we have to rely on case studies of which we think that they best describe the situation in the African commercial organic agri-food sector.

3.2.1 Competitiveness, constraints and risks along the organic value chains

Competitiveness of organic agriculture is often indicated through price premiums for farm gate prices, in some cases also through higher yields compared to traditional (no or low input) systems. However, data availability for benefit/cost ratios is limited, and it can only be hypothesized that the price premiums lead to better benefit/cost relations (Parrot and van Elzakker 2003). Other case studies deny the higher yields, finding that yields, despite higher than under declining traditional systems, are lower under organic management than under integrated management, i.e. a combination of organic and synthetic fertilizers (Mucheru et al. 2005, Okalebo and Woomer 2005, Omare and Woomer 2005). A third group of case studies finds somewhat similar yields between conventional and organic farming, assuming that profitability of organic farming is consequently higher or at least equal to conventional farming Kandil et al. (2002).

Yet it has to be considered that in organic agriculture, despite the fact that input costs may be lower due to abolishment of external synthetic inputs, management costs are supposed to be significantly higher, partly because of increased pest and disease management, and the application of organic manure. Another problem seems to be the sustainability of systems, as none of the so far considered examples are based on long-term systems or research trials, so even if yields are competitive and equal to conventional agriculture, they might decline over time, which has actually happened in some cases (Parrot and van Elzakker 2003).

Table 5. Competitiveness of organic bananas from Uganda vs. Ecuador

	Uganda (Price in US cent)	Ecuador (Price in US cent)	Advantages/ constraints of Uganda vs. Ecuador
Fresh bananas, farm gate price	11.10	27.00	Lower production costs than competitor
Transport and handling from farm to collection center	9.22	0.00	High handling costs
Boxes/packaging material	7.78	7.78	
Transport and handling to airport	1.48	2.56	
Airfreight	170.00	40.00	High air freight rates
Total costs cif Europe (Hamburg)	199.58	77.33	
Transport to ripening chamber	10.67	10.67	
Ripening	11.93	11.93	
Delivery to retailer	0.44	0.44	
Total costs retail store Europe	222.63	100.38	
Retail price Europe	300.00	300.00	
Profit margin	77.37	199.62	

Source: Mwadime 2004, Fischer 2004, Spilsbury et al. 2002, FAO 2004.

However, organic agriculture in Africa can be competitive not only in terms of internal competitiveness with traditional production, but also competitive in terms of being able to compete with global organic market competitors. In table 5, an example is depicted of a comparison between organic bananas produced in Uganda and Ecuador which highlights at the same time competitiveness and constraints. It shows that primary production of organic bananas in Uganda can compete with the one from Ecuador. However, the competitiveness is reduced significantly by high transport and handling costs from farms to collection centres, probably due to the scattered small scale farm structure and poor infrastructure, and especially the high air freight rates from East Africa to Europe. These are more than four times higher than the ones from South America and are consequently a considerable drain on the comparative profit margin reduction. The constraints quantified in the case study below quantified constraints are summarized by Parrot and van Elzakker (2003) as: “Poor quality and badly maintained roads and vehicles, rail links and rolling stock all pose problems for transportation. Lack of refrigeration, erratic power supplies, poor communications, underdeveloped banking and credit systems and, sometimes, political and economic instability, all raise serious and often insuperable problems".

In addition, the lack of local certification bodies imposes significant constraints and risks to organic agriculture in Africa. They increase the costs of certified organic production, as certifiers have to be flown in. So far, only Tunisia has its own European-standard certification bodies (Parrot and van Elzakker, op. cit.). The costs of certification have to be seen as investment costs and hence risks, for if the investment costs are not amortised by the revenues, e.g. in the case of harvest failures or a sudden shortfall of market outlets, investments in certification are lost and hence the respective farmers are prone to a significant investment risk.

