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Science and Technology Options Assessment

S T O A

Agricultural Technologies for Developing Countries

STUDY

(IP / A / STOA / FWC / 2005-28 / SC42)

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SCIENCE AND TECHNOLOGY OPTIONS ASSESSMENT

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Abstract

The study investigates the contribution of selected important agricultural production systems and technologies (incl. rainwater harvesting, conservation agriculture, rice intensification system, organic farming, agroforestry systems and transgenic plants) to higher food production and food security with focus on small-scale farmers in developing countries. It then suggests options for action within European development policies and development cooperation

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AUTHOR

PD Dr. Rolf MEYER (ITAS)

RESPONSIBLE ADMINISTRATOR

Jarka CHLOUPKOVA
Policy Department Economic and Scientific Policy
European Parliament
Rue Wiertz 60 - ATR 00K074
B-1047 Brussels
Tél: +32-2-2840606
Fax: +32-2-2849002
E-mail: jarka.chloupkova@europarl.europa.eu

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ABOUT THE EDITOR

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CONTENTS

ABBREVIATIONS

ACP	Africa, the Caribbean and Pacific
AGRA	Alliance for a Green Revolution in Africa
AKST	Agricultural knowledge, science and technology
Bt	Bacillus thuringiensis
CA	Conservation Agriculture
CAADP	Comprehensive Africa Agriculture Development Programme
CAPRi	CGIAR Systemwide Program on Collective Action and Property Rights
CGIAR	Consultative Group on International Agricultural Research
DCI	Development Cooperation Instrument
EIARD	European Initiative for Agricultural Research for Development
EIDHR	European Instrument for Democracy and Human Right
EIB	European Investment Bank
ENPI	European Neighbourhood and Partnership Instrument
FAO	Food and Agriculture Organisation of the United Nations
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHG	Greenhouse Gas
GMO	Genetically modified organism
HIV/AIDS	Human immunodeficiency virus/acquired immune deficiency syndrome
HR	Herbicide resistance
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
IAC	InterAcademy Council
IFAD	International Fund for Agricultural Development
IFI	International Financing Institutions
IFOAM	International Federation of Organic Agriculture Movements
IFPRI	International Food Policy Research Institute
IPM	Integrated Pest Management
IPR	Intellectual Property Rights
LCD	Least Developed Countries

LEISA	Low External Input Agriculture
LISA	Low Input Sustainable Agriculture
MDGs	Millennium Development Goals
MFI	Microfinance institution
NEPAD	New Partnership for African Development
NGO	Non-Governmental Organisation
ODA	Official Development Assistance
OECD / DAC	Organisation for Economic Cooperation and Development/Development Assistance Committee
OF	Organic Farming
PRSP	Poverty Reduction Strategy Paper
RWH	Rainwater Harvesting
R&D	Research and Development
RDI	Rural Development Institute
SIWI	Stockholm International Water Institute
SOM	Soil organic matter
SRI	System of Rice Intensification
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	UN Framework Convention on Climate Change
UNRISD	United Nations Research Institute for Social Development
WHO	World Health Organization
WUA	Water User Associations

EXECUTIVE SUMMARY

Agriculture in developing countries and for development is back on the agenda. Around half of the world's population is living in rural areas, with agriculture being the centre of their lives. The vast majority of farmers in developing countries (85%) are small-scale farmers, producing on less than 2 hectares. Furthermore, most of the poor in developing countries (75%) live in rural areas. Climate change will disproportionately affect developing countries and the poor, demanding for adaptations of agricultural production systems to climate change. Increasing production and strong economic growth in agriculture – with small-scale farmers in the centre of attention – are urgently needed for achieving poverty reduction and other Millennium Development Goals.

In this context, the STOA project "Agricultural technologies for developing countries" investigates the contribution of selected important agricultural production systems and their technologies as well as their management practices to higher food production and food security with focus on small-scale farmers. The following agricultural production systems were analysed in case studies:

- Rainwater Harvesting
- Conservation Agriculture
- System of Rice Intensification
- Organic Farming
- Agroforestry systems
- Transgenic plants

From the assessed production systems, Conservation Agriculture, System of Rice Intensification, Agroforestry systems and Organic Farming can be described as complex agricultural production systems of intensification by higher agro-ecological and biological productivity, without necessarily increasing external inputs (mineral fertiliser, pesticides) and addressing input optimisation. This can be subsumed under *low-input intensification*: The aim is to achieve higher crop yields without or with restricted additional external inputs, combined with an improved soil and water management. These agricultural production systems have the potential to address especially the needs and possibilities of small-scale farmers.

Sustaining and improving soil fertility is a common key element. Key principles are diversified crop rotations, plant associations in case of perennial crops (especially in Agroforestry), permanent soil cover and minimal or no mechanical soil disturbance. At the same time, a better retention and use of water can be achieved. An important component is also integrated pest management. Additionally, technologies of Rainwater Harvesting can contribute to balance water demand of small-scale farmers in dry regions with irregular and scarce water supply.

An acceptance of modified agricultural production methods and improved livelihoods can only be achieved when parallel market access for the increased production is built up and the food chain requirements are met. The successful development, introduction and use of agricultural technologies and their integration into adapted practices in developing countries depend on many framing conditions. For example, longer-term investments like soil improvements depend on secure land rights.

In contrast, transgenic crops are until today restricted to a small number of cash crops and are mainly working in the frame of high-input production systems. The ability of transgenic crops to increase yields, to address food security and to be useful for small-scale farmers is discussed very controversially.. The complexity of transgenic crops lays mainly outside the agricultural production system, in demanding risk assessment and management as well as regulation strategies and policies, which are still considered to be inadequate or completely lacking in many developing countries.

The identified *options for action* concentrate on the development, adaptation and introduction of the agricultural production systems Conservation Agriculture, System of Rice Intensification, Agroforestry systems, Organic Farming and Rainwater Harvesting – in other words, on possibilities of intensification by higher agro-ecological and biological productivity, with low external inputs. With the European Consensus on Development, the European development policy is focused on the Millennium Development Goals and poverty reduction. The importance of agriculture for development and the key role of small-scale farmers therein still have to be implemented into the practice of the European development cooperation. The potential of low-input intensification should be much more recognised. For European development policies and development cooperation, options for action are:

Policy commitment: Political and societal commitment is a key factor for the introduction and spreading of low-input agricultural production systems, which demand important changes of traditional or introduced agricultural production methods. The aim should be to bring the appropriate production system into the main stream of agricultural activity.

Incorporation into European development policies: European actors in development policy should be an advocate for giving agriculture high priority and for low-input intensification focused on small-scale farmers. Key elements for achieving these goals are the integration into the complex system of European development cooperation, lead donor arrangements, integration into international programmes and processes and national and regional planning and programming.

Approaches for scaling-up: A single global strategy for up-scaling of Conservation Agriculture, System of Rice Intensification, Organic Farming, Agroforestry systems or Rainwater Harvesting will not work: The strategic approaches and principles must be tailored to countries, regions, farming systems or even local sites, reflecting specific technical, economic and social conditions. Nonetheless the need for local adaptation, important components for scaling-up approaches are farmer-to-farmer extension and Farmer Field Schools, linking large-scale and small-scale farmers, share of knowledge, support by counsel and education, setting of standards and certification, development of market access and assessing benefits.

Introducing financial support: Beside support for scaling-up initiatives and activities, financial support to small-scale farmers is needed for some initial investments and for compensating possible decreasing profits and risk during the adaptation period as incentives for changing production systems and introduction of price premiums.

Science and technology development: Conservation Agriculture, System of Rice Intensification, Organic Farming, Agroforestry systems and Rainwater Harvesting are dynamic systems which demand the development of new technological solutions, the making operational (and economically viable) of existing technologies and the local adaptation, particularly in smallholder systems. A close interaction between farmers and researchers is needed. Despite the importance of local adaptations, some areas overall relevant for science and technology development are production system research, mechanisation, biomass production and processing, pest control, water control, adaptation to climate change and socio-economic research.

Assessing the agricultural potential of GM plants: There are many arguments in favour of steering towards a problem-oriented approach in the assessment of potential future agricultural technologies and cultivation methods. For transgenic plants, this means examining green genetic engineering options without a predetermined result and in comparison to other approaches. In developing countries, potentials of GM plants are heavily dependent from adequate risk assessment and management, the solution of intellectual property right problems and the successful connection of centralised breeding activities with local adaptations.

European Agriculture: For the concerned promotion of production system changes in developing countries and the integration into development cooperation, own research capacities, knowledge bases and practical experience with low-input intensification in European agriculture are desirable. Based on own practices and experiences and research and development activities, the recommended actions in development policies would be more credible and better founded.

1. SUMMARY

The STOA project “Agricultural technologies for developing countries” investigates the contribution of selected, important agricultural production systems and their technologies as well as their management practices to higher food production and food security with focus on small-scale farmers.

1.1 The Context

This part is based on a literature study and an evaluation of important international assessments on agricultural science and technology. The objective is to provide an overview on the strengths and weaknesses of the international agricultural science and technology system, the access to and the adoption of agricultural technologies in developing countries, the possibilities and problems of improving agricultural productivity and output and of reducing food insecurity in developing countries.

Agriculture in developing countries

The first part of the analysis gives an overview on agriculture in developing countries.

Agriculture, small-scale farmers and poverty

Around half of the world’s population is living in rural areas, with Sub-Saharan Africa and South Asia having some 75% of its population in rural areas, North Africa and Central Asia some 50% and Latin America around 10%. Agriculture is in the centre of their life. The vast majority of farmers in developing countries are small-scale farmers. Estimated 85% of the farmers in developing countries produce on less than 2 hectares. Many poor countries still have high agricultural shares in the Gross Domestic Product (GDP) and employment. The large share of agriculture in poorer economies is the reason why strong growth in agriculture is critical for fostering overall economic growth in the early stages of national economic development and diversification.

Most of the poor in developing countries (75%) live in rural areas. More than 80% of the decline in rural poverty in the past is attributable to better living conditions in rural areas. But the decline in the number of rural poor (from 1,036 million in 1993 to 883 million in 2003) has been mainly confined to East Asia and the Pacific region. The latest assessment of the World Bank shows that poverty has been more widespread across the developing countries over the past 25 years than previously estimated. For 2005, the World Bank now estimates that 1.4 billion people, or one quarter of the population of the developing world, lived in poverty defined as less than $2 per day.

Hunger and malnutrition inflict heavy costs on individuals and households, communities and nations. Agricultural growth plays a crucial role in enhancing food security and reducing poverty in developing countries. The lessons learned to date suggest that no sustainable reduction in poverty is possible without improving rural livelihoods which is essentially a process of economic and asset development. Hunger reduction is needed as a first step for fast development and poverty reduction.

The implication is that interplay is needed between policies for economic and agricultural development and policies for poverty and hunger reduction.

Productivity growth

The productivity growth in developing countries drove the global agricultural development. The major contributor to growth in Asia and the developing world in general were productivity gains rather than the expansion of agricultural land. The increases in productivity have contributed to a net increase in global food availability. But people have benefited unevenly from the yield increases across regions, in part because of different organisational capacities, socio-cultural factors and institutional and policy environments and in part due to differential growth and diversification of national economies and consequently in the growth of effective demand for food and agricultural products.

Increasing yields and productivity have in many cases caused negative environmental impacts because of the promotion and use of intensive tillage-based production systems and the excessive use of pesticides and mineral fertilisers. Equally, environmental shortcomings of some of the traditional tillage-based agricultural practices associated with poor socio-economic conditions create a vicious circle of soil degradation, due to loss of organic matter and soil porosity, in which poor small-scale farmers have to deforest and use new, often marginal lands.

Agricultural knowledge, science and technology

In developing countries, 94% of the agricultural research and development (R&D) is conducted by the public sector. At the same time, worldwide public spending in agricultural R&D was concentrated in only a handful of industrial countries. A dramatic slowdown in agricultural R&D spending took place in the first half of the 1990s. Overall, there is a pervasive underinvestment in agricultural R&D. The knowledge gap between industrial and developing countries is widening and especially African countries face specific disadvantages.

The traditional linear process by which the results of research are passed on to extension services for dissemination to farmers has produced many important advances in agriculture, but also failed in many cases, particularly when dealing with knowledge-intensive practices. In response to these problems, new integrated approaches were developed such as integrated pest management (IPM), Conservation Agriculture, crop-livestock system development.

International spillovers of public (and private) agricultural R&D results are extremely important. The world's poorest countries are highly dependent on the spillover of technologies from industrialised countries. But since some time the research agenda of industrial countries is shifting. In rich countries, the emphasis on enhancing the production of staple food is declining. Instead, environmental, food safety and health issues of production and processing of products are gaining importance. Additionally, with automation and other advanced technologies in industrial countries, the differences between poor and rich countries are growing regarding the innovation demand and use of technologies.

Finally, the rise of modern biotechnology and enhanced intellectual property rights (IPR) regimes mean that once freely accessible technologies will be more difficult to access in the future.

The consequence is an increasing pressure for more self-reliance of developing countries in the development of applicable agricultural technologies. Less-developed countries may have to extend their own R&D efforts further upstream to more strategic areas of science and also increasingly harness improved technologies and practices through South-South cooperation which is starting to happen. But self-reliance will be beyond the possibilities of many poor countries so that a strengthening of multinational efforts is needed.

Public spending and development assistance

Successful countries have invested in agriculture before taxing it to finance industrial development. The low levels of agricultural spending in Sub-Saharan Africa are insufficient for sustained growth. High taxation of agriculture is associated with low growth in agriculture and slower growth in the economy as a whole.

The share of agriculture in official development assistance (ODA) declined sharply over the past two decades, from a high of 18% in 1979 to 3.5% in 2004. In almost all Least Developed Countries (LCD), ODA is the main catalyst of investment in agriculture.

The funding of research by governments, donors and international financial institutions declined since the 1980s. A factor for the continuing decline was the notion that technologies available ‘on-the-shelf’ are sufficient to solve all or most agricultural problems in Africa. For example, the World Bank funding for African agricultural research went from a peak of $120 million in 1991 to $8 million in 2002 (in 1993 US dollar value). That of USAID went from a peak of $80 million in 1982 to $4 million in 1999. Keeping the technology pipeline flowing requires a renewed emphasis on long-term strategic and applied research.

Framing conditions

The successful development, introduction and use of agricultural technologies and their integration into adapted practices in developing countries depend on many framing conditions. Key points are summarised below.

Land rights and access

Land is one of the most important assets for rural people in developing countries. In developing countries, roughly 100 million farm families, compromising about 500 million people, lack ownership or owner-like rights to the land they cultivate. Latin America has the most unequal land distribution system in the world. Although the term “land reform” is still associated with the redistribution of land, land policies include registration, redistribution, restitution and recognition of rights. Secured and increased access to land and natural resources for the landless and land-poor families is a key means of achieving food security and poverty reduction.

Water

Agriculture uses 85% of water consumed in developing countries, mainly for irrigation. Irrigated farming accounts for only 18% of the cultivated area in developing countries, but it produces about 40% of the value of agricultural output. Water scarcity is a critical constraint to agriculture in many areas of the world. A fifth of the world's population, more than 1.2 billion people, live in areas of physical water scarcity.

Rainfed agriculture can be upgraded by improving soil moisture conservation and, where feasible, Rainwater Harvesting. These techniques hold underexploited potential for quickly lifting the greatest number of people out of poverty and for increasing water productivity, especially in Sub-Saharan Africa and parts of Asia.

The era of rapid expansion of irrigated agriculture is mostly seen as being over. Nonetheless, some experts and policy makers want to expand the irrigation areas particularly in Africa. A major new task is adapting yesterday's irrigation systems to tomorrow's needs. Modernisation, a mix of technological and managerial upgrading will enable more productive and sustainable irrigation.

Climate change

Climate change, which is taking place at a time of increasing demand for food, feed, fibre and fuel, has the potential to irreversibly damage the natural resource base on which agriculture depends. The relationship between climate change and agriculture is a two-way street: Agriculture contributes to climate change in several major ways and climate change in general adversely affects agriculture. Climate change will disproportionately affect the poor.

Adapting agricultural systems to climate change is urgently needed because impacts are already evident and these trends will continue even if Greenhouse Gas (GHG) emissions are stabilised at the current levels. This adaptation can substantially reduce the adverse economic and social impacts. A scope of activities is currently being developed in order to integrate the adaptation, including agricultural production, within development and poverty reduction programmes.

Inputs

Agricultural productivity growth and higher yields depend on inputs such as seeds, equipment, fertilisers and pesticides. Input requirements depend largely on the applied agricultural production systems. In high-input farming, particularly the tillage-based systems, the future challenge is to reduce the environmental and health impacts of pollution caused by fertilisers and pesticides via a better management of these inputs without sacrificing yields. The depletion of soil fertility is a major biophysical cause of low per capita food production in Africa. Fertiliser use is extremely low in many Sub-Saharan Africa countries, but initiatives are underway to improve fertiliser use.

Financing

Financial constraints in agriculture remain pervasive. They are costly and inequitably distributed, severely limiting small-scale farmers to develop their productivity and to compete. An important approach to resolve rural financial problems are Microfinance Institutions (MFIs). However, MFIs cannot provide the mainstay of rural finance. Promoting, improving or even creating rural institutions to support a wide range of rural financial transactions remain one of the fundamental challenges governments are facing in developing countries.

Infrastructure

Adequate infrastructure is an important element in the process of alleviating poverty and providing opportunities for rural citizens in developing countries. Agricultural development is related to access to markets and services. The road system in Africa today is only a fraction of what India had decades ago and leaves about 70% of its farmers poorly connected to markets. Many farmers can neither procure fertilisers and other inputs at affordable prices nor market their own products effectively. Achieving realistic levels of infrastructure and rural services will require substantial increase in public investment.

Changing food chains

The combination of growing cities and rising incomes has contributed to significant changes in diet. The changing dietary patterns have fuelled on the one side and been promoted on the other side by the increasing concentration of food processing and retail trade. Supermarkets in the developing countries of Africa, Asia and Latin America are rapidly spreading. The impacts are double-edged: On the one hand, this can lower food prices for consumers and create opportunities for farmers and processors to gain access to quality-differentiated food markets and raise incomes. On the other hand, this can create challenges for small retailers, farmers and processors. To achieve compliance with quality, quantities and timing requirements of supermarkets, effective producer organisations are essential.

Education and health

Education and health are important factors for reducing hunger and malnutrition and for increasing agricultural productivity.

Gender

Gender, that is socially constructed relations between men and women, is an organising element of existing farming systems worldwide. In many poor countries, women cannot own land, obtain credit to buy land or make decisions to improve land. Women have more limited access to credit, markets and technologies. Gender is a determining factor of ongoing agricultural restructuring. Empowering women and reducing gender disparities are keys to ensure food and nutrition security in the developing world.

Governance

The success of development policies for agriculture is depending on many governance issues, as political stability, government effectiveness, regulatory quality, rule of law and control of corruption. A comprehensive overview on governance is not given in this report. Instead, corruption in irrigation is discussed as an example.

Strategies for development

The high importance of agriculture for the economic development, for food security and livelihoods as well as for ecosystem services is a common conclusion in the current international assessments. Increasing productivity and output in agriculture through effective technologies and environmentally friendly production practices are seen as a key element to achieve the Millennium Development Goals. The strengthening of agricultural knowledge, research and technology development and farmer-based innovation and extension together with their sharply increased public funding are broadly recognised recommendations.

In line with the complex issues and the broad assessments, a number of strategies and many different strategic elements are proposed in the reports. Beyond the common demand for higher recognition and investment in agriculture, the strategies for development show different emphases and priorities.

1.2 The results of the case studies

The characteristics, the current relevance and use, restricting framing conditions, the potentials for improvements and the effects for small-scale farmers were assessed for six agricultural production systems. The main outcomes are presented here.

Rainwater Harvesting

The technologies of Rainwater Harvesting (RWH) are decentralised water distribution systems including the collection, filtration and storage of local rainwater and surface runoff. Corresponding to the local conditions (climate, morphology, soil, etc.) many various techniques can be applied. Therewith, the local water demand for small-scale farming can be balanced. The methods of Rainwater Harvesting can be applied in every climatic zone with water deficiency. Nowadays, RWH installations are often not as efficient as they could be, sometimes far below their potential, and they need to be improved.

The introduction or improvement of RWH systems should be combined with Conservation Agriculture in order to increase the water use efficiency and the soil fertility. Examples demonstrate that the crop yield of rainfed cultivation can be doubled or even quadrupled by using techniques of RWH. Compared with other methods to produce usable water (e.g. deep wells), RWH techniques are much cheaper and easy to maintain – therewith favourable for resource-poor small-scale farmers.

Conservation Agriculture

Conservation Agriculture (CA) is characterised by three principles:

- Continuous no or minimal mechanical soil disturbance (e.g. non-tillage in combination with direct seeding/direct planting);
- Permanent organic-matter soil cover (e.g. crop residues and cover crops);
- Diversified crop rotations (or plant associations in case of perennial crops).

Conservation Agriculture aims to prevent soil degradation und to preserve and/or enhance soil fertility by strengthening natural biological processes above and below the ground. In tropical and subtropical areas, the danger of erosion through rainfall is high, the soils are usually poor and eroded and the temperatures are high and thus decomposition is rapid. These problems are addressed by Conservation Agriculture.

Worldwide, there are now almost 100 million hectares of arable crops which are grown each year without tillage in CA systems. Potential for CA systems in the 21st century agriculture development is based on the large amount of field-based evidence from all continents regarding the role of CA systems in raising productivity and income, improving livelihoods and reducing production costs, increasing resilience of production, contributing to climate change adaptation and mitigation, enhancing water resources and protecting ecosystem services and the environment.

Conservation Agriculture as farming concept and a set of practices has a wide range of compatibility and complementarity with other resource conserving approaches and technologies, and is applicable in rainfed and irrigated farming systems, including Organic Farming. It is suitable for different crop types such as grain crops including rice, roots and tubers, vegetables, perennials and Agroforestry systems.

System of Rice Intensification

The System of Rice Intensification (SRI) is an innovation in rice production systems that is still evolving and ramifying. The System of Rice Intensification (SRI) is basically a set of modified practices for managing rice plants and the soil, water and nutrients that support their growth. These changes in often age-old cultural practices can be seen as a “civil society innovation”. SRI addresses the major constraints affecting the livelihoods of small and poor farmers: their limited resources of land, labour, water and cash, as well as losses from pest, diseases and adverse climatic conditions.

SRI does not require rice farmers to commercially purchase and use any external inputs, since its benefits derive from changes in the ways that existing resources are used for rice production, which reduces their dependence on commercial input. At the same time, SRI concepts and methods can be adapted by larger rice producers.

The System of Rice Intensification is a relative young innovation, but is now demonstrated and spreading in all world regions except Europe and North America, and its methods have proved to be productive in a wide variety of agroecosystems. In the meantime, the approach is also transferred to other crops. SRI is currently used by 1 million small farmers producing rice around the world on over 1 million hectares.

Organic Farming

The fundamental distinction of Organic Farming (OF) from conventional agriculture consists in its focus on input optimisation rather than output maximisation. It aims at more efficient nutrient use and re-use by optimising the scope of nutrient recycling. Especially readily soluble mineral fertilisers, synthetic pesticides and performance stimulants are renounced. Organic Farming is at first a legally defined production method for food and may also be part of a lifestyle, e.g. a movement with agro-political and ideological-philosophical influence.

A little more than 30.4 million hectares were managed organically by more than 700,000 farms worldwide in 2006. More than one quarter of the world's organic land is found in developing countries (8.8 million hectares). Due to the growing international demand for healthy food and its global trading there is a need for the standardisation of Organic Farming systems. This standardisation turns out as highly controlled certification based on precepts and rules for production.

Agroforestry systems

Agroforestry systems are understood as land use systems which simultaneously combine deliberately interplanted annual crops and trees. Agroforestry consists of a set of reasoning and design principles rather than fixed planting schemes. Agroforestry aims to diversify and sustain production for increased social, economic and environmental benefits for land users. There are countless Agroforestry systems that have been developed across the globe.

In Sub-Saharan Africa, tree-based agricultural systems could potentially cover an area of almost 1 billion hectares (over 40% of the land area). Currently, only 9% of this potential has been realised. Tree crops for export, in particular cocoa and coffee, play a dominant role, but tree fruit exports have distinctly increased in the past decades. In South Asia, tree-based systems are established on 112 million hectares but could be potentially doubled. In the East Asia-Pacific region (including China and Mongolia) the potential for tree-based systems is estimated at more than 1.1 billion hectares with around 14% of the area being currently under such type of land use. In China, Agroforestry has a long tradition and plays a major role in the context of reduction of wind erosion. For Latin America and the Caribbean, estimations indicate a potential of some 1.2 billion hectares of tree-based systems extending over a very wide range of agro-ecological zones with less than 9% of the potential area currently cultivated in such forms.

Various case studies illustrate that, in the long run, Agroforestry systems often prove to be superior to conventional systems in terms of common economic indicators. Agroforests can be considered as appropriate setting for self-sufficiency. This also implies their ability to mitigate economical and ecological risks, which can be strongly interrelated. This quality is gaining increasing relevance in the context of climate change. On a macroeconomic level, Agroforestry products account for a significant share (up to 50%) of agricultural exports earnings in many developing economies. On a global scale, the potential of Agroforestry to provide environmental services recently adds a new dimension, which goes beyond conventional economic criteria and approaches.

Transgenic crops

Genetically modified (or transgenic) plants are the results of recombinant DNA techniques used in plant breeding. Even after 20 years of research and 12 years of cultivation, there are as yet no transgenic varieties that are specific to developing countries. There are, however, adapted HR (herbicide resistance) and Bt (*Bacillus thuringiensis* toxin) varieties, mainly as a result of hybridisation into regional varieties.

Although there are a large number and variety of overall research and development projects on transgenic plants for the particular benefit of agriculture in developing countries – in the countries in question, in international agricultural research centres and in some cases in cooperation with institutions in industrial countries –, it is widely assumed that up to now comparatively few resources have been used worldwide, from which it is inferred that the actual potential of transgenic plants has not yet been properly determined for developing countries.

In 2007, the estimated global acreage of transgenic crops was around 114 million hectares. Genetically modified crops were grown in 23 countries. Twelve years after the commercial introduction of transgenic plants, more than 99% of the acreage still displays only two genetic traits (herbicide tolerance and/or insect resistance) and consists of four crops: soybean, maize, cotton and rapeseed/canola. Commercial cultivation has taken place up to now almost exclusively in the so-called emerging countries and is quite predominantly restricted to two cash crops: HR soybean in South America and Bt cotton in India and China.

Due to insufficient data, it is currently impossible to carry out a final evaluation of the size and distribution of profits in terms of business and economics which have been achieved by cultivating transgenic plants in developing and emerging countries. Studies which claim to be able to do this are not scientifically backed up and are based on unstable projections. In consequence, the effects for small-scale farmers are discussed very controversially.

In the area of risk regulation, regulation strategies and policies are still considered to be inadequate or completely lacking in many developing countries. Even existing legislation is of little use, however, if the political and economic balance of power stands in direct opposition to an application. And where the social debate on the use of transgenic seeds is conducted very intensely, there is often only poor development of comprehensive risk communication on the part of the authorities.

Conclusions

Sustaining and improving soil fertility are key elements of Conservation Agriculture, System of Rice Intensification, Agroforestry systems and Organic Farming. Key principles are diversified crop rotations, plant associations in case of perennial crops (especially in Agroforestry), permanent soil cover and minimal or no mechanical soil disturbance. At the same time, a better retention and use of water can be achieved. A further component is an integrated pest management. The overall aim of all these systems is intensification by higher agro-ecological and biological productivity, without necessarily increasing external inputs (mineral fertiliser, pesticides).

These concepts represent complex agricultural production systems. Therefore, a high level of knowledge and information is requested. The common approach is to formulate fundamental principles and to highlight key elements. But for the concrete application, these have to be translated case by case into production technologies and farmer practices. A standardised best approach is not possible due to the diversity and variability in agro-ecological and socio-economic conditions associated with farming in general and with less favourable areas and smallholders in particular.

Local and indigenous knowledge and traditional elements are important in optimising the available resources, in a productive dialogue without simply continuing traditional practices.

Participation processes and "ownership", including farmer organisations and cooperatives, are of high relevance in all complex systems. For learning by seeing and doing, Farmer Field Schools (FFS) are strongly recommended. Visiting demonstration plots and farmer-to-farmer communication are usually the most effective way to overcome resistance.

Societal and political commitment is a key issue for all new agricultural production systems, which demand important changes of traditional or introduced agricultural production methods. For all longer-term improvements and investments, secure land rights are an essential precondition. Conservation Agriculture, System of Rice Intensification, Organic Farming and Agroforestry systems aim at a restricted use of external inputs or on low-input systems. Rainwater Harvesting can be build up with local materials. Nonetheless, some initial investments are needed, which can be a relevant hurdle for resource-poor small-scale farmers and is demanding public support.

In contrast, until today transgenic crops are restricted to a small number of cash crops and are mainly working in the frame of high-input production systems. The available GM crops can only partly and indirectly contribute to soil fertility. Pest management approaches with the current GM crops are simple strategies themselves. But nonetheless, these GM crops make more or less complex resistance management strategies necessary. The complexity of transgenic crops lays mainly outside the agricultural production system, in demanding risk assessment and management as well as regulation strategies and policies which are still considered to be inadequate or completely lacking in many developing countries.

1.3 The options for action

Starting from the importance of agriculture for development and the need for agricultural productivity growth, different agricultural production systems (and their technologies) were assessed in the STOA project "Agricultural Technologies for Developing Countries". From the assessed production system, Conservation Agriculture, System of Rice Intensification, Agroforestry systems and Organic Farming can be described as complex agricultural production systems of intensification by higher agro-ecological and biological productivity, without necessarily increasing external inputs (mineral fertiliser, pesticides). They have the potential to address especially the needs and possibilities of small-scale farmers.

Whereas approaches of so called Green Revolution aimed in the last decades on output maximisation and were input-intensive, more focus on the input optimisation is needed under the economic and environmental conditions of the 21st century. Low-input intensification refers to achieving higher crop yields without or with restricted additional external inputs, combined with an improved soil and water management. In such systems, the external input use is low relative to the high external inputs needed in intensive tillage-based systems or relative to European or Eastern Asian standards. Conservation Agriculture, System of Rice Intensification and Agroforestry do not exclude the improved use of external inputs such as mineral fertiliser.

With improving quality and health of soils (especially with increasing soil organic matter), the focus is on the higher efficiency of input use. Organic Farming is with its specific restrictions of agrochemical use so far a special case, which includes in its principles also social aspects and produce for a special market (with higher prices). Therewith, it is not applicable in all cases.

Development and introduction of low-input intensification is discussed also in the context of climate change which will disproportionately affect developing countries and the poor. Adopting agricultural systems to climate change is urgently needed because impacts are already evident and the trends will continue even if Greenhouse Gas (GHG) emissions are stabilised. The recognition of the links between tillage- and input-intensive farming and climate change processes make it vital for the world's farmers to raise output using methods that do not demand inputs based on fossil fuels and do not further compromise the natural resource base of agriculture and diverse ecosystems.

Low-input production systems have potentials for resolving current global issues affecting agriculture and the environment – e.g., slowing climate change through reduced fossil fuel use, reduced gaseous emissions, increased carbon sequestration from residue retention and build-up of soil organic matter; improved soil quality and health; reduction of the impacts on food security of seasonal weather volatility; contributions to watershed repair through reduced runoff, improvements in water quality and reduced siltation; reduction of desertification due to reduced erosion and increased permanent ground cover. However, means and capacity for advocacy and change are at present inadequate.

Acceptance of modified agricultural production methods and improved livelihoods can only be achieved when at the same time market access for the increased production is built up and the food chain requirements are met. The successful development, introduction and use of agricultural technologies and their integration into adapted practices in developing countries depend on many framing conditions. For example, longer-term investments as soil improvements depend on secure land rights. Better infrastructure is another important element in the process of alleviating poverty and providing opportunities for rural citizens in developing countries, because inter alia agricultural development is related to access to markets and services.

The identified options for action concentrate on the development, adaptation and introduction of the agricultural production systems Conservation Agriculture, System of Rice Intensification, Agroforestry systems, Organic Farming and Rainwater Harvesting – in other words, on possibilities of intensification by higher agro-ecological and biological productivity, with low external inputs. With the European Consensus on Development, the European development policy is focused on the Millennium Development Goals and poverty reduction. The importance of agriculture for development and the key role of small-scale farmers therein still have to be implemented into the practice of the European development cooperation. The potential of low-input intensification should be much more recognised. For European development policies and development cooperation, options for action are:

Policy commitment: Political and societal commitment is a key factor for the introduction and spreading of low-input agricultural production systems, which demand important changes of traditional or introduced agricultural production methods. The aim should be to bring the appropriate production system into the main stream of agricultural activity.

Incorporation into European development policies: European actors in development policy should be an advocate for giving agriculture high priority and for low-input intensification focused on small-scale farmers. Key elements for achieving these goals are:

Integration into the complex system of European development cooperation;

Lead donor arrangements;

Integration into international programmes and processes;

National and regional planning and programming.

Approaches for scaling-up: A single global strategy for up-scaling of Conservation Agriculture, System of Rice Intensification, Organic Farming, Agroforestry systems or Rainwater Harvesting will not work: The strategic approaches and principles must be tailored to countries, regions, farming systems or even local sites, reflecting specific technical, economic and social conditions.

Nonetheless the need for local adaptation, important components for scaling-up approaches are:

- Farmer-to-farmer extension and Farmer Field Schools;
- Linking large-scale and small-scale farmers;
- Share of knowledge;
- Support by counsel and education;
- Setting of standards and certification;
- Development of market access;
- Assessing benefits.

Introducing financial support: Beside support for scaling-up initiatives and activities, financial support to small-scale farmers is needed for some initial investments and for compensating possible decreasing profits and risk during the adaptation period as:

Incentives for changing production systems;

Introduction of price premiums.

Science and technology development: Conservation Agriculture, System of Rice Intensification, Organic Farming, Agroforestry systems and Rainwater Harvesting are dynamic systems which demand the development of new technological solutions, the making operational (and economically viable) of existing technologies and the local adaptation, particularly in smallholder systems. A close interaction between farmers and researchers is needed. Despite the importance of local adaptations, some areas overall relevant for science and technology development are:

- Production system research;
- Mechanisation;
- Biomass production and processing;
- Pest control;
- Water control;
- Adaptation to climate change;
- Socio-economic research.