In addition to the mere infrastructural factors affecting organic exports, there are a number of agronomic and, above all, institutional constraints that affect the performance of commercial organic agriculture, as listed below (FAO/ITC/CTA 2001). Although these examples are drawn from case studies in Madagascar, Cameroon and Zambia, it can be assumed that similar constraints apply to the establishment and sustainability of commercial organic agriculture elsewhere in Africa. Such constraints are:

- Lack of experience of intensive organic production in general and especially of fruits and vegetables
- Lack of experience in handling and exporting of fresh produce
- Lack of professional management
- Diseconomies of scale in exporting small quantities, e.g. for test exports
- Poor communication between foreign importers and exporters
- Competition from technically more advanced neighboring countries (e.g. South Africa)
- Poor negotiation skills and judgment of negotiation power of exporters, e.g. cases where prices are increased significantly after first successful trial shipments, and markets were lost
- Lack of familiarity with international markets, including knowledge of the organic market place overseas
- Lack of information for the potential importers, for example, on timing of production (which is locked into the main harvest), and estimated quantities of supply and prices.
- Lack of up-to-date market information
- Lack of governmental action to support exports
- Lack of knowledge on improving soil fertility, pest and disease control

It is however visible that most of these constraints are not "natural" or "naturally fixed", but can be removed by training, research and development measures specifically targeting organic exporters. A few exemptions are transportation infrastructures and long distances to markets, which cannot be shortened – except if new markets open up, like the Middle East for Africa, or growing domestic or intra-African markets, as well as local or export infrastructure and logistics (e.g. airfreights), which are subject to a more complex overall economic system.

3.2.2 Equity along the organic value chains

Equity in this section is discussed in three dimensions: first, the equity in terms of farm size and number of farms in the African organic sector, which indicates equity between organic and non-organic farmers, second the distribution of revenues along the value chains, which indicates equity across different vertical actors, and third, gender equity.

Whereas organic farming in the developed countries is perceived as being characterized by few but large farms, the perception of organic agriculture in developing countries and in particular in Africa is that it is undertaken on many relatively small farms, which may be correct in relation to global farm sizes. From this perception, the assumption of importance in generating alternative employment for poor households in these countries is derived. Table 6 summarizes the number of organic farms in 14 African countries. Uganda, Kenya and Tanzania have the highest number of organic farms. A look at the average farm size gives a first hint on equity in terms of whether organic farms are "average or even small sized", not in global terms, but in terms of African farms. It can be seen that with a few exceptions (Benin, Mozambique, Senegal), organic farms are considerably bigger than the assumed average of less than one hectare in most African countries. This holds in particular for the big schemes in Sudan, Tunisia and South Africa, but also for many other countries. For example in Western Uganda, the average farm is less than one hectare (Okech et al. 2004), whereas the average Ugandan organic farm is 3.6 hectare. In Kenya, farm sizes are at average 2 to 3 hectares (Qaim 1999), whereas the "organic" average in Kenya is slightly above 6 hectares, double the size of the average Kenyan farm. It can be concluded that in most cases, organic farming is not undertaken by the average farm, but by relatively large farms in an African context, although compared to farm sizes in developed countries such farms may be considered as small. An exemption may be common outgrowers' schemes, which mostly combine large commercial farms for basic production and employ small farmers around the base farm to supply either constantly or periodically to cover shortages. The above observation of inequity is supported by a look of distribution of farm land across farmers in North Africa ((Parrot and van Elzakker 2003). It is observed that e.g. in Egypt, 0.02 percent of the farmers are commercial organic farmers, while this group of farmers holds 0.19 percent of the total agricultural land in Egypt. The same magnitude of relations is given for Morocco (0.01/0.14) and Tunisia (0.08/0.36). This again means that not the average farmers, but most probably relatively large farmers in Africa are practising commercial organic agriculture.

The aspect of distribution of profits along value chains can be exemplified by once more looking at the distribution of profits along the market chain for Ugandan organic bananas (Table 7). It is clear that, although farm gate prices increase for organic bananas, profit increases are much higher at the end of the chain, which implies that the major share of the increased margin goes to exporters, importers, and European traders. This holds both for relative and absolute values. As a conclusion, there potentially is inequity in the share of profits along the chain, in favour of middlemen and organizers of the chain in African countries as well as Northern traders and retailers. Such middlemen are needed in the organic chain in order to organize certification and appropriate transport and handling, and market linkages in import countries. However, also in conventional chains, farmers often get a much lower share of the market price than any other actor (Abele et al. 2003).