Assessing the agricultural potential of GM plants: There are many arguments in favour of steering towards a problem-oriented approach in the assessment of potential future agricultural technologies and cultivation methods. For transgenic plants, this means examining green genetic engineering options without a predetermined result and in comparison to other approaches. In developing countries, potentials of GM plants are heavily dependent from adequate risk assessment and management, the solution of intellectual property right problems and the successful connection of centralised breeding activities with local adaptations.

European Agriculture: For the concerned promotion of production system changes in developing countries and the integration into development cooperation, own research capacities, knowledge bases and practical experiences with low-input intensification in European agriculture are desirable. Based on own practices and experiences and research and development activities, the recommended actions in development policies would be more credible and better founded.

2. BACKGROUND AND APPROACH

2.1 STOA Project "Agricultural technologies for developing countries"

The project investigates the contribution of selected important agricultural farming systems (Rainwater Harvesting, Conservation Agriculture, System of Rice Intensification, Organic Farming, Agroforestry systems and transgenic plants) and their technologies to higher food production and food security with focus on small-scale farmers and farming systems.

In recent years, a number of international assessments on agricultural science and technology and on international agricultural research activities have been undertaken. After pervasive underinvestment, this indicates that agricultural science and technology for and in developing countries has received increasing attention.

Developing countries include very diverse geographical areas, natural conditions, farming systems, economic and political structures. National Agricultural Research Systems are very different and need specific addressing.

It is broadly recognised that the development and application of science and technology alone will not have a significant impact on improving agricultural productivity or on reducing food insecurity (see Braun/Pandya-Lorch 2007). The adoption of technologies depends on many factors such as institutions, social groups (especially women), education, economic resources, market access and potential to reduce people's vulnerability to loss of income. In consequence, people have benefited unevenly from past agricultural improvements across regions, in part because of different institutional and political environments.

The challenges agriculture is facing will require a broad spectrum of technologies, from new and emerging technologies to traditional and community-based technologies, and in the first place more integrated approaches. Farming systems in developing countries are very diverse and range between large-scale, capital-intensive to small-scale, labour-intensive systems. At the same time, developing countries represent a broad range of climate zones and cultivation conditions, political systems and governance structures, states of economic development and structural transformation.

The STOA project aims to collect information about possible contributions of agricultural technologies in the frame of improved agricultural production systems (and the necessary conditions) to higher productivity and efficiency in agriculture, as a baseline for action in the framework of the EC development policy.

More specifically, objectives are:

- to assess key agricultural technology systems for small-scale farmers and
- to identify areas of action for capacity building and empowerment in developing countries.

For the project, it was necessary to reduce the indicated complexity to a manageable degree. Based on existing (general) assessments, the contribution of selected, important agricultural production systems and their technologies to higher food production and food security are investigated with focus on small-scale farmers and farming systems in developing countries. Further, the assessment is restricted to crop production.

In the focus of the project are the following agricultural production systems:

- Rainwater Harvesting,
- Conservation Agriculture,
- Agroforestry systems,
- Organic farming, and
- Transgenic plants.
- During the project execution, an additional case study on
- System of Rice Intensification was added.

2.2 Understanding of agricultural production systems

The project works with a broad understanding of agricultural production systems. In general, production systems include every step in cultivation and harvesting of crops (or steps in animal production). For specific agricultural production systems, an explicit definition is existing in many cases and principles for agricultural practices as well as soil and ecosystem management are formulated.

In the case of transgenic crops, the changes in agricultural crop growing are analysed together with the transgenic crops. Beside the agricultural production, the systemic specifics of transgenic crops are the requirements for biosafety, risk management and authorisation (see chapter 4.6).

A special case is Rainwater Harvesting (see chapter 4.1): In itself, it is not an agricultural production system but a set of techniques to collect rainwater, to store it if needed and to use it for irrigation. But Rainwater Harvesting can be an important component in rainfed agricultural production.

In the case of Organic Farming (see chapter 4.4), a legal definition exists in the EU. Genetically modified plants themselves are also legally defined. The definition of the other agricultural production systems is based on principles achieved by scientific consensus and/or by agreements in international organisations.

In this project, core ideas and essential characteristics of agricultural productions systems are in the focus and regarded as more important than definitions in the sense of classification. The intention is to understand their chances and problems, and to work out their dynamics.

All production systems have in common that they are usable for different crops and under a variety of agro-ecological conditions. They all need adaptation to local conditions.

In contrast to the more technical oriented understanding of agricultural production systems, farming systems describes more or less numerous groups of farming households which have broadly similar resource bases, enterprise patterns, household livelihoods and constraints. The farming systems approach gives more emphasis on horizontal and vertical integration, on multiple sources of household livelihoods, and on the role of the community, the environment and support services (Dixon et al. 2001). These contexts of household livelihoods are in this project discussed as framing conditions.

2.3 Objectives and approaches

The context of agricultural technologies for developing countries

The objective of chapter 3 is to give an overview on the strengths and weaknesses of the international agricultural science and technology system, the access to and adoption of agricultural technologies in developing countries and the possibilities and problems of improving agricultural productivity as well as of reducing food insecurity in developing countries. Special focus will be put on general framing conditions (as infrastructure, financing and corruption) which influence the introduction and successful use of agricultural technologies.

The analysis is based on a literature study and an evaluation of important international assessments. In recent years, a number of international assessments on agricultural science and technology were undertaken. These international assessments are in the focus:

- *World Development Report 2008 - Agriculture for Development of the World Bank* (World Bank 2007), for 25 years the first of the annual World Development Reports on agriculture.
- *International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD)* (IAASTD 2008a + b): IAASTD was endorsed as a multi-thematic, multi-spatial, multi-temporal intergovernmental process with a multi-stakeholder bureau, co-sponsored by FAO, GEF, UNDP, UNEP, UNESCO, World Bank and WHO. About 400 experts, nominated by stakeholder groups, contributed to IAASTD. Additional individuals, organisations and governments were involved in the peer review process. At the final intergovernmental plenary session in April 2008 in Johannesburg, South Africa, the Global Summary for Decision Makers was approved by 57 states, 3 states (Australia, Canada, USA) did not fully approve it and made reservations.[1]

[1] In 2008, only the Executive Summary of the Synthesis Report and the Global Summary for Decision Makers were available, the Synthesis Report and the five regional sub-global assessments were published in March 2009.

- *Comprehensive Assessment of Water Management in Agriculture (CA)* (Molden 2007): CA is an open process. More than 90 international and national research institutes, as well as local, regional, national and international organisations active in water, agriculture and environment are participating to the CA through specific research and development projects, with contributions of 700 agricultural and environmental scientists. CA was launched in 2001 and funded by the Governments of the Netherlands, Switzerland, Sweden, Taiwan, Japan, Austria as well as FAO, OPEC, CGIAR Challenge Program on Water and Food, the CGIAR Gender and Diversity Program, the EU through the ISIIM Project and the Rockefeller Foundation.
- *Study "Realizing the promise and potential of African agriculture" of the InterAcademy Council (IAC)* (InterAcademy Council 2004): The IAC was requested by United Nations Secretary-General Kofi Annan in March 2002 to undertake a study and develop a strategic plan by which the best of science and technology (S&T) could be harnessed to help Africa substantially increase its agricultural productivity, thereby contributing to improved food security. Leading scientific, economic and technological experts took part in the exercise.
- For specific issues, other major reports and publications were included to achieve a comprehensive overview.

The results of the case studies

The objective of chapter 4 is to give an overview on the results of the case studies. For every production system, information on characteristics of the production system, the current relevance and use, restricting framing conditions, potentials for improvement, and effects for small-scale farmers will be given. These summaries of results are based on the case studies, but the responsibility for selection and presentation of the results remains by the author.

Chapter 4 is the outcome of phase II of the project "Agricultural technologies for developing countries" and is based on the case studies. The case studies were carried out by:

- Case study "Rainwater Harvesting": Prof. Dr. Klaus-Dieter Balke, University Tübingen, Institute for Geoscience, Germany
- Case study "Conservation Agriculture": Dr. Theodor Friedrich, Prof. Dr. Amir Kassam, Francis Shaxson, FAO, Plant Production and Protection Division, Rome, Italy
- Case study "System of Rice Intensification": Prof. Dr. Norman Uphoff, Cornell University, Cornell International Institute for Food, Agriculture and Development (CIIFAD), USA, and Prof. Dr. Amir Kassam, FAO, Plant Production and Protection Division, Rome, Italy
- Case study "Organic Farming": PD Dr. Heide Hoffmann, Humboldt Universität zu Berlin, Germany
- Case study "Agroforestry systems": C. Marohn, terra fusca, Stuttgart, in cooperation with the University of Hohenheim, Institute for Agroecology and Plant Production in the Tropics and Subtropics, Germany

- Case study "Transgenic plants": Dr. Arnold Sauter, Institute for Technology Assessment at the German Bundestag (TAB), Germany

The case studies are documented in the annex.

The options for action

The objective of the last part of this report (chapter 5) is to work out policy implications and to present options for action. In this context, possibilities for European development policies and development cooperation are described. Due to the shared competency of Community and Member States for development cooperation, parliamentarians and policy makers in the Member States are at the same time addressed.

Areas of action and options for action were identified in the case studies. For the final report, these options for action were assessed, consolidated, complemented and concentrated by the project group.

A draft of the chapter "options for action" was reviewed by:

Dr. Paul Engel, European Centre for Development Policy Management (ECDPM), Maastricht, The Netherlands

Michael Brüntrup, German Development Institute, Bonn, Germany

Furthermore, the draft was commented by the authors of the case studies. Once again, the responsibility for selection and presentation of the options for action remains by the author.

3. THE CONTEXT OF AGRICULTURAL TECHNOLOGIES FOR DEVELOPING COUNTRIES

The objective of this chapter is to give an insight into the context in which agricultural technologies and agricultural production systems are used and have to be improved. It provides an overview on the strengths and weaknesses of the international agricultural science and technology system, the access to and the adoption of agricultural technologies in developing countries and the possibilities and problems of improving agricultural productivity and output on the one hand and of reducing food insecurity in developing countries on the other hand.

3.1 Agriculture in developing countries

An overview on agriculture in developing countries, including developments in the past, is given in this chapter. The dominance of small-scale farmers in global agriculture, and the importance of agriculture for development are worked out in chapter 3.1.1. In the next step, the productivity growth of agriculture in developing countries is analysed (chapter 3.1.2). Higher yields and productivity in developing countries drove the global agricultural development. The result was a net increase in global food availability over the last decades, but people have benefited unevenly from the yield increases across regions. The contribution of agricultural knowledge, science and technology to agricultural development and the pervasive underfunding of agricultural research are assessed in chapter 3.1.3. The investment of developing countries in their agriculture and the official development assistance for agriculture are described in the following chapter 3.1.4.

3.1.1 Agriculture, small-scale farmers and poverty

Rural population and agriculture

Around half of the world's population is living in rural areas. In developing countries, 3 billion people of 5.5 billion in total live in rural areas. *Agriculture constitutes the centre of their life.* An estimated 2.5 billion people of rural inhabitants in developing countries live in households involved in agriculture, 1.5 billion represent smallholder households. All in all, agriculture is the source of livelihood for an estimated 86% of the rural population in the developing world. It provides jobs for 1.3 billion smallholders and landless workers (World Bank 2007, p. 3). The share of rural population differs widely between regions, with Sub-Saharan Africa and South Asia having some 75% of its population in rural areas, North Africa and Central Asia some 50% and Latin America around 10%.

Many poor countries have still high agricultural shares in the Gross Domestic Product (GDP) and employment. In Sub-Saharan Africa, the share of agriculture in the GDP is 34% and 64% in employment (excluding South Africa). In countries in the $400-to-$1,800 GDP per capita range, many of them in Asia, agriculture accounts for an average of 20% of GDP and 43% of the labour force. In countries in the $1,800-to-$8,100 GDP per capita range, many of them in Eastern Europe and Latin America, these ratios decline to 8% and 22% respectively.

Adding the forward and backward links to agriculture typically increases the share in the economy by half or more, especially in the middle-income countries (World Bank 2007, p. 27).

With the growth of GDP per capita, agriculture's share declines, and so does its contribution to economic growth. The decline in share is nevertheless combined with an increase of the agricultural output in absolute values, because the non-agricultural sectors are growing faster. Therefore, *the large share of agriculture in poorer economies suggests that strong growth in agriculture is critical for fostering overall economic growth* (World Bank 2007, p. 28).

However, the importance of agriculture and agriculture-related post production processing activity including employment in the food processing, agro-industrial and agro-business sectors does not decrease in an absolute sense with overall economic development. In fact, the combined GDP of agriculture, agro-industry and agro-business in industrial countries in North America and Europe amounts to 15 to 20% of the total economy. In developing countries such as Malaysia where abject poverty is negligible, the agriculture-related GDP corresponds to 50% of the total national GDP. The economic importance of agriculture and its related sectors continues to grow as economies grow because there is redistribution of labour and economic opportunities along the supply and service chains.

Small-scale farmers

The vast majority of farmers in developing countries are small-scale farmers – also called smallholders or family farming. Estimated 85% of the farmers in developing countries produce on less than 2 hectares. In countries as diverse as Bangladesh, China, Egypt and Malawi, 95% of the farms are smaller than 2 hectares (World Bank 2007, p. 90).

In most countries, there is a dualism in the small-scale farming sector between market-oriented farmers and smallholders engaged in subsistence farming. Only a very small share of all marketed agricultural products is produced by subsistence-oriented farmers. The dualism in household farming strategies usually reflects differences in assets. Farmers with larger land endowments are more likely to be market-oriented. Educated household heads are often more likely to sell a large share of their products to the markets, while female-headed households more often produce for self-consumption (see chapter 3.2.9) (World Bank 2007, p. 78).

Poverty and hunger

Most of the poor in developing countries live in rural areas. 75% of the developing world's poor live in rural areas, whereas only 58% of its population is rural. Poverty rates in rural areas have declined in the past 10 years, but remain extremely high (World Bank 2007, p. 45).

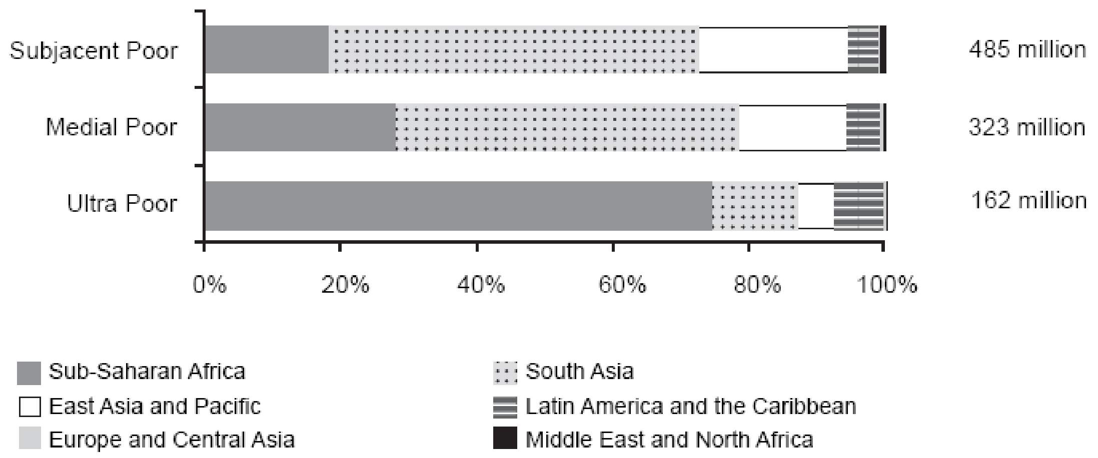
The recent decline in the overall $1-a-day poverty rate – from 28% in 1993 to 22% in 2002 – has been mainly achieved by reducing rural poverty (from 37% to 29%) while the urban poverty rate remained nearly constant (at 13%). *More than 80% of the decline in rural poverty is attributable to better conditions in rural areas* rather than to out-migration of the poor. In consequence, migration to cities has not been a main reason for overall poverty reduction (World Bank 2007, p. 3).

The decline in the number of rural poor (from 1,036 million in 1993 to 883 million in 2003) *has been mainly confined to East Asia and the Pacific.* In China and East Asia, GDP per capita more than tripled and the proportion of people in poverty fell from 56% to 17% over the past two decades. In contrast, in South Asia and Sub-Saharan Africa, the number of rural poor has continued to rise. In these regions, a high priority is seen to mobilise agriculture for poverty reduction (Pingali et al. 2006, p. 7; World Bank 2007, p. 4).

The newest assessment of the World Bank shows that poverty has been more widespread across the developing countries over the past 25 years than previously estimated. For 2005, the World Bank now estimates that 1.4 billion people, or one quarter of the population of the developing world, lived in poverty. This estimation is based on improved cost-of-living data for developing countries and a revised international poverty line of $1.25 a day. The new data further show that *there has been strong – but regionally uneven – progress towards reducing overall poverty* (Chen/Ravallion 2008). Contrary to this decline, first estimates show that the recent surge in food prices has caused another 100 million people in developing countries to fall into poverty (Fan 2008).

The severity of poverty (and hunger) also varies widely across regions of the world. Most of the subjacent poor (living on between 75 cents and 1$ a day) and medial poor (living on between 50 and 75 cents a day) live in South Asia, whereas most of ultra poor (living on less than 50 cents a day) live in Sub-Saharan Africa (see Figure 1). The poorest people tend to live in remote rural areas, have little education and assets and belong to socially excluded groups. Furthermore, the poor are not a static group. Although there exists no global data on movements into and out of poverty, some studies show that people are constantly moving in and out, even if the overall number of poor may not change significantly. Until today, the focus of development interventions is often on pulling people out of poverty, but not on preventing them from falling into poverty in the first place (Braun/Pandya-Lorch 2007, p. 3).

Figure 1: **Regional distribution of the poor in the Developing World**, 2004



Source: Braun/Pandya-Lorch 2007, p. 4

At FAO's 1996 World Food Summit (WFS), and again at the 2002 Millennium Summit, the international development community established an ambitious agenda for reducing hunger and poverty. The Millennium Development Goals (MDG) and the World Food Summit both set targets for 2015, using 1990 as a benchmark. As projections show, the goal of halving the proportion of people living in poverty (for 2015, in relation to 1990) may be achieved, but the absolute number in poverty may not be halved. Especially in Sub-Saharan Africa, the absolute number of poor continues to increase (Pingali et al. 2006).

The FAO estimates that 852 million people worldwide were undernourished in 2000-2002, of which 815 million live in developing countries. Just under two-thirds of the total number of undernourished are found in Asia and Pacific, followed by Sub-Saharan Africa, which accounts for nearly a quarter of the total (FAO 2004, p. 6-7; Pingali et al. 2006, p. 3).

Undernourishment is defined as food consumption insufficient to meet minimum levels of dietary energy requirements.

Food security is a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for active and healthy life.

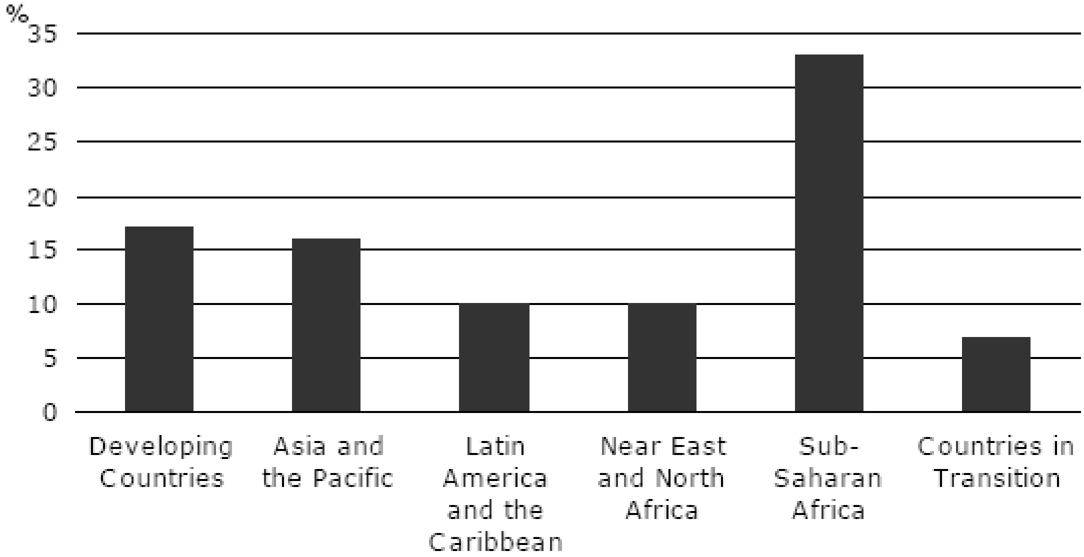
Food sovereignty is defined as the right of peoples and sovereign states to democratically determine their own agricultural and food policies.

(Pingali et al. 2006, p. 3; IAASTD 2008b, p. 18)

The proportion of the population which is undernourished varies between the different developing country regions (Figure 2), similar to the distribution of poor people. The highest incidence of undernourishment is found in Sub-Saharan Africa (an estimated 33%). This is well above the 16% undernourished estimated for Asia and the Pacific and the 10% estimated for both Latin America and the Caribbean and the Near East and North Africa (Pingali et al. 2006, p. 3). The vast majority of the world's chronically hungry population are small farmers and landless labourers in rural areas (UN Millennium Project 2005).

The Millennium Development Goal (and the WFS target) of halving the proportion of hungy people by 2015 may be achieved if high levels of investments and policy commitment are targeted towards hunger reduction. But the goal of reducing the actual number of hungry people by half by 2015 is probably not attainable, given current trends in hunger reduction and projected population growth rates (Pingali et al. 2006, p. 8). High global food prices have contributed to the difficulties of achieving hunger reduction.

Figure 2: Percentage of population undernourished in developing countries, by region, in 2000-2002



Source: Pingali et al. 2006, p. 4

Hunger and malnutrition inflict heavy costs on individuals and households, communities and nations. Undernourishment and deficiencies in essential vitamins and minerals are responsible for the death of more than 5 million children every year, account for more than 220 million years of productive life from family members of households in the developing countries whose lives are cut short or impaired by disabilities related to malnutrition and cost developing countries billions of dollars in lost productivity and consumption. For example, the FAO conducted a macroeconomic study to estimate the benefits of reducing undernourishment by meeting the target of WFS and MDG.

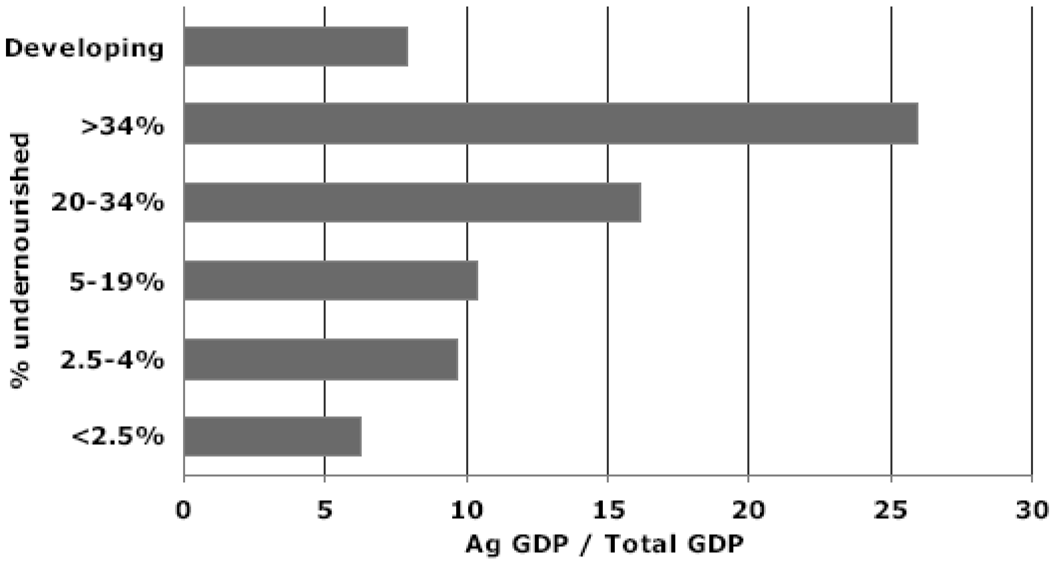
The study estimated the value of increased production that would be unleashed by reducing the number of undernourished people in developing countries to around 400 million by the year 2015. In result, it was estimated that an increase of just 24 billion $ per year in public investment would make it possible to attain the WFS and MDG goal and produce annual benefits of 120 billion $ (FAO 2004, pp. 8-13).

Agricultural growth and development

Formal, traditional and local agricultural knowledge, science and technology (AKST) have made positive contributions to addressing hunger, food security, human health and nutrition. Substantial gains in agricultural productivity (see chapter 3.1.2) have reduced rates of hunger and undernourishment, improved the health and livelihoods of many million people and stimulated economic growth in numerous countries. *Globally, until recently, food has become cheaper and average calories availability has increased.* In the mid-1960s, 57% of the world's population lived in countries where the average caloric availability was below 2,200 kcal, today the proportion is 10%. Gains in China, India, Brazil and Indonesia were primarily responsible for this improvement in average nutrition (IAAST 2008b, p. 17).

Agricultural growth plays a crucial role in enhancing food security and reducing poverty in developing countries. There is ample evidence that combating hunger and extreme poverty requires a renewed and expanded commitment to agriculture and rural development in developing countries. The dependence on agriculture is greater in those countries where hunger is most prevalent. Figure 3 presents the percentage share of agriculture in GDP in 1998-2002 for developing countries grouped according to the incidence of undernourishment in 2000-2002. For countries with more than one third of the population undernourished, the share of agriculture in GDP is almost 25% (Pingali et al. 2006, p. 8).

Figure 3: **Share of Agriculture in GDP and incidence of undernourishment**



Source: Pingali et al. 2006, p. 9

Cross-country estimates show that GDP growth originating in agriculture is at least twice as effective in reducing poverty as GDP growth originating outside agriculture. For China it is estimated that aggregate growth originating in agriculture was 3.5 times more effective in reducing poverty than growth outside agriculture, and for Latin America 2.7 times more. Rapid agricultural growth – in India following technological innovations (the diffusion of high yielding varieties) and in China following institutional innovations (the household responsibility system and market liberalisation) – was accompanied by major declines in rural poverty (World Bank 2007, p. 6).

The lessons learned to date suggest that no sustainable reduction in poverty is possible without improving rural livelihoods. Economic growth originating in agriculture can have a particularly strong impact in reducing poverty and hunger. Increasing employment and incomes in agriculture stimulate the demand for non-agricultural goods and services, providing a boost to non-farm rural incomes as well. This implies that additional demand for agricultural products must come from outside of the rural communities and the communities must be able to meet the expectations of these external markets (Pingali et al. 2006, p. 9).

Hunger reduction is needed as a first step for fast development and poverty reduction. Poverty is a cause of hunger, but it is equally true that hungry people will always be poor. Hungry people cannot take full advantage of a pro-poor development strategy because hunger negatively affects health, labour productivity and investment choices, perpetuating poverty. Investment in hunger reduction is too often seen as "welfare", whereas, in practice, it is an investment with a potential for generating high economic rates of return. It is obvious that hunger reduction is critical for reducing poverty but also for meeting the international goals related to health, child and maternal mortality, education and literacy.

Poverty reduction is more effective when carefully targeted programmes, such as food for work, provide immediate hunger relief. As another example, school meal programmes lead to long-term inter-generational gains in poverty reduction (Pingali et al. 2006, p. 9).

In conclusion, poverty and hunger reduction are a prerequisite for agricultural development, and agricultural growth is a prerequisite for combating poverty and hunger – both statements can be found in the literature, because they are closely connected. *The implication is that interplay is needed between policies for agricultural development and policies for poverty and hunger reduction.*

Types of countries and development

The way agriculture works for development varies across countries depending on how they rely on agriculture as a source of growth and as an instrument for poverty reduction. In the World Bank report, *three distinct rural worlds* are worked out, with three types of countries (see Table 1) (World Bank 2007, p. 4):

Agriculture-based countries: Agriculture is a major source of growth, accounting for 32% of GDP growth on average, mainly because agriculture has a large share of GDP. Most of the poor live in rural areas (70%). This group of countries has 417 million rural inhabitants, mainly in Sub-Saharan African countries. 82% of the rural Sub-Sahara population live in agriculture-based countries.

Transforming countries: Agriculture is no longer a major source of economic growth, contributing on average only 7% to GDP growth, but poverty remains overwhelmingly rural (82% of all poor). This group is typified by China, India, Indonesia, Morocco and Romania and has more than 2.2 billion inhabitants. 98% of the rural population in South Asia, 96% in East Asia and the Pacific and 92% in the Middle East and North Africa live in transforming countries.

Urbanised countries: Agriculture contributes even less to economic growth, 5% on average, and poverty is mostly urban. Even so, rural areas still have 45% of the poor. Agribusiness and the food industry and services account for around one third of GDP. This group with 255 million rural inhabitants includes most countries in Latin America and the Caribbean and many in Europe and Central Asia. 80% of the rural population in both regions live in urbanised countries.

Countries develop over time and they can move from one country type to another. China and India moved from the agriculture-based to the transforming group over the past 20 years. As another example, Indonesia develops in the direction of an urbanised country (World Bank 2007, p. 4).

Depending on the country type, *different priorities in the development agenda* can be identified (World Bank 2007, pp. 19-22):

Agriculture-based countries: Achieving economic growth and food security.

Transforming countries: Reducing rural-urban income disparities and rural poverty.

Urbanised countries: Linking small-scale farmers to modern food markets and providing good jobs.

Table 1: Characteristics of three country types

	Agriculture-based countries	Transforming countries	Urbanised countries
Rural population (millions, 2005)	417	2,220	255
Share of population rural (%, 2005)	68	63	26
GDP per capita (1000 US$, 2005)	758	2,136	6,978
Share of agriculture in GDP (%, 2005)	29	13	6
Annual agricultural GDP growth (%, 1993-2005)	4.0	2.9	2.2
Annual non-agricultural GDP growth (%, 1993-2005)	3.5	7.0	2.7
Number of rural poor (millions, 2002)	170	583	32
Rural poverty rate (%, 2002)	51	28	13

Source: World Bank 2007, p. 5

Large countries represent a regional heterogeneity that replicates the three worlds of agriculture. In very large countries, individual states may fall into different categories. India, an overall transforming country, also has agriculture-based states like Uttar Pradesh and Bihar and a few urbanised states. Similarly, Mexico as an overall urbanised country also has some transforming states and two agriculture-based states. In contrast to these examples, all states of Brazil are urbanised and in China all provinces but Hainan are transforming (World Bank 2007, p. 33).

Many countries with fairly high agricultural growth rates saw substantial reductions in rural poverty, for example (World Bank 2007, p. 45):

Vietnam, with land reform, and trade and price liberalisation;

Moldova, with land distribution;

Bangladesh, with rising farm and rural non-farm earnings and lower rice prices resulting from new technologies;

Uganda, with economic reforms and a resulting boom in coffee production;

Ghana, with better economic policy, better investment climate and high commodity prices.

But in some other countries rural poverty did not decline, despite agricultural growth, for example: Brazil and Bolivia, with agricultural growth concentrated in a dynamic export-oriented sector of very large farms (World Bank 2007, p. 45).

Beyond the rural-urban income divide, within-country heterogeneity in poverty across rural areas is a significant concern in many countries. Analyses for Brazil, Ecuador, Thailand, Malawi and Vietnam show that poverty rates tend to be higher in remote areas than in more accessible areas. *But the numbers of poor people (poverty density) are strikingly different from those for poverty rates (poverty incidence)*. In all the countries studied, the majority of the rural poor live in localities with good access. For example, in Brazil, 83% of the rural population lives within two hours of a large city. In contrast, there is no clear pattern among countries for the distribution of the poor population and agricultural potential. For example, whereas in Brazil most poor people (75%) live in low and medium agricultural potential areas, in Thailand and Cambodia more than 70 to 80% live in good agricultural potential areas (World Bank 2007, p. 49).

Where poverty incidence does not coincide with poverty density, there are important tradeoffs in the regional targeting of policy interventions. The greatest impact on poverty may be through fostering growth in more favoured regions where most poor people live. Yet the extreme poor in more marginal areas are especially vulnerable, and until migration provides alternative opportunities, the challenge is to improve the stability and resilience of livelihoods in these regions (World Bank 2007, p. 49).

3.1.2. Productivity growth

The productivity growth in developing countries drove the global agricultural development. From 1980 to 2004, developing countries achieved much faster agricultural growth (2.6% per year) than industrial countries (0.9% per year). During this period, developing countries accounted for 79% of the overall agricultural growth. Their share of world agricultural GDP rose from 56% in 1980 to 65% in 2004. The transforming economies in Asia accounted for two-thirds of the developing world's agricultural growth. Only Sub-Saharan Africa did not take part in rising cereal yields (World Bank 2007, p. 50-51).

Components of productivity growth

The major contributor to growth in Asia and the developing world in general were productivity gains rather than the expansion of land devoted to agriculture. Since the 1960s, rising cereal yields have been achieved primarily through improved crop varieties and increased inputs (irrigation respectively water use, agrochemicals like fertiliser) and mechanisation (IAASTD 2008, p. 8; World Bank 2007, p. 51). Asian agriculture has been intensified through expanding irrigation: Today 39% of the crop area in South Asia is irrigated, 29% in East Asia and the Pacific, but only 4% in Sub-Saharan Africa. In contrast to Asia, the increasing cereal production in Sub-Saharan Africa was mainly achieved by expansion of the cereal production area (World Bank 2007, pp. 51, 55).

Modern crop varieties of cereals were sown in the year 2000 on about 80% of the cereal area in South and East Asia, up from less than 10% in 1970. Although Sub-Saharan Africa is also expanding the use of improved cereal varieties, the respective value was only 22% in 2000 (World Bank 2007, p. 51).

Chemical fertiliser use expanded significantly in most of the developing countries, except Sub-Saharan Africa (see chapter 3.2.4). The developing-country share of global fertiliser use has risen from about 10% in the 1960s to more than 60% today. Asian farmers are the major users, with 143 kilograms per hectare in 2000-02, more than in developed countries (World Bank 2007, p. 51).

Livestock expansion has also contributed to high agricultural growth rates. Livestock is one of the fastest growing sub-sectors in developing countries, where it already accounts for a third of agricultural GDP. Production of meat has doubled over the last 15 years, led by a 7% annual increase in poultry production (World Bank 2007, p. 52).