Table 6. Number and size of organic farms by country

Country	Number of farms	Area (ha)	Average farm size (ha)
Egypt	460	15,000	33.33
Algeria	n.a.	1,400	n.a.
Ghana	n.a.	19,132	n.a.
Sudan	650	200,000	307.69
Zambia	2,425	187,694	77.40
Zimbabwe	10	1,000	100
Kenya	30,000	182,000	6.07
Tunisia	608	155,323	255.47
Uganda	33,900	122,000	3.60
Tanzania	30,000	55,867	1.86
South Africa	250	45,000	180.00
Morocco	12,051	20,000	1.66
Senegal	3,000	2,500	0.83
Mozambique	5,000	600	0.12
Mali	n.a.	170	n.a.
Benin	650	400	0.62
Malawi	13	325	25.00
Mauritius[1]	3	175	58.33
Burkina Faso	n.a.	30	n.a.
Madagascar	n.a.	129	n.a.
Niger	n.a.	12	n.a.
Togo	1	90	90.00
Rwanda	10	50	5.00

Source: Yussefi (2006), based on data from Parrot and van Elzakker (2003)

Table 7. Prices and margins for conventional and organic bananas from Uganda to Europe

	Conventional by sea (US cents/kg)	Organic by air (US cents/kg)	Absolute increase (US cents/kg)	% increase
Raw material, farm gate price	7	11	4	59
Retail price Europe	170	300	130	76
Profit margin European retailer	37	77	40	107

Source: Abele et al. unpubl. data, based on base year 2004.

Gender equity is supposed to be higher in organic farming, both commercial and non-commercial, than in conventional farming (Goldberger 2005, Parrot and van Elzakker 2003, Woomer et al. 2005, Kibwage and Momanyi 2005). Goldberger (op. cit.), however stated that adoption according to gender varies across technologies. Another concern is that during the transition from subsistence to commercial organic agriculture, gender equity changes in disfavour of women, as men gain control over commercialisation and the respective cropping systems. This argument is fostered by the above observation that often larger scale farms are engaged in African commercial organic agriculture, and that women are assumingly not holding these larger scale farms, nor do they have access to resources like credit or others.

4 Organic agriculture, overall agricultural trade and food security

Whereas the previous section has discussed organic agriculture as per the first category – commercial organic agriculture for organic niche markets in developed countries – this section will discuss the issue of the contribution of organic agriculture to food security and overall livelihoods of the African rural population. It will also discuss the above addressed "research gaps" in organic agriculture in Africa, whether they really exists and ways to overcome them.

It is certainly beyond the framework of this review paper to go into an in-depth analysis of trade and food security issues in relation to organic agriculture, first of all due to the often stated weakness of data on organic agriculture and its actual performance, secondly due to the complexity of such interrelations, which can only be depicted in a multivariate statistical assessment for which there is no framework. However, we can ask the following questions: Are countries where organic agriculture is practiced as a whole better of in terms of food security, dependency on food aid, and agricultural trade?

To look at these issues, it is necessary to discriminate between those Sub-Saharan Africa countries which have a long established commercial and non-commercial organic sector (long term organic, LTO), those who have newly emerged in this field (short term organic, STO), and those without organic agriculture (rest of Africa, ROA). It can be assumed that those who have a longer tradition in organic agriculture are better off than the others, if organic agriculture really has a large impact on the overall performance of the agricultural sector. Table 8 indicates the time elapsed since the establishment of the organic sector in the respective countries.

Table 8. Organic agriculture in Sub-Saharan Africa: timelines

Country	Organic agriculture since (estimates)
Countries with long term organic agriculture (LTO)	
Zambia	1990
Zimbabwe	1990
Kenya	1987
Uganda	1994
Tanzania	1991
South Africa	1970
Senegal	1986
Mali	1988
Burkina Faso	1991
Madagascar	1990
Countries with short term organic agriculture (STO)	
Ghana	1999
Benin	1996
Malawi	2000
Mauritius	1999

Source: Estimates according to Parrot and van Elzakker (2003)

Defining food security as the availability of calories per capita per day (and well aware that this does not necessarily cover the whole range of food security), we find that neither the countries with long term organic agriculture nor those with recent establishments are better off than the ones without established organic agriculture. Figure 3 shows that all of the countries are in the same range with a few downward outliers like the Democratic Republic of Congo, Burundi or Eritrea, which are or have been distressed countries. It seems that there is little or no relationship between the practice of organic agriculture and food security on country level. Reasons for this could be that the formal organic sectors in these countries are still too small to really contribute to increased food security, be it that even non-commercial organic agriculture is not practised by really vulnerable groups, or be it that in most of the countries, organic agriculture focuses on cash crops and not really on genuine and domestic food crops.