Sub-Saharan Africa shows high variability among countries and over time. Only Nigeria, Mozambique, Sudan and South Africa maintained annual agricultural growth rates per capita of agricultural population above 2%. The yields of food staples are generally poor, even in the most recent period. The green revolution breakthrough in cereal yields has not reached Sub-Saharan Africa, where the adoption of productivity-enhancing inputs is still low. There are many reasons for this situation: dependence on rainfed agriculture, diverse food crops, poor infrastructure, policy discrimination against agriculture, and low investments (World Bank 2007, pp. 53-54).

Impacts of growing productivity

The increases in productivity have contributed to a net increase in global food availability: from 2360 kcal in the 1960s to 2803 kcal per person per day in the 1990s, and this at a time when world population significantly increased (IAASTD 2008b, p. 8).

But people have benefited unevenly from the yield increases across regions, in part because of different organisational capacities, socio-cultural factors and institutional and policy environments (IAASTD 2008b, p. 8). In most cases, countries with high growth rates of agricultural value added per capita of agricultural population – as China, Malaysia, and Vietnam – were also successful in their general rural poverty reduction.

In contrast, Brazil and Pakistan have been less successful in reducing poverty, mainly because of the highly unequal ownership of and access to productive assets such as land and irrigation water (World Bank 2007, p. 53).

The increasing yields and productivity have in many cases caused negative environmental impacts. These environmental consequences were often not foreseen and occurred over time, and some occurred outside traditional farm boundaries. For example, 1.9 billion ha and 2.6 billion people today are affected by significant levels of land degradation. Fifty years ago water withdrawal from rivers was one-third of what it is today, and currently 70% of freshwater withdrawal globally is attributable to irrigated agriculture, which in some cases has caused salinisation.

Around 1.6 billion people live in water-scarce basins. Agriculture contributes to climate gas emissions, about 60% of anthropogenic emissions of CH_4 and about 50% of N_2O emissions come from agriculture. Inappropriate fertilisation has led to eutrophication and large dead zones in a number of costal areas and some lakes. Inappropriate use of pesticides has lead to groundwater pollution and other effects, for example loss of biodiversity (IAASTD 2008b, p. 8).

While there was success in developing improved varieties and increasing fertiliser use, development of sustainable production systems have lagged behind, leading to environmental and health problems which beset the industrial and standardised production approaches which are input and supply driven with high negative externalities. This is beginning to change with practices such as Conservation Agriculture, Integrated Pest Management (IPM), System of Rice Intensification (SRI) and the use of Farmer Field Schools for farmer-based learning and empowerment.

The environmental shortcomings of agricultural practice associated with poor socio-economic conditions create a vicious circle in which poor small-scale farmers have to deforest and use new, often marginal lands, thus increasing deforestation and overall degradation. Loss of soil fertility, soil erosion and breakdown in agro-ecological functions lead to poor crop yields, land abandonment, deforestation and movement into marginal land, including steep hillsides. Existing multifunctional agricultural systems that minimise these problems have not been sufficiently prioritised for research (IAASTD 2008b, pp. 8-9).

Underlying agro-ecological conditions

Differences in agricultural growth have many reasons. The different performances reflect the huge diversity of agricultural production systems and their agro-ecological potential, their population density, their infrastructure and so on. The socio-economic framing conditions will be discussed in chapter 3.2.

Agricultural potential, especially that of rainfed agriculture, is highly sensitive to soil quality, temperature and rainfall. *Two-thirds of the developing countries' rural population (1.8 billion) live in areas with favourable agro-ecological conditions.* These are irrigated areas with 42% of the rural population, and humid and semihumid rainfed areas with reliable moisture, where 26% of the rural population live (World Bank 2007, p. 54).

But one-third or 820 million people live in less favoured rainfed areas, characterised by frequent moisture stress that limits agricultural production. These less favoured areas account for 54% of all agricultural land and for 45% of the cropped area, but produce only 30% of the total value of agricultural production. Latin America, the Middle East and North Africa as well as Sub-Saharan Africa have fairly high shares of rural population in these moisture-stressed areas (World Bank 2007, p. 54).

The so called Green Revolution showed that well regulated crop water access is crucial for stable long-term yield increases. Not only because yield growth is directly related to plant water uptake, but also because secured crop water supply reduces risks for crop failure, thereby increasing farmers' incentives to invest in farm inputs, such as fertilisers, hybrid seed and pest management.

Even though irrigation plays a very important role in supplying foods, the potential for further increasing water withdrawals for irrigation is considered limited. *Despite the higher risks of crop yield fluctuations in rainfed agriculture in drought prone areas, rainfed agriculture will have to contribute considerably to higher agricultural production.* A significant gain in crop production in rainfed agriculture will therefore have to come from small-scale harvesting of water in combination with protective irrigation (SIWI 2001). In this STOA project, production systems based on Rainwater Harvesting will be examined more deeply in one of the case studies (chapter 4.1). Similarly, in the case of Conservation Agriculture, up to 100% of rainfall can be effective as there is a very large improvement in infiltration rate so that all the rainfall water is captured, which will be analysed in more detail in one of the other case studies (chapter 4.2).

Climate change will have negative impacts on agriculture which will disproportionately affect the poor (see chapter 3.2.3). Crop-climate models predict a small impact on global agricultural production because negative impacts in tropical and mostly developing countries are offset by gains in temperate and largely industrial countries, under moderate to medium estimates of rising global temperature (1-3^{o}C). In tropical countries, even moderate warming (1^{o}C for wheat and maize, 2^{o}C for rice) can reduce yields significantly because many crops are already at the limit of their heat tolerance. Further, climate change will probably increase droughts and floods. Dry subtropical zones like the Middle East and North Africa are likely to become even drier. It is also assumed that, worldwide, population growth and economic development will cause greater water shortages and water stress than climate change alone (Falkenmark et al 2007, p.4; World Bank 2007, p. 200).

Future productivity growth and food security

Projections based on a continuation of current policies and practices indicate that global demographic changes and changing patterns of income distribution over the next 50 years will lead to different patterns of food consumption and increased demand for food. In the reference run, global cereal demand is projected to increase by 75% between 2000 and 2050, and global meat demand is expected to double. More than three-fourths of growth in demand in both cereals and meat is projected to be caused by developing countries.

This will probably lead to a tightening of world food markets with increasing resource scarcity adversely affecting poor consumers and poor producers. Overall, current terms of trade and policies and growing water and land scarcity, coupled with projected changes in climate, is projected to constrain growth in food production (IAASTD 2008b, p. 9).

The uncertainty of future developments is demonstrated by an IFPRI study on policy scenarios for Africa (Rosegrant et al. 2005):

- The business-as-usual scenario assumes a continuation of current trends and existing plans in food policy, management and investment. Investments by international donors and national governments in the agricultural sector continue to decline through 2025. Under this scenario, per capita kilocalorie consumption in Sub-Saharan Africa is projected to increase from 2,231 kilocalories per capita per day in 1997 to 2,526 kilocalories in 2025, lagging behind the rest of the world. Although kilocalorie consumption rises and the percentage of malnourished children under the age of five (as an important indicator for food security) falls from 32.8 to 28.2% in Sub-Saharan Africa, the absolute number of malnourished children rises from 32.7 million in 1997 to 38.3 million in 2025.
- The pessimistic scenario envisions a future in which trends in agricultural production and nutrition deteriorate by comparison with business-as-usual. African countries experience a decline in both domestic and international investments. Education investments fall, and higher numbers of households lack access to clean water in 2025. HIV/AIDS continues to affect a large proportion of the population in many African countries. Malnutrition in Africa proliferates under this scenario. Daily per capita kilocalorie availability in Sub-Saharan Africa increases only slightly under this scenario, to 2,333 kilocalories in 2025, cutting improvements made under business-as-usual by almost 300 kilocalories. The total number of malnourished children less than five years old in Sub-Saharan Africa escalates from 32.7 million to 55.1 million in 2025. The share of malnourished children in Sub-Saharan Africa also increases under the pessimistic scenario, from 32.8% in 1997 to 33.2% in 2025.
- The vision scenario attempts to show what type of transformation would be necessary for Africa to battle childhood malnutrition as effectively as the rest of the developing world. This scenario models the interventions necessary to reach the Millennium Development Goal (MDG) target of cutting the proportion of people suffering from hunger in half by 2015. In this scenario national governments and international donors increase investments in African countries to help overcome many of the challenges agriculture is facing today.

- Labour productivity increases through greater investments in education and HIV/AIDS prevention and treatment. Improvements are also seen in productivity in rainfed areas, thanks to water-harvesting technologies and extension assistance to farmers. Under this scenario, available kilocalories per capita increase in Sub-Saharan Africa to 3,455 per day in 2025. The total number of malnourished children in Sub-Saharan Africa is reduced to 9.4 million in 2025.
- Most notably, the percentage of malnourished children younger than five years meets – or comes close to meeting – the proposed MDG target of cutting the percentage of malnourished children in half by 2015 in all African regions. But these results are difficult to achieve. This scenario requires a 78% increase in projected investments for Africa over business-as-usual levels, for a total of $303 billion. Investments in rural roads would need to rise 56% above business-as-usual levels, in education 117%, in clean water 55%, in irrigation 141% and in agricultural research 44%.

Part of the policy conclusions is that the management of crops, agricultural pests, land and soil, water and inputs must be improved through environmentally friendly practices. Sustainable productivity growth is one of the keys to food security improvements. Thus, agricultural input and crop technologies should focus on land and natural resources conservation, while at the same time increasing agricultural productivity. Agricultural policy must also take into account the importance of secure land tenure in encouraging farmers to make agricultural investments (Rosegrant et al. 2005, p. 5).

3.1.3 Agricultural knowledge, science and technology

Agricultural knowledge, science and technology (AKST) have accounted for substantial increases in agricultural production over time (chapter 3.1.2), contributing to food security. This has been achieved primarily through a strong focus on increasing yields with improved varieties, increased inputs (water, agrochemicals) and mechanisation (IAASTD 2008b, p. 8). On the other side, there is a pervasive underfunding of agricultural research. Public spending on research slowed sharply in most regions in the last decades, opening a knowledge divide between poor and rich countries. The rich-country support for the international agricultural research systems was reduced (Pardey et al. 2006a, World Bank 2007, p. 166).

Agricultural research expenditures

In developing countries, 94% of the agricultural research and development (R&D) is conducted by the public sector so that private investment in agricultural R&D has been very limited (World Bank 2007, p. 166).

Worldwide public investments in agricultural research grew by 51% (in inflation-adjusted terms) during the past two decades, from an estimated $15.2 billion (2000 international dollars) in 1981 to about $23 billion in 2000 (see Table 2).

This public spending was concentrated in only a handful of countries. Just four countries – the United States, Japan, France, and Germany – accounted for two-thirds of the $12.8 billion of public research done by developed countries in 2000. Similarly, four developing countries – China, India, Brazil, and South Africa – spent almost 50% of the developing world's public agricultural research money in 2000 (Pardey et al. 2006b; World Bank 2007, p. 167).

Table 2: Total public agricultural R&D expenditures by regions

	Public agricultural R&D spending (in millions international $2000)		R&D spending as % of agricultural GDP	
	1981	2000	1981	2000
Sub-Saharan Africa	1,196	1,461	0.84	0.72
Asia + Pacific	3,047	7,523	0.36	0.41
China	1,049	3,150	0.41	0.40
India	533	1,858	0.18	0.34
West Asia + North Africa	764	1,382	0.61	0.66
Latin America + Caribbean	1,897	2,454	0.88	1.15
Brazil	690	1,020	1.15	1.81
Developing Countries	**6,904**	**12,819**	**0.52**	**0.53**
Japan	1,832	1,658	1.45	3.62
United States	2,533	3,828	1.31	2.65
Developed Countries	**8,293**	**10,191**	**1.41**	**2.36**
Total	**15,197**	**23,010**	**0.79**	**0.80**

Source: World Bank 2007, p. 167

A dramatic slowdown in agricultural R&D spending took place in the first half of the 1990s, after rapid growth during the 1970s and early 1980s. In the industrial countries, the public spending shrank annually in inflation-adjusted terms (by 0.58%) between 1991 and 2000. Investment in Africa grew by only 0.82% per year, much slower than in the 1980s. Reasons were the debt crises in the 1980s, the slow-down of government spending and the waning of donor support in the 1990s. Spending growth slowed also in the Middle East and North Africa and in Asia, with the exceptions of China and India.

In Latin America as a whole, annual growth in spending was higher in comparison to other regions and the previous decade (2.06% per year from 1991 to 2000). But the recovery in Latin America seems fragile and is not shared throughout the region. Many of the poorer (and smaller) countries have failed to experience sustained growth in funding for the past several decades (Pardey et al. 2006b, p. 4). *Overall, there is a pervasive underinvestment in agricultural R&D*.

Adding up public and private spending, developing countries invest only a ninth of what industrial countries spend for agricultural R&D as a share of agricultural GDP. Thus, *the knowledge gap between industrial and developing countries is widening* (World Bank 2007, p. 14).

African countries face specific disadvantages because the specificity of their agro-ecological features gives them fewer opportunities to benefit from international technology transfer, and the small size of most African countries prevents them from benefiting from economics of scale in R&D. Low investments in R&D and low international transfer of technology have gone hand in hand with stagnant cereal yields in Sub-Saharan Africa, widening the yield gap with the rest of the world (World Bank 2007, p. 14).

The following *reasons for the underinvestment in agricultural R&D* are seen by the World Bank (World Bank 2007, p. 166-167):

Agricultural R&D investments are long-term (10 years and more) and risky, but political decisions on public spending tend to emphasise short-term payoffs and subsidies that are "visible".

Trade distortions and national policies with disadvantages for farmer in developing countries are a disincentive to both public and private R&D investments.

For small countries it might make not much sense to spend their scarce resources on agricultural science as long as they can benefit from spillovers of R&D results from other countries.

International agricultural research funded by CGIAR

The Consultative Group on International Agricultural Research (CGIAR), established in 1971, has 64 members and supports 15 international agricultural research centres (see box). CGIAR members include 21 developing and 26 industrialised countries, four co-sponsors as well as 13 other international organisations. CGIAR collaborates with many hundreds of government and civil society organisations as well as private businesses around the world. Today, more than 8,000 CGIAR scientists and staff are active in over 100 countries throughout the world. An important task for 11 of the CGIAR centres is to maintain gene banks, which preserve and make readily available the plant genetic resources that form the basis of food security worldwide in the long run (CGIAR 2008).

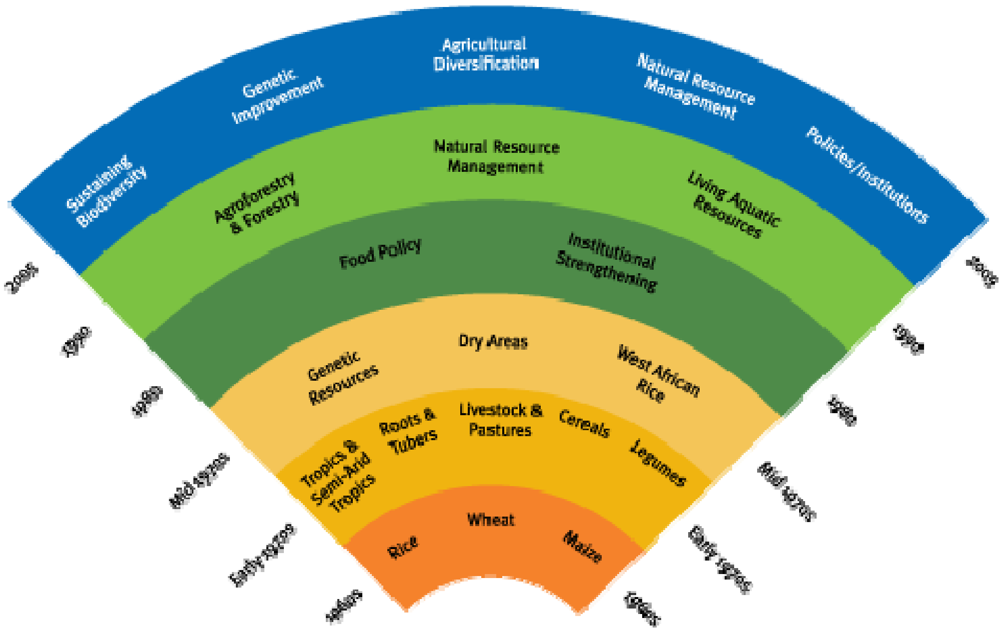
The total CGIAR system revenues in 2007 were $520 million, an increase of $72 million (16%, or 14% in real terms) from $448 million in 2006. Of the total contributions of $495 million, 36% was unrestricted, a decrease of 6 percentage points from 42% in 2006. Correspondingly, restricted contributions increased in 2007 to 64% from 58% in 2006. Nearly half of the contributions ($222 million) in 2007 came from European countries (CGIAR 2008, p. 55).

International Agricultural Research Centres
Africa Rice Center WARDA (Cotonou, Benin)
Bioverstity International (Rome, Italy)
Centro Internacional de Agricultura Tropical – CIAT (Cali, Colombia)
Center for International Forestry Research – CIFOR (Bogor, Indonesia)
Centro Internacional de Mejoramiento de Maiz y Trigo – CIMMYT (Mexico City, Mexico)
Centro Internacional de la Papa – CIP (Lima, Peru)
International Center for Agricultural Research in the Dry Areas – ICARDA (Aleppo, Syrian Arabian Republic)
International Crops Research Institute for the Semi-Arid Tropics – ICRISAT (Patancheru, India)
International Food Policy Research Institute – IFPRI (Washington DC, USA)
International Institute of Tropical Agriculture – IITA (Ibadan, Nigeria)
International Livestock Research Institute – ILRI (Nairobi, Kenya)
International Rice Research Institute – IRRI (Los Banos, Philippines)
International Water Management Institute – IWMI (Colombo, Sri Lanka)
World Agroforestry Centre ICRAF (Nairobi, Kenya)
World Fish Center (Penang, Malaysia)

CGIAR focuses on five areas:

- Sustainable production (crops, livestock, fisheries, forests and natural resources),
- Enhancing national capacities (through joint research, policy support, training and knowledge-sharing),
- Germplasm improvement (for priority crops, livestock, trees and fish),
- Germplasm collection (including holding in public trust the world's largest seed collections in 11 gene banks),
- Policy (fostering research on policies that have a major impact on agriculture, food, health, spread of new technologies and the management and conservation of natural resources).

Figure 4: Development of CGIAR Research focuses



Source: http://www.cgiar.org/impact/index.html (18.09.2008)

The research focuses of the CGIAR centres have evolved over time (Figure 4). Starting with semidwarf varieties of rice and wheat and improved varieties of maize from international agricultural research centres of the Consultative Group on International Agricultural Research (CGIAR), public breeding programmes in developing countries have released more than 8,000 improved crop varieties over the past 40 years. The contribution of improved crop varieties to yield growth since 1980 has been even larger than in the Green Revolution decades. Without this gain in yields, world cereal prices would have been 18-21% higher in 2000, and caloric availability per capita in developing countries would have been 4-7% lower (World Bank 2007, p. 159 et seq.).

Another focus is on improving the management of crops, livestock and natural resources. The CGIAR invests about 35% of its resources in sustainable production systems, twice the 18% it invests in genetic improvement. Much of this work has emphasised soil and water management and agro-ecological approaches that exploit biological and ecological processes to reduce the use of non-renewable inputs, especially agricultural chemicals. Examples include conservation agriculture, green manure cover crops, soil conservation and pest control using biodiversity and biological control more than pesticides (World Bank 2007, p. 163).

There is criticism that CGIAR pursued the wrong type of research. For example, CGIAR is seen weak in agronomic research and in systems development research. Consequently, agronomic practices, integrated pest management technologies, Conservation Agriculture, System of Rice Intensification practices and social research have received little attention compared to germplasm enhancement and crop improvement research. The negligible socio-cultural research in the CGIAR over the past three decades is mentioned as a particularly serious case (Cernea/Kassam 2006).

Research approaches

The traditional linear process by which the results of research are passed on to extension services for dissemination to farmers has produced many important advances in agriculture, but also failed in many cases. Some 'solutions' remained on the research station shelves because, although they show technical potential, they were poorly adapted to the complex situations of farmers in developing countries. Farming systems research, which emphasises on-farm experimentation, has had considerable success on participating farms or locally, but also often failed to spread further to neighboring localities. Reasons are for example insufficient access to inputs such as fertiliser and price reductions in case of local production increases (Jones 2004).

In response to these problems, new integrated approaches were developed. The dominant model now regards national agricultural research systems within an innovation framework. Therewith, research, extension and education, farmers and non-governmental organisations should be integrated around a common goal: the generation, dissemination and use of innovations. Such integration emphasises a non-linear pattern of interaction and feedback between research and development and other related organisation (Jones 2004).

However, such participatory processes in themselves do not give rise to discovering what types of production systems and practices should be promoted to capture sustainable agricultural intensification. For this, an additional dimension of vision and understanding of how scientific principles can be converted to real-life practices adaptable by farmers is needed.

Changing research agenda in industrial countries

International spillovers of public (and private) agricultural R&D results are extremely important. The world's poorest countries are highly dependent on the spillover of technologies from industrialised countries (especially the United States and the Member States of the European Union), both individually and through the CGIAR. Until recently, successful innovation efforts in most developing countries took place mainly at the very end of the innovation process, for example, by selecting and adapting varieties for local conditions using breeding lines and other material developed elsewhere. Only a few large countries, as Brazil, China and India, were able to conduct works successfully at the more upstream stages of the research and innovation process (Pardey et al. 2006b, detailed in Pardey et al. 2006a).

But now the research agenda of industrial countries is shifting. In rich countries, emphasis on enhancing the production of staple food is declining. Instead, environmental and health issues of production and products are gaining importance. Examples are certain attributes of food (such as processed food and so-called functional food), environmentally friendly agricultural production systems (as Conservation Agriculture, Organic Farming, local food) and food security (Pardey et al. 2006b).

Additionally, the differences between poor and rich countries are growing in the use and innovation demand of technologies for producer and processors. For example, precision farming technologies and other capital-intensive technologies are in development for farmers in rich countries. These are often not relevant for farmers in developing countries, especially for subsistence agriculture. As well as differences in value-adding processes to serve consumer demands, there are differences in farm production technologies to serve evolving agribusiness demands for farm products with specific attributes to serve particular food, feed, energy, medical or industrial applications (Pardey et al. 2006b).

Furthermore, the rise of modern biotechnology and enhanced intellectual property rights (IPR) regimes mean that the types of technologies that were once freely accessible will be more difficult to access in the future. Biotech companies are mostly located in the rich countries – particularly in the United States – and they emphasise technologies that are applicable at home (Pardey et al. 2006b).

In summary, the industrial countries will no longer provide the same level of productivity-enhancing agricultural technologies, suitable for adaptation and adoption in developing countries, as they did in the past. The consequence is an increasing pressure for more self-reliance of developing countries in the development of applicable agricultural technologies. Less-developed countries may have to extend their own R&D efforts further upstream to more strategic areas of science. They may also increasingly harness improved technologies and practices through South-South cooperation as is beginning to occur. But self-reliance will be beyond the possibilities of many poor countries so that a strengthening of multinational efforts is needed (Pardey et al. 2006b).

Returns from research

Agricultural productivity improvements have been closely linked to investments in agricultural R&D. Published estimates of nearly 700 rates of return on agricultural R&D and extension investments in developing countries average 43% return a year. Returns are high in all regions. The high payoffs also indicate that agricultural science is grossly underfunded (World Bank 2007, p. 165).

Policy conclusions

The strengthening of agricultural knowledge, research and development as well as their extension and their sharply increased public funding are broadly recognised recommendations (IAASTD 2008a, p. 7; Pardey et al. 2006b, p. 6; World Bank 2007, p. 14).

Beyond the common demand for higher recognition and investment in agriculture, the proposed strategies for development show different emphasis and priorities, which will be discussed in chapter 3.3.

3.1.4 Public spending and development assistance

The development of agricultural productivity and the contributions of agricultural research and development depend on public spending on agriculture in the developing countries and on official development assistance given by the rich countries.

Public spending on agriculture

Successful countries have invested in agriculture before taxing it (directly and indirectly) *to finance industrial development*. The share of public spending on agriculture in agriculture-based countries (mostly in Africa) is significantly lower (4% in 2004) than in the transforming countries during their agricultural growth decade (10% in 1980). *The low levels of agricultural spending in Sub-Saharan Africa are insufficient for sustained growth.* In Asia and Latin America, the decline in public funding for agriculture partly reflects agriculture's declining importance in their national economy (see Table 3). Recently, there have been reversals in several countries, including China, India and Mexico, motivated by the need to fight poverty and to narrow the rural-urban income gap (World Bank 2007, pp. 40-41).

Table 3: Public spending on agriculture

	Agriculture-based countries		Transforming countries		Urbanised countries	
	1980	2004	1980	2004	1980	2004
Public spending on agriculture as a share of total public spending (%)	6.9	4.0	14.3	7.0	8.1	2.7
Public spending on agriculture as a share of agricultural GDP (%)	3.7	4.0	10.2	10.6	16.9	12.1
Share of agriculture in GDP (%)	28.8	28.9	24.4	15.6	14.4	10.2

Source: World Bank 2007, p. 41

High taxation of agriculture is associated with low growth in agriculture, and slower growth in the economy as a whole. The poorest developing countries taxed agriculture the most, and reinvestments of tax revenues in agriculture were low and inefficient. (World Bank 2007, p. 98)

The composition of government expenditures varies across regions. In 2002, the top three areas of expenditure for Africa were education, defence and health. In Africa, the spending on agriculture, transportation and telecommunications has gradually declined. Asia has steadily increased the spending on education and social security, but the region's spending on agriculture has decreased by roughly half. Asian governments have also reduced their spending on health as a share of total government spending, which indicates that the economy is continuing to recover from the 1997 Asian financial crisis. In Latin America, social security ranks at the top of all government expenditures, while agriculture accounts only for a small fraction, reflecting the small share of agriculture in national GDP (Fan 2008).

Development assistance

The share of agriculture in official development assistance (ODA) declined sharply over the past two decades, from a high of 18% in 1979 to 3.5% in 2004. The agricultural ODA also declined in absolute terms from about $8 billion (2004 US$) in 1984 to $3.4 billion in 2004. The ODA from multilateral financial institutions (especially from the World Bank) declined more than the bilateral ODA (World Bank 2007, p. 41).

The figures of ODA for "agriculture" do not include "rural development" (which is classified in the statistical code of the OECD/DAC as multisectoral aid) or "food aid" (a subcategory of general programme assistance). Therefore, the recent trend towards programme-based approaches and multisectoral projects is not reflected in the statistics and underestimates to some extend the ODA for agriculture (World Bank 2007, p. 41, endnote 52).

In the late 1970s and early 1980s, most agricultural ODA went to Asia, especially India, in support of the Green Revolution. Thereafter, it declined dramatically. Total ODA to agriculture in Africa increased somewhat in the 1980s, but is now back to the level of 1975 of about $1.2 billion. This declining attention to agriculture took place in parallel to the rising rural poverty (World Bank 2007, p. 41-42).

In almost all Least Developed Countries (LCD), official development assistance (ODA) is the main catalyst of investment in agriculture. The total ODA to LCDs increased from $12.4 billion to $23.4 billion between 1999 and 2003, but the share addressed to the agricultural sector declined from 19% to 15% during the same period. Changing this trend in external assistance is seen as essential to enhance agricultural productivity (UNDP 2007, p. 5).

A number of reasons can explain the declining donor support to agriculture and rural development (World Bank 2007, p. 42):

Falling international commodity prices made agriculture less profitable and attractive in developing countries.

The competition within ODA increased, especially from social sectors.

Emergency responses to numerous crises were necessary.

Farmers and stakeholders in some donor countries objected the support of agriculture in their major export markets.

Opposition from some environmental groups who pointed out agriculture's contribution to natural resource destruction and environmental pollution.

Failed agricultural development efforts influenced the expectation of donors.

As the last point mentioned, the reduction of ODA to agriculture can be related with past unsuccessful interventions, such as large-scale integrated rural development and the training-and-visit system for extension, which were both promoted heavily by the World Bank. Poor understanding of agrarian dynamics, weak governance and the tendency of donors to seek one-size-fits-all approaches contributed to the failures (World Bank 2007, p. 42).

Another factor in the continuing decline in the funding of research by governments, donors and international financial institutions since the 1980s was the notion that technologies available 'on-the-shelf' are sufficient to solve all or most agricultural problems in Africa. For example, the World Bank funding for African agricultural research went from a peak of $120 million in 1991 to $8 million in 2002 (in 1993 US dollars). That of USAID went from a peak of $80 million in 1982 to $4 million in 1999 (InterAcademy Council 2004, p. 126).

The Study Panel of the InterAcademy Council concurs with a short-term strategy of exploiting technologies on-the-shelf by enhancing investments in infrastructure, adaptive and participatory research with farmers by improved policies, market access and information. However, keeping the technology pipeline flowing requires a renewed emphasis on long-term strategic and applied research in, and for, Africa by Africans. This type of research has much longer lead and lag times than adaptive research. The lack of priority accorded to agricultural research in the Poverty Reduction Strategy Papers does not augur well for this to happen. However, there may now be a window of opportunity for the renewal of the priority accorded to agricultural research with the New Partnership for Africa's Development (NEPAD 2002) (InterAcademy Council 2004, p. 126-127).

3.2 Framing conditions

The successful development, introduction and use of old and new agricultural technologies in developing countries depend on many framing conditions. Major facts and problems are discussed for land rights and access (chapter 3.2.1), water (chapter 3.2.2), climate change (chapter 3.2.3), inputs (chapter 3.2.4), financing (chapter 3.2.5), infrastructure (chapter 3.2.6), changing food chains (chapter 3.2.7), education and health (chapter 3.2.8), gender (chapter 3.2.9) and governance (chapter 3.2.10).

3.2.1 Land rights and access

Land is one of the most important assets for rural people in developing countries. Land combines being a factor of production, with its role as family or community property, a capital asset and a source of identity. Land tenure systems are made up of rules, authorities, institutions and rights. Missing or insecure land tenure is closely linked to poverty, hunger and the displacement of small farmers, peasant farmers, indigenous farmers from rural to urban areas and cultural and biodiversity erosion. Secured and increased access to land and natural resources for the landless and land-poor families is a key means of achieving food security and poverty reduction.

In developing countries, roughly 100 million farm families, compromising about 500 million people, lack ownership or owner-like rights to the land they cultivate. Most of these families earn their living as tenant farmers or agricultural labourers. The tenant farmers typically pay high rents and have little security of land possession from season to season. The landless agricultural labourers generally work for extremely low wages and often as itinerants. These people belong to the poorest.

They constitute majorities, or near-majorities, of the agricultural population in countries such as India, Bangladesh, Pakistan, Indonesia, the Philippines, South Africa, Brazil, Colombia, Guatemala and Honduras (Prosterman/Hanstad 2003, p. 1).

A smaller group of 25 million households, or about 125 million people, have insecure tenure, often on public lands. Some of these families are economically desperate squatters who have moved onto the land to cultivate it. Others are traditional landholders, often indigenous groups, who have occupied the land for decades or more. Their rights are often recognised by customary law, but not adequately by the state's formal laws. In this group are included some traditional pastoralists who use land in extensive or migratory patterns, but without sufficiently recognised group tenure rights to the land. In some cases, these holders come into conflict with settlers, ranchers, loggers or miners today (Prosterman/Hanstad 2003, p. 2).

Latin America has the most unequal land distribution system in the world, despite longstanding land reform programmes. Market-based reforms failed in the past. There is also a large group of landless people. Furthermore, Latin America has a large number of squatters and others with informal holdings, but no legal status. Finally, there are major areas in which indigenous peoples and minority groups claim rights (Armbrecht et al. 2008, p. 18; EU Task Force on Land Tenure 2004, p. 12).

In *Africa*, a very low part of land is subject to title, with strong customary and colonial legacy, colonial administration, structures and legislation. The result is legal pluralism with many conflicting and overlapping laws and systems for land administration, establishing land claims and conflict resolution. Common property resources are essential for poorer groups. More than 30% of the land in Africa is jointly held by members of a group or community, making common property rights as important as individual rights. Major disparities exist within the continent: in East & South Africa large-scale alienation of land by colonial powers, commercial farmers and national parks can be observed; West Africa experiences the continued strength of customary powers, overlaid by sequence of legal, political and institutional changes; and North Africa has a legacy of strong central governmental control with few incentives for local management (EU Task Force on Land Tenure 2004, p. 12; Meinzen-Dick/Mwangi 2006).

Asia shows a continued duality of customary and statutory systems with relatively little land subject to title. Development in Asia is characterised by population pressure, a declining size of holding and growing landlessness. Strong centralised systems of land administration lead to lengthy bureaucratic procedures and backlog land disputes. Major problems are exploitative tenancy arrangements, unresolved indigenous rights claims and conflicts between titling and the common property system of regulating access to land (EU Task Force on Land Tenure 2004, p. 12).

Land tenure reform policies

Although the term “land reform” is still associated with redistribution of land, there are many types of land tenure reform or land policy. Four broad categories can be distinguished (Meinzen-Dick/Di Gregorio 2008, p.2):

Registration of existing rights to land, which can range from relatively simple registration procedures to full cadastral surveys and titling.

Redistribution, including state or market led land reform, to achieve a more equitable distribution of land.

Restitution, rectifying past injustices by reinstating rights or providing alternative land where original landholders were evicted by war, conquest, forced collectivisation or other expropriation deemed unjust.

Recognition of rights that are currently being exercised by individuals or groups, but have not previously been sanctioned by the state.

These different forms of land tenure reform have different characteristics and objectives (Table 4). Only some important points can be highlighted in this background paper.

Table 4: Comparison of different types of land tenure reform

Type of reform	Registration	Redistribution	Restitution	Recognition
Objective	Strengthen existing rights	Transfer from large landowners to landless	Transfer land back to original holders	Strengthen existing rights
Context	Customary tenure	Highly unequal landholdings	History of expropriation or conflict	Indigenous people, others using forests, rangelands, etc.
Type of rights	Ownership	Ownership	Ownership	Use, some management rights
Individual/collective rights	Usually individual	Usually individual	Usually individual	Usually collective
Potential role of decentralised bodies	Identify right holder, keep local registry, conflict solution	Identify recipients (and sellers if market-based), conflict solution	Identify rightful claimants, conflict solution	Identify claimants, manage resource on continuing basis
Care needed for pro-poor outcomes	Include recognition of secondary rights important for poor and marginalised groups, including women	Support (e.g. credit, marketing) to enable poor to use land productively	Avoid further exclusion of poorer sections without restitution rights	Safeguard women's rights in patriarchal systems

Source: changed after Meinzen-Dick/Di Gregorio 2008, p. 8

Land registration is one of the most prevalent forms of land tenure reform, often designed to reduce ambiguity and increase tenure security. Codification can strengthen existing rights by making it clear that the state will enforce the rights that are duly registered. But this may come at a cost to other users of the resource whose rights are not recorded. In particular, registration is often associated with full ownership, following a western model. Secondary claimants such as pastoralists who have a customary right to graze on the fallow fields, landless households who have been able to catch wild fish on flooded paddy fields or those who have gathered wild foods on the land are generally not registered and may thereby lose their claims (Meinzen-Dick/Di Gregorio 2008, p. 9 et seq.). In Sub-Saharan Africa, the introduction of modern forms of property titling has undermined women's land claims (see also chapter 3.2.9). Where land reform has been accompanied by individually registered title, women have often lost their customary claims to land while men's claims have been strengthened (UNRISD 2006). Land titling is not always seen as the best way of increasing tenure security, and does not automatically lead to greater investment and productivity (EU Task Force on Land Tenure 2004, p. 6).