Figure 4 shows the dependency of the three country groups on food aid since 1993. Especially since the mid nineties, Sub-Saharan Africa is increasingly depending on food aid, which holds especially for the non-organic group of countries, but also for the group of long term organic farming countries. The only country group that is seemingly better off in terms of food security are the countries that have recently established organic agriculture.

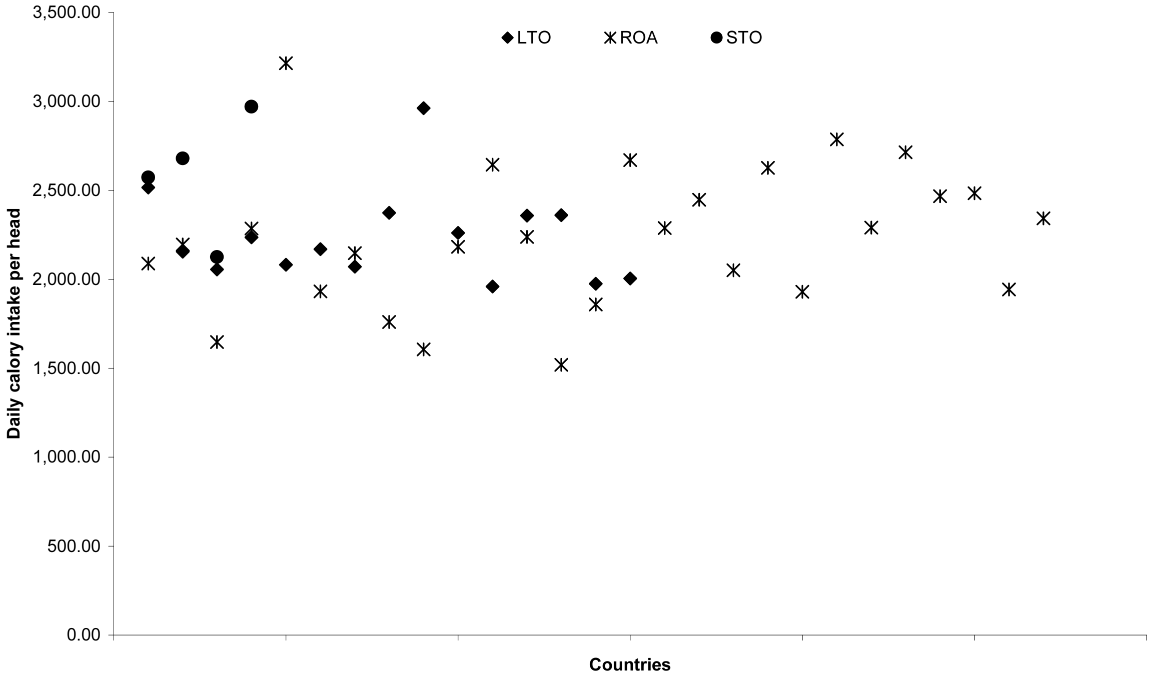


Figure 3. Daily calorie intake in Sub-Saharan Africa (Source: FAO 2006).

Although a more detailed data breakdown would throw a better light on food security issues (e.g. in sub-regions within countries, individual households of practitioners/non practitioners of organic agriculture) it is clear that there is no relationship on a national level between efforts to establish formal organic agriculture and food security, and we will discuss in the section on agricultural research below whether there is a chance at all to significantly increase food production without external synthetic inputs.

To further assess the possible effect of organic agriculture on the economic performance of the agricultural sector, we assess the monetary trade balance in terms of exports minus imports. This gives not only an indication of the deficits or surpluses in agricultural trade and their development, but also indicates the development of terms of trade over time. Here we find that trade balances are positive for the countries with a formal organic sector, both the longer term established and the short term established, while those for countries without any formal organic agriculture are negative throughout the considered time period. What is alarming is that all the trends significantly go the same downward direction, which indicates that there are declining terms of trade, and that this process cannot be stopped by commercial organic agriculture in its present form and scale.