Land redistribution reforms require a strong central government commitment, either to expropriate land from private land owners or to transfer state lands to individuals. Unless initiatives by peasants to take over lands reach critical mass or are supported by the state, they are often repressed. Decentralisation can make redistributive reforms more difficult if landed elites dominate the locally-elected bodies and can block redistribution. Usually pressure from below, demands by civil society organisation and a degree of contention are needed to design and implement reforms (Meinzen-Dick/Di Gregorio 2008, pp. 13, 15). Land redistribution reform can promote small-scale farmers entry into the market, reduce inequalities in land distribution, increase productivity and be organised in ways that recognise women's rights. Redistributing underutilised large estates to settle smallholders can work if complemented by reforms to secure the competitiveness of beneficiaries (World Bank 2007, p. 9).

Land restitution can be seen as variant of redistributive land reform that addresses past injustices, as in South Africa, Zimbabwe, in post-socialist societies such as Eastern Europe and Central Asia, or after violent conflict. In addition to the challenges of regular land redistribution programmes, land restitution is invariably linked to rectifying injustices of the past and the state has to decide what constitutes legitimate claims to that end. Land restitution itself can be seen as the settlement of long existing "old" land disputes as well as redistribution of a major economic asset in society. Although many countries have addressed restitution at the individual level, South Africa and Namibia also used the approach of restoration of communal property ownership (Meinzen-Dick/Di Gregorio 2008, p. 16).

State recognition of land uses that are already being exercised without government approval represents a fourth category of land tenure reform. The recognition of the land rights of indigenous peoples provides an important example of such reforms. The rights of people living on land that the state claims as government property for protected areas (such as national parks), forests, or rangelands may also be strengthened or transformed through state recognition.

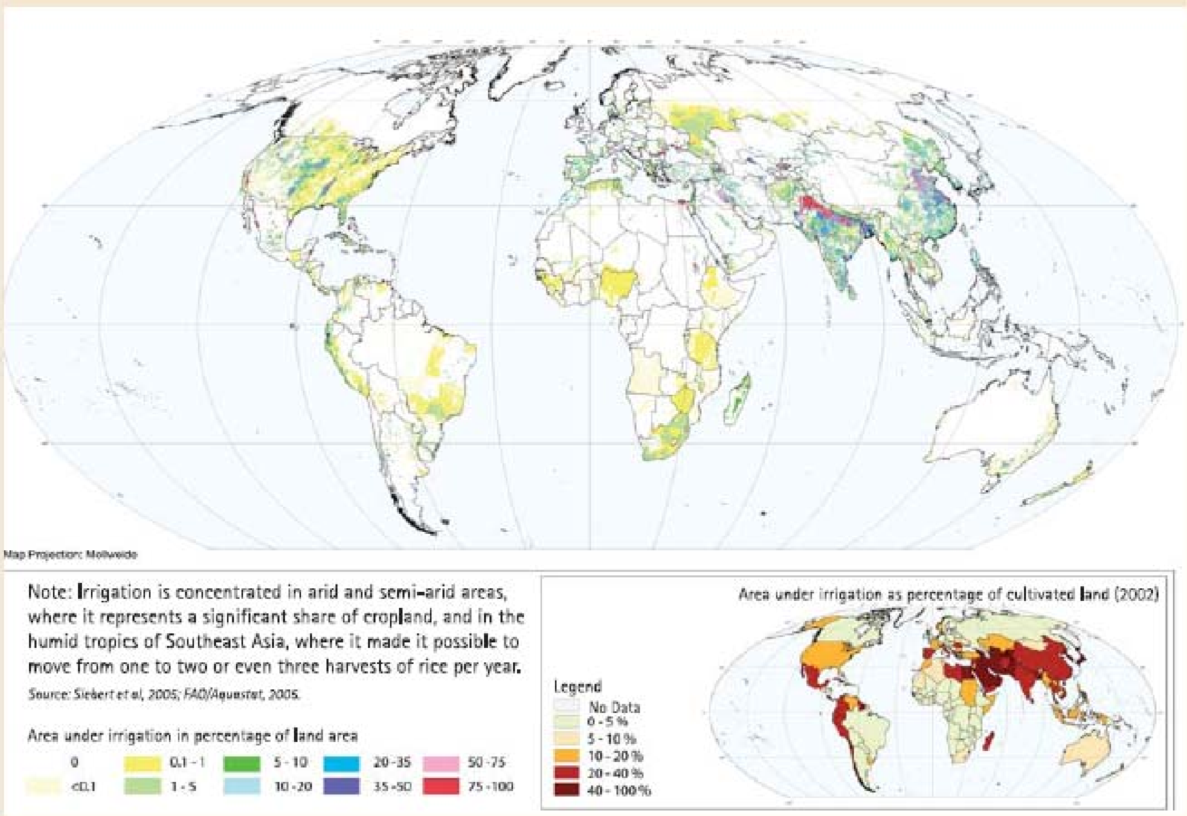
These two categories often overlap. However, even with good legislation to support indigenous right, in practice commercial exploitation of resources, often promoted by donors and multilateral development agencies, has priority over indigenous rights. For example, problems have been found in India, where mining or other major commercial interests compete with tribal land uses in forest areas, and in Africa, where commercial interests seek concessions to exploit forest resources, develop plantations, mining or even ecotourism (Meinzen-Dick/Di Gregorio 2008, p. 19).

3.2.2 Water

Agriculture uses 85% of water consumed in developing countries, mainly for irrigation. Irrigated farming accounts for only 18% of the cultivated area in developing countries, but it produces about 40% of the value of agricultural output. Therewith, the productivity of irrigated land is more than double that of rainfed land (World Bank 2007, pp. 9, 182). These freshwater withdrawals from rivers, lakes and groundwater are also called blue water (Molden 2007, p. 5).

Water resources and irrigation are distributed with huge variations across and within countries. In Sub-Saharan Africa, only 4% of the area in production is under irrigation, compared with 39% in South Asia and 29% in East Asia (Figure 5) (World Bank 2007, p. 9; UNESCO 2006, p. 22). In the last five decades, irrigated land has doubled.

Figure 5: Global distribution of areas under irrigation in 2000



Source: **UNESCO 2006, p. 22**

Poor water management can lead to land degradation in irrigated areas through salinisation and waterlogging. Waterlogging usually occurs in humid environments or irrigated areas with excessive irrigation and insufficient drainage (e.g. in Egypt). Salinisation is a problem in arid and semiarid areas (for example, Pakistan's large irrigation perimeters and the Aral Sea basin). Nearly 40% of irrigated land in dry areas of Asia is regarded to be affected by salinisation. The consequences are declining productivity and loss of agricultural land (World Bank 2007, p. 183).

The vast majority of farming systems in Africa is rainfed and only a small area is irrigated. The possibilities for full and supplementary irrigation are limited. In 1995, 96% of cereals in Sub-Saharan Africa were grown in rainfed agricultural systems. Only 4% were irrigated. Because yields in rainfed systems are lower than in irrigated ones, 89% of cereal production in the region was derived from rainfed agriculture.

These proportions are not expected to change significantly in baseline projections to 2021-25 (InterAcademy Council 2004, p. 47-48). Other assessments see a large untapped potential for irrigation (of some 85%) in Africa.

Water scarcity, defined in terms of access to water, is a critical constraint to agriculture in many areas of the world. A fifth of the world's people, more than 1.2 billion, live in areas of physical water scarcity, lacking enough water for everyone's demands. About 1.6 billion people live in water-scarce basins, where human capacity or financial resources are likely to be insufficient to develop adequate water resources.

Behind today's water scarcity lie factors likely to multiply and gain in complexity over the coming years. A growing population is a major factor, but the main reasons for water problems lie elsewhere: lack of commitment to water and poverty, insufficient and inadequately targeted investment, insufficient human capacity, ineffective institutions and poor governance (Molden 2007, p. 10).

Groundwater can be of great value, particularly in arid regions where surface water is often scarce, but its (over)use bears serious risks. Although aquifers can be tapped to supplement inadequate surface resources, there are high potential risks if the aquifers are not replenished naturally or by human intervention. Intensive use of groundwater for irrigation rapidly expanded with the adaption of tubewell and mechanical pump technology. It becomes only a matter of time before these resources run out or become economically inaccessible. High levels of exploitation - more than 50% of recharge - are currently occurring in many countries in the Middle East, Southern and Northern Africa, Asia and Cuba (UNESCO 2006, p. 12; World Bank 2007, p. 182).

Future challenges in rainfed agriculture

Rainfed agriculture can be upgraded by improving soil moisture conservation and, where feasible, providing supplemental irrigation through Rainwater Harvesting. These techniques hold underexploited potential for quickly lifting the greatest number of people out of poverty and for increasing water productivity, especially in Sub-Saharan Africa and parts of Asia. Mixed crop and livestock systems hold good potential, with the increased demand for livestock products and the scope for improving the productivity of these systems (Molden 2007, p. 4).

Future rainfed agricultural strategies in Sub-Saharan Africa should emphasise sustainable yield increases rather than area expansion, the latter being the dominant factor involved in increasing production in the past. Sustainable intensification strategies for rainfed systems require improved integrated soil, water and nutrient management innovations. These include run-off management, water harvesting and supplementary irrigation, conservation agriculture, organic and inorganic fertilisers and integration of more leguminous species into rotation systems. There is increasing evidence from Asia that research and development investments in rainfed areas offer win-win outcomes, in terms of both productivity growth and reductions in poverty, far in excess of similar investments in irrigated agriculture (InterAcademy Council 2004, p. 48-50).

At the global level the potential of rainfed agriculture is large enough to meet present and future food demand through increased productivity. In the Comprehensive Assessment of Water Management in Agriculture, an optimistic rainfed scenario assumes significant progress in upgrading rainfed systems while relying on minimal increases in irrigated production, by reaching 80% of the maximum obtainable yield. This leads to an average increase of yields from 2.7 metric tons per hectare in 2000 to 4.5 in 2050 (1% annual growth). With no expansion of irrigated area, the total cropped area would have to increase by only 7%, compared with 24% from 1961 to 2000, to keep pace with rising demand for agricultural commodities. But focusing only on rainfed areas carries considerable risks.

If adoption rates of improved technologies are low and rainfed yield improvements do not materialise, the expansion in rainfed cropped area required to meet rising food demand would be around 53% by 2050. Globally, the land for this is available, but agriculture would then encroach on marginally suitable lands and add to environmental degradation, with more natural ecosystems converted to agriculture (Molden 2007, p. 16).

Rainwater Harvesting encompasses any practice that collects and stores runoff for productive purposes. It includes three components: a watershed area to produce runoff, a storage facility and a target area for beneficial use of the water (e.g. agriculture or domestic). Water harvesting techniques are used in a range of contexts in drylands to concentrate and make more effective use of rainwater, and to enhance the reliability of agricultural production. The potential for poverty reduction through Rainwater Harvesting is high in smallholder settings in semi-arid and subhumid areas. Water harvesting technologies have been successfully developed over many years by populations seeking to improve water control. Many ancient water harvesting practices are today widely applied and adapted, such as "half-moons" in West Africa. Others have tended to be abandoned, as economies develop and labour costs of maintenance become excessively high. However, there is still scope for better dissemination of a range of water harvesting technologies that are still relatively little known outside their area of origin (Faures/Santini 2008, pp. 50-51).

Future challenges in irrigation

The era of rapid expansion of irrigated agriculture is over. A major new task is adapting yesterday's irrigation systems to tomorrow's needs. Modernisation, a mix of technological and managerial upgrading to improve responsiveness to stakeholder needs, will enable more productive and sustainable irrigation. As part of the package irrigation needs to be better integrated with agricultural production systems to support higher value agriculture and to integrate livestock, fisheries and forest management (Molden 2007, p. 4).

Under optimistic assumptions about water productivity gains, three-quarters of the additional food demand in 2050 can be met by improving water productivity on existing irrigated lands. In South Asia – where more than 50% of the cropped area is irrigated and productivity is low – additional food demand can be met by improving water productivity in irrigated agriculture rather than by expanding the area under production. But in parts of China and Egypt and in developed countries, yields and water productivity are already quite high, and the scope for further improvements is limited (Molden 2007, p. 16).

3.2.3 Climate change

Climate change, which is taking place at a time of increasing demand for food, feed, fiber and fuel, has the potential to irreversibly damage the natural resource base on which agriculture depends. *The relationship between climate change and agriculture is a two-way street: Agriculture contributes to climate change in several major ways and climate change in general adversely affects agriculture* (IAASTD 2008a, p. 15).

In mid- to high-altitude regions moderate local increases in temperature can have small beneficial impacts on crop yields; in low-altitude regions, such moderate temperature increases are likely to have negative yield effects. *Some negative impacts are already visible in parts of the world; additional warming will have increasingly negative impacts in all regions.* Water scarcity (see chapter 3.2.2) and the timing of water availability will increasingly constrain production. Climate change will require a new look at water storage to cope with the impacts of more and extreme precipitation, higher intra- and inter-seasonal variations and increased rates of evapotranspiration in all types of ecosystems. Extreme climate events (floods and droughts) are increasing and expected to amplify in frequency and severity, and there are likely to be significant consequences in all regions for food and forestry production and food insecurity. There is a serious potential for future conflicts over habitable land and natural resources such as freshwater. Climate change is affecting the distribution of plants, invasive species, pests and disease vectors and the geographic range and incidence of many human, animal and plant diseases is likely to increase (IAASTD 2008a, p. 15).

Climate change will have a disproportionately high bearing on the poor. Greater risks of crop failures and livestock deaths are already imposing economic losses and undermining food security. They are likely to become far more severe as global warming continues. In tropical countries even moderate warming (1°C for wheat and maize and 2°C for rice) can reduce yields significantly because many crops are already at the limit of their heat tolerance. For temperature increases above 3°C, yield losses are expected to occur everywhere and be particularly severe in tropical regions. In parts of Africa, Asia and Central America yields of wheat and maize could decline by around 20 to 40% as temperature rises by 3 to 4°C, even assuming farm-level adjustments to higher average temperatures (World Bank 2007, p. 200).

Adapting agricultural systems to climate change is urgently needed because impacts are already evident and the trends will continue even if emissions of Greenhouse Gas (GHG) emissions are stabilised at current levels. *Adaptation can substantially reduce the adverse economic and social impacts.* Farmers are already adapting, for example by planting different varieties of the same crop, changing planting dates and adapting practices to shorter growing season. Major barriers to adaptation are the lack of credit or savings, and the lack of access to water.

In countries with severe resource constraints, farmers will not be able to adapt to climate change without outside help. Especially the poor will need additional help in adapting (World Bank 2007, p. 200, see also IFAD 2008b).

A scope of activities is currently being developed in order to integrate adaptation within development and poverty reduction programmes. It is predicted that adaptation will be ineffective and inequitable if it fails to learn from and build on understanding of the multidimensional and differentiated nature of poverty and vulnerability. Adaptation, and its finance, will play a significant role in future global agreements. Current financial flows to adaptation fall magnitudes short of the estimated necessities, but they are likely to increase significantly, both through aid flows and through mechanisms outside the aid architecture including UN Framework Convention on Climate Change (UNFCCC) (Tanner/Mitchell 2008).

The earlier and stronger the cuts in GHG emissions, the quicker concentrations will approach stabilisation. Emission reduction measures clearly are essential because they can have an impact due to inertia in the climate system. However, since further changes in the climate are inevitable adaptation is also imperative. Actions directed at addressing climate change and promoting sustainable development share some important goals such as equitable access to resources and appropriate technologies (IAASTD 2008a, p. 15).

Some “win-win” mitigation opportunities have already been identified. These include land use approaches such as lower rates of agricultural expansion into natural habitats; afforestation, reforestation, increased efforts to avoid deforestation, Agroforestry, agro-ecological systems and restoration of underutilised or degraded lands and rangelands and land use options such as carbon sequestration in agricultural soils, reduction and more efficient use of nitrogenous inputs; effective manure management and use of feed that increases livestock digestive efficiency. Policy options related to regulations and investment opportunities include financial incentives to maintain and increase forest area through reduced deforestation and degradation and improved management and the development and utilisation of renewable energy sources. The post-2012 regime has to be more inclusive of all agricultural activities such as reduced emission from deforestation and soil degradation to take full advantage of the opportunities offered by agriculture and forestry sectors (IAASTD 2008a, p. 16).