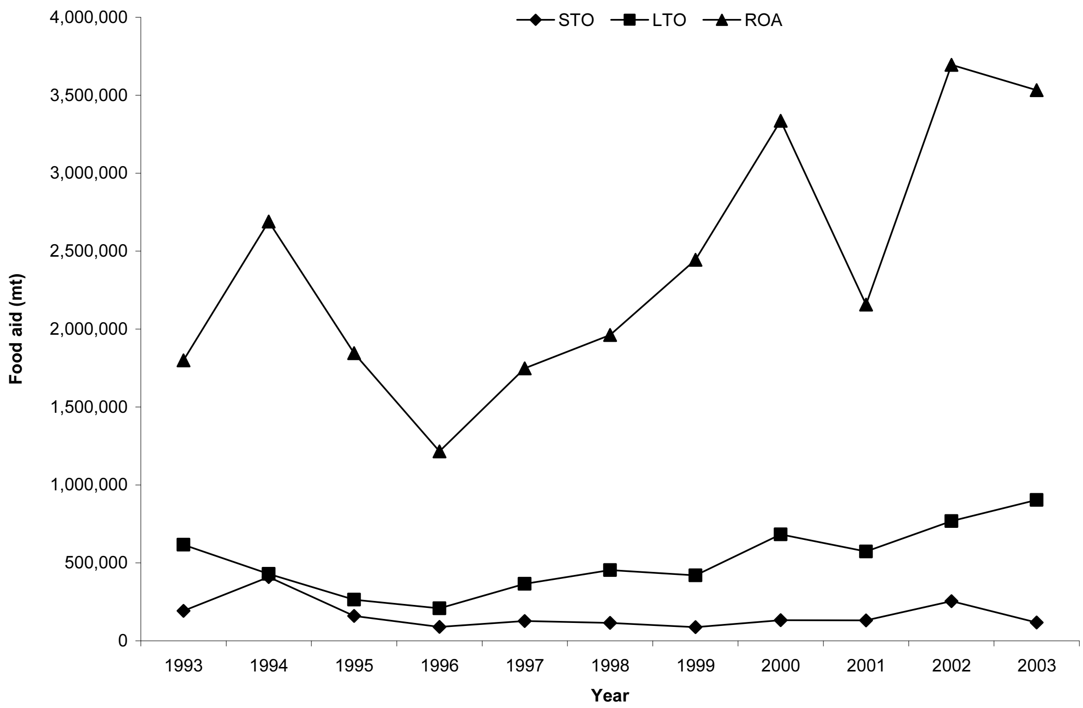


Figure 4. Dependency on food aid (Source: FAO 2006).