To address expected climate change challenges and impacts, a major role for AKST is needed to increase adaptive capacity and enhance resilience through purposeful biodiversity management. Options include irrigation management, water harvesting and conservation technologies, diversification of agriculture systems, the protection of agrobiodiversity and screening germplasm for tolerance to climate change. These measures would need to be supported by appropriate policy options, integrated spatial planning and early warning and communication infrastructure that support the generation and dissemination of adaptation knowledge, technologies and practices (IAASTD 2008b, p. 35).

3.2.4 Inputs

Agricultural productivity growth and higher yields are dependent from inputs as fertilisers and pesticides. Input requirements depend largely on the applied agricultural production systems.

Chemical fertiliser use has expanded significantly in most developing countries, except Sub-Saharan Africa. The developing countries' share of global fertiliser use has risen from about 10% in the 1960s to more than 60% today. Asian farmers are the major users, with an annual average of 143 kg per hectare in 2000-02 (in comparison: 6 kg per hectare in 1961-63), more than in developed countries. Higher fertiliser use accounted for at least 20% of the growth in the developing-country agriculture (excluding dryland agriculture) over the past three decades (World Bank 2007, p. 51). But nevertheless, the increasing use of fertiliser is distributed very unevenly over regions (see chapter 3.1.2).

High-input farming systems

High-input farming typically involves mono-cropped fields and a package of modern seed varieties, fertilisers and pesticides. There has been mounting evidence that productivity of many of these intensive systems cannot be sustained using current management approaches. There is also growing evidence that soil-health degradation and pest and weed build-up are slowing down productivity growth. These trends are best documented in the intensive rice-wheat systems of South Asia which cover 12 million hectares in the Indio-Gangetic Plain of India and Pakistan (World Bank 2007, p. 188).

Furthermore, high-input farming has produced serious environmental problems. Fertiliser nutrient runoff from agriculture has become a major problem in the intensive systems of Asia, causing algal bloom and destroying wetlands and wildlife habitats (World Bank 2007, p. 188). Fertiliser use efficiency in tillage based cropping systems is low due to high losses through erosion and leaching. In many cases, this is the reason for the environmental pollution problems in fertiliser-intensive farming.

Pesticide poisoning is estimated to cause 355,000 deaths annually (World Bank 2007, p. 10, 224). Especially horticulture is characterised by heavy use of cash inputs and chemicals. Therefore, it can inflict considerable harm to the environment: horticultural crops account for 28% of global pesticide consumption (World Bank 2007, p. 59).

Reasons for the slow uptake of more sustainable and integrated management practices in high-input agriculture are (World Bank 2007, p. 189):

The subsidies that some governments provide to intensive systems make inputs less costly, and thus encourage farmers to be more careless in their use.

Improved practices are knowledge-intensive and require research and extension systems that can generate and transfer knowledge and decision-making skills to farmers. Farmers also need greater ecological literacy to better understand interactions in complex ecosystems.

Environmental damages in high-input farming are normally negative externalities, producing a conflict between the private interests of farmers and the social value of the environmental services they degrade. Incentives to prevent offside degradations are still missing.

A future challenge is to reduce the environmental and health impacts of pollution caused by fertilisers and pesticides by better management of these inputs without sacrificing yields. Integrated pest management that combines agro-ecological principles with judicious use of pesticides and more efficient application technologies and use can increase yields and reduce pesticide quantities and environmental damage. Other improvements in management that represent win-win solutions for farmers include using pest-resistant varieties, better timing and application of fertiliser and water as well as low-tillage farming (World Bank 2007, p. 188).

New forces are emerging which are inducing many farmers to use intensive systems more sustainably. An expanding demand for organic food and other environmentally-certified products are some of these factors. The high food safety, quality and environmental standards of emerging supply chains and supermarkets (see chapter 3.2.7) also compel farmers to shift to better and more sustainable farming practices. Civil society has the capacity to provide technical assistance and help organise farmers and communities to meet more stringent environmental standards. Community organisations and producer cooperatives were at the heart of the recent expansion of organic export production in East Africa (World Bank 2007, p. 189; see also IAASTD 2008a, p. 9).

Low-input systems in Sub-Saharan Africa

Depletion of soil fertility is a major biophysical cause of low per capita food production in Africa. Smallholders have removed large quantities of nutrients from their soils without applying sufficient quantities of manure or fertiliser to replenish the soil. This has resulted in a very high average annual depletion rate: 22 kilograms of nitrogen, 2.5 kilograms of phosphorus and 15 kilograms of potassium per hectare of cultivated land over the last 30 years in 37 African countries – an annual loss equivalent to $4 billion in inorganic fertiliser (InterAcademy Council 2004, p. 47).

Fertilisers have been applied to counteract loss of nutrients. Productivity trends demonstrate that the benefits of science and technology in Africa have been captured most consistently in the commercial and irrigated farming systems where purchased inputs are used most extensively. In the more traditional upland rainfed farming systems there has been some limited success with root crops, especially in systems where cassava is the principal crop. However, at the very low levels of soil fertility the efficiency of use of external resources is extremely low. This and the often poor input-output price ratios and difficulties with market access are major contributors to low input use in Sub-Saharan Africa (InterAcademy Council 2004, p. 47).

Overall, *fertiliser use is extremely low in many Sub-Saharan Africa countries*: assessments see an average fertiliser use between 8.8 and 13 kilogrammes per hectare (kg/ha) (Fan/Rosegrant 2008, p.3; World Bank 2007, p. 52).

The total fertiliser use has to increase by 5 to 6 times if a rise to an average application of 50 kg/ha will be achieved, a level that has already been reached by most middle-income Sub-Saharan Africa countries and which is a target established by an Africa Fertilizer Summit (2006). Fertiliser prices in Sub-Saharan Africa are extremely high because of inefficient distribution systems and high transportation costs (Fan/Rosegrant 2008).

Assessments come to the result that for Sub-Saharan Africa total annual costs of more than $9 billion (and additional annual cost of about $6.8 billion in comparison to the current situation) for fertiliser and improved seeds are required to achieve an agricultural growth rate of 7.5% annually. *It is unrealistic to expect farmers to pay these costs, or to have access to credit to facilitate market participation. Public support is therefore unavoidable for achieving the target.* Fertiliser subsidy programmes should be designed in such a way that they avoid crowding out the private sector and distorting markets and farmers' incentives. A fertiliser voucher system designed to target the poorest 50% of farmers would likely have few such negative effects. If the subsidy component for these farmers is 60% of costs, the (additional) public-sector cost (including operational costs) would be about $2.25 billion per year for Sub-Saharan Africa (Fan/Rosegrant 2008).

Initiatives are underway in Sub-Saharan Africa to improve fertiliser use. For example, in the frame of the Alliance for a Green Revolution in Africa (AGRA), an African-led partnership formed in 2006 and supported by the Bill & Melinda Gates Foundation, a "Soil Health Program for Farm Households in Africa" was introduced. Its aim is to work with farmers throughout Sub-Saharan Africa on advanced soil management methods and with policymakers to create incentives for better soil management. In this context, one of the targets is to deliver 187,000 tons of fertiliser to small farmers through wholesale and retail networks by December 2011 (Bill & Melinda Gates Foundation 2008). Another target is to introduce soil and crop management practices such as Conservation Agriculture that can optimise the use of applied fertiliser.

Agricultural development in less-favoured regions is constrained by fragile, sloped and already degraded soils, erratic and low rainfall, poor market access and high transport costs – in varying degrees. In many cases, a shift to more intensive agricultural production systems is needed to raise productivity and to reduce or reverse the need for further crop area extensions. The future challenge is to achieve this while ensuring the sustainable use of resources at local levels. Two key interventions are proposed: Improving technologies for sustainable management of land, water and biodiversity resources; and putting local communities in the driver's seat to manage natural resources (World Bank 2007, p. 192 et seq.).

3.2.5 Financing

Financial constraints in agriculture remain pervasive. They are costly and inequitably distributed, severely limiting small-scale farmers to develop their productivity and to compete.

Financial constraints originate in the lack of asset ownership to serve as collateral and in the reticence to put assets at risk as collateral when they are vital to livelihoods. Problems of financing are strongly interlinked with land right issues (see chapter 3.2.1) and gender issues (see chapter 3.2.9). Asset-poor households are limited to considerably smaller loans at much higher rates than wealthier farmers (World Bank 2007, p. 13, 144).

An important approach to resolve rural financial problems are Microfinance Institutions (MFIs), following the pioneer efforts of the Grameen Bank. MFIs work with new arrangements that substitute for collateral. They often have guidelines to favour groups – particularly women – excluded from borrowing through other channels. Many MFIs lend to local groups whose members select one another and share the liability for repaying loans. The microfinance revolution has opened access to loans for millions of poor people, especially women, but it has not reached most agricultural activities, except high-turnover activities such as small livestock and horticulture. It works less well for crop activities, where all producers are subject to a common set of weather risks and where project periods are long and share the same timing. In addition, reformed financial regulations are needed in many countries for MFIs. Nonetheless, the range of financial products available to the rural poor has broadened to include savings, money transfers, insuring services and leasing options (World Bank 2007, pp. 13, 144-145).

However, MFIs cannot provide the mainstay of rural finance. Promoting, improving or even creating rural institutions to support a wide range of rural financial transactions remain some of the fundamental challenges governments are facing in developing countries. Options are (World Bank 2007, pp. 145-147):

Reforming public agricultural banks: Unless state-owned agricultural banks undergo a radical transformation in governance arrangements that prevent them from political capture, they are unlikely to function in a commercially sustainable manner and serve the needs of small-scale farmers.

Providing financial services through self-help groups and financial cooperatives: Financial cooperatives and their networks are re-emerging as promising institutions in rural finance in many countries, combining advantages of proximity with modern management tools. Locally based, their transaction costs are typically lower than those of other financial institutions. But because they are members of a larger network, they can offer the variety and volume of services that rural customers require, and they can pool risks as well as costs.

Financing through interlinked agents: Agents in value chains (input suppliers or output processors) are often more able to reduce monitoring costs and enabling financial institutions to accept non-standard forms of wealth as collateral. But further work is needed to determine whether these (often spatially monopolists) practices offer finance at competitive rates and whether they bias against smallholders.

Reputational collateral through microcredit reporting bureaus: Microcredit reporting bureaus that establish individual reputations can help small-scale farmers use their past credit histories as an asset. However, a client's credit history addresses risks related to the borrower's financial behaviour, but it does not, and cannot, address business risks related to weather and prices in agriculture.

3.2.6 Infrastructure

So-called "hard" infrastructure includes telecommunication, electrification and transportation infrastructure as roads, railways and harbours. Adequate infrastructure is an important element in the process of alleviating poverty and providing opportunities for rural citizens in developing countries (see e.g. UN Millennium Project 2005). Hard infrastructure is one precondition for the development of social and economical networks.

Agricultural development is related to access to markets and services. Rural areas by definition are spatially dispersed, which affect the costs of transport, the quality of public services and the reliance on subsistence production. In developing countries 16% of the rural population or 439 million people live in areas with poor market access, requiring five or more hours to reach a market town of 5,000 or more inhabitants. In Sub-Saharan Africa and the Middle East and North Africa, the percentage of rural population with poor market access is much higher with more than 30%. Poor market access reflects low investments in infrastructure (World Bank 2007, p. 54). In Ethiopia for example, 68% of the rural population lives in medium- to high-rainfall areas, but farm households are on average 10 km from the nearest road and 18 km from the nearest public transport (World Bank 2007, p. 57). On the other hand, infrastructure development can cause new environmental problems. New road development is a major cause of deforestation (World Bank 2007, p. 192).

Inadequate investments in rural development have taken a severe toll on the provision of infrastructure and services. The road system in Africa today is only a fraction of what India had decades ago and leaves about 70% of its farmers poorly connected to markets. Many farmers can neither procure fertilisers and other inputs at affordable prices nor market their own products effectively. Poor telecommunications infrastructure also keeps farmers in isolation. Similarly, poor access to health and education services diminishes agricultural productivity, contributes to the spread of infectious diseases and locks rural people into a poverty trap (InterAcademy Council 2004, pp. 197-199).

Rural households in Sub-Saharan Africa pay much higher transportation costs than do rural households in developing countries in Asia. This is equally true for passenger fares and freight charges. For instance, a comparative study of rural transportation carried out in 1994-95 found that Ghana's and Zimbabwe's transportation charges were two to two and a half times higher than those in Thailand, Pakistan and Sri Lanka. Similarly, in the 1986–88 period, long-distance freight transport tariffs in francophone Africa were more than five times higher than tariffs in Pakistan (Torero/Chowdhury 2005).

Africa's low population densities make per capita infrastructure investment and maintenance costs high and difficult to finance. Capacity building in Africa should not be limited to science and technology but also involve technical and vocational training for staff of agro-service centres, engineers to maintain infrastructure and machines. New technologies present alternatives to expensive conventional large-scale infrastructure development, which are often difficult to maintain. The use of wireless communication technologies and the convergence of technologies give new affordable possibilities for telephony and internet access. Wind and solar power can be viable alternatives to conventional sources of energy. Encouraging greater use of locally available labour could contain the costs of feeder roads.

Encouraging greater local ownership of investments through co-financing arrangements and by devolving responsibility for maintenance to local governments and communities addresses many previous problems associated with upkeep (InterAcademy Council 2004, pp. 197-199).

Achieving realistic levels of infrastructure and rural services will require substantial increase in public investment. Public investment in rural areas has fallen in many African countries in the past decade or so due to the fiscal pressures imposed on governments through structural adjustment programmes and a precipitous decline in donor support for such fundamentals. The over-zealous downsizing of the public institutions that provide essential public goods and services like research and development, infrastructure, education and health will also need to be reversed. These institutions have key roles to play and need to be revamped and strengthened to fulfil their functions in cost-effective and demand-responsive ways (InterAcademy Council 2004, pp. 197-199).

3.2.7 Changing food chains

Almost all of the world's population growth between 2000 and 2030 will be concentrated in urban areas in developing countries, according to the latest UN estimates. Urban population will equal rural population around 2017 if present trends continue. By 2030, almost 60% of the people in developing countries will live in cities (FAO 2004, p. 18).

The combination of growing cities and rising incomes has contributed to significant changes in diet, and here not only in the average amount of calories that people in developing countries consume. The proportion of calories derived from vegetable oils, meat, sugar and wheat has increased. To a large extent this reflects the preferences of consumers whose rising incomes allow them to purchase more expensive and more highly valued foods (FAO 2004, p. 18).

Nutrition experts identify two distinct trends: dietary convergence and dietary adaptation. Dietary convergence refers to the increasing similarity in diets worldwide. It is characterised by a greater reliance on a narrow base of staple grains (wheat and rice), increased consumption of meat, dairy products, edible oil, salt and sugar, and lower intake of dietary fibre. Dietary adaptation, on the other hand, reflects the rapid pace and time pressures of urban lifestyles. In households where both parents often commute long distances and work many hours, consumers eat more meals outside the home and purchase more processed foods (FAO 2004, p. 19).

The trends towards dietary convergence and adaptation have fuelled on the one side and been promoted on the other side by the *increasing concentration of food processing and retail trade*. Latin America and Asia, the regions where these trends have been most pronounced, have experienced explosive growth both in investments by transnational food corporations and in the proportion of food sold through supermarkets. In the decade 1988-1997, foreign direct investments in the food industry increased from $743 million to more than $2.1 billion in Asia and from $222 million to $3.3 billion in Latin America, outstripping by far the level of investments in agriculture (FAO 2004, p. 19).

Beside urbanisation and increased incomes, *other factors* also played important roles. A crucial factor was the liberalisation of foreign direct investment in retail. Intense competition, consolidation and multinationalisation in the supermarket sector have also accelerated the spread of supermarket chains seeking to improve their competitive positioning. In addition, domestic policies have often included tax incentives for supermarkets and hygiene and location regulations for wetmarkets. Finally, the modernisation of supermarkets' procurement systems has reduced costs and made supermarkets more competitive with traditional retailers (Reardon/Gulati 2008).

Supermarkets in the developing countries of Africa, Asia and Latin America have spread in three waves (Table 5). The category "supermarkets" refers to all modern retail, which includes chain stores of various formats such as supermarkets, hypermarkets as well as convenience and neighbourhood stores. A fourth wave is just barely emerging in the poorest countries, such as Bangladesh, Cambodia and many West African states (Reardon/Gulati 2008). Over recent decades, a handful of vertically integrated, transnational corporations have gained increasing control over the global trade, processing and sales of food. The 30 largest supermarket chains account for about one third of food sales worldwide (FAO 2004, p. 20).

Table 5: Waves of supermarket diffusion in developing countries

Period	Countries/Regions	Growth in supermarkets' average share in retail sales
First wave: Started in early 1990s	Many countries of South America, East Asia (outside China), South Africa	From about 10% around 1990 to about 50-60% by the mid-2000s
Second wave: Started in mid- to late 1990s	Mexica, Central America, many countries of Southeast Asia	From 5-10% in 1990 to 30-50% by the mid-2000s
Third wave: Started in late 1990s to early 2000s	China, India, Vietnam	Reached about 2-20% by mid-2000s; supermarket sales growth at 30-50% per year

Source: Reardon/Gulati 2008

Africa is also rapidly urbanising, and by 2020 almost half the African population will live in urban areas. This will be an engine for most national market developments. Although peri-urban agriculture can be an important source of food, urban people depend primarily on purchased rather than home-grown foods. They also usually consume less coarse grains, roots and tubers and more livestock products, fats, fresh horticultural products as well as processed and pre-cooked foods. This offers important new opportunities for agricultural diversification into higher