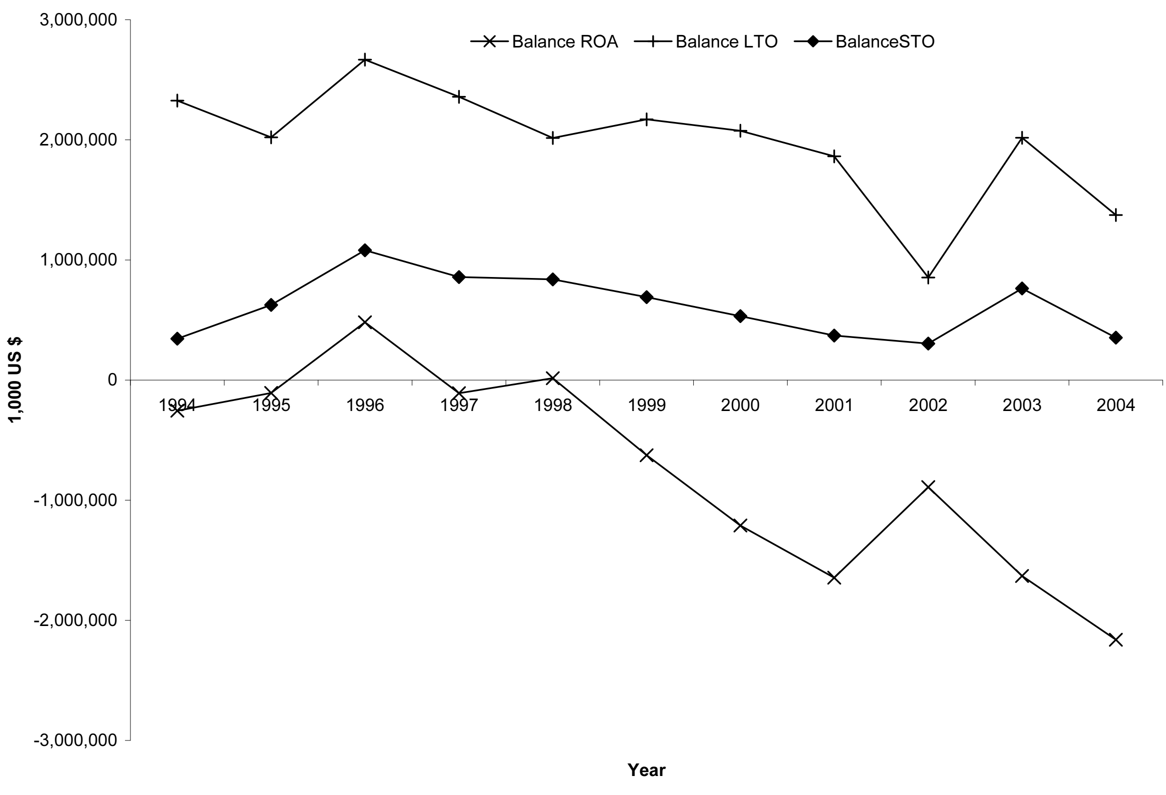


Figure 5. Agricultural trade balances (Source: FAO 2006).

Summing up this section, we state that formal organic agriculture in its present form and scale in Sub-Saharan Africa has had no or at best little visible impact on the overall performance in terms of food security and terms of trade, although in the latter category, those countries having a formal organic sector seem to be slightly better off – yet with negative trends of the same magnitude. However, there is no way to establish a causal relationship between the existence of the formal organic sector and the performance. This basically means that most probably the formal organic sector is much too small to have a positive effect on food security or trade on a national level. The example of the STOs shows that they already had been better off before going into formal organic agriculture, which may even turn around the cause-effect relationship: Better off countries with well functioning conventional agriculture and agricultural trade are more likely to engage in organic agriculture than those with distressed agriculture. Its is however clear that the engagement in organic agriculture has not been able to mitigate negative trends in overall agricultural and trade performance, most probably simply because it is still a too small segment within the whole sector.

The next section will discuss research findings that might indicate whether these trends can be turned around by applying organic agriculture on a larger scale, both commercial and non-commercial. It may also give a hint as to why the segments are still considerably small, by looking at their potential efficiency in terms of increasing food production.

5 Organic agriculture in African research

In this section we first discuss the above cited research rift between research for conventional agriculture in Africa and research into formal organic or “de facto” organic agriculture. This rift is particularly clear with respect to soil fertility management. Among the main constraints of agriculture in Sub-Saharan Africa are poor soils. As traditional farming practices become untenable under growing population pressure, overexploitation of soils, and subsequent soil depletion is threatening the future of African agriculture (Blackie 1994, Breman et al 2001, Heerink 2005). In Sub-Saharan Africa, due to government-induced price increases, the removal of subsidies and market liberalisation, inorganic fertilizer use has actually declined from 16 kg/ha in the beginning of the 80s to less than 14 kg/ha at the end of the 90s, attributing to declining soil fertility (Heerink, 2005). Organic fertilizers can contribute to increasing nutrient availability and water retention capacity as well as increased soil stability, especially in sandy soils and soils low in organic matter. Unfortunately, organic fertilisers are usually not as cost-efficient in providing the main nutrients and are usually not available in sufficient quantities (Sanders *et al.* 1996, Sanders 2002). Rock phosphates, for example, are poorly soluble. Adding these phosphates to compost heaps does not enhance the short-term availability of phosphorus (Vanlauwe and Giller, in press). Organic resources can also potentially stimulate harmful pests and diseases (Vanlauwe and Giller, in press). Inorganic fertilizers rarely damage the soil when properly used. Inorganic fertilizers are being used in Sub-Saharan Africa, often with favourable value-to-cost ratios. Contrary to some reports, these fertilizers are not cause of eutrophication in Sub-Saharan Africa (Vanlauwe and Giller, in press). The integrated soil fertility management (ISFM) paradigm is currently adapted by the science community specializing in tropical soil fertility management. A fundamental aspect of ISFM is the synergism among its components (Breman

1997, Kauffman et al. 2000, Koning et al. 2001). Application of organic fertilizers can increase both nutrient and water use efficiency, and therefore make application of inorganic fertilizers much more attractive to farmers, and vice versa (Vanlauwe and Giller, in press). ISFM advocates the utilization of locally available resources, the combined application of organic resources and inorganic fertilizer, and enhancement of the use efficiency of both types of inputs (Vanlauwe, 2004), rather than exclusion based on principle. Nowadays, in the research community, it is acknowledged that the way forward for soil fertility management is to combine mineral and organic inputs (Vanlauwe *et al.* 2002).

Examples for such synergies are many and have already been cited in the above section on efficiency of organic agriculture. Especially data on the technical coefficients (inputs, yields) of organic vs. integrated approaches have been well documented by the agricultural research community. Analyses, however, often lack monetary data, mainly cost/benefit assessments of integrated vs. pure organic agriculture and of their related technologies, for example biological control of pests (Coulibaly et al. 2005). The lack of monetary data is understandable for the cases of private enterprises who might not be willing to reveal their figures, but less understandable for other parts of the sector like development projects etc. However, it has to be said that the data gap rather exists on the organic agriculture side, and to a much lesser extent on the side of conventional agricultural research.

6 Conclusions

6.1 Commercial organic agriculture in Africa

Commercial organic agriculture may be a profitable option for African farmers, however, seemingly it is not the small scale farmers who benefit, but larger farmers, and their organising enterprises. Benefits from commercial organic farming seem to go to a large extent to middlemen, organisers and traders, and hence there is no difference between the commercial organic sector in Africa and other commercial agricultural sectors.

The above mentioned actors face markets in particular in Europe, which are still not saturated and rapidly growing. Yet these markets are niche markets, and limited in the mid- to long term, due to limited consumers' readiness to pay high prices, and lack of information among consumers. Access to these markets is impeded through various barriers, starting with strict regulations that differ across consumer countries, subsidies paid to European organic growers, but most of all institutional and infrastructural problems in Africa, and high investment costs of establishment of organic farms. Especially the latter impose considerable risks to commercial organic farmers in Africa. Increasing competition and declining prices in the long run, induced by market saturation will definitely affect African organic farmers most, as they are already the most vulnerable producer group in the global organic sector.

Many of the risks and constraints affecting commercial organic agriculture can be removed by objectively validated research and development, as well as policy activities, such as. the improvement of infrastructure and the establishment of certification bodies in African countries. Other constraints, such as long distances to markets can only be removed by the establishment of new markets for organic products in Africa, or nearer locations like the middle East.

6.2 Non-commercial organic agriculture

Organic agriculture for non-export purposes, i.e. organic agriculture as a means to improve food production in Africa has not yet induced the desired results on a macro economic scale. Reasons for this may be many. Obviously, one reason might be that organic agriculture is still in its infancy in most of the African countries. However, agricultural research has provided evidence that pure organic agriculture does not have the potential to increase productivity as needed, and that integrated agriculture, combining organic and non-organic inputs is superior in terms of yields and sustainability. The often claimed research gap as stated by the supporters of organic agriculture does not exist, in fact there is a considerable amount of research results available to support the above argument of integrated agriculture. It is objectively validated research on organic agriculture that is still lacking, especially in terms of cost/benefit analysis, which would finally give a clear picture on how to optimise integrated organic and non-organic approaches. Here the ball lies clearly in the court of those who support merely organic approaches to link up with international agricultural research to close these gaps. Unless this is done, organic agriculture remains a niche often only for commercial producers, for niche markets outside of Africa, with an uncertain future.

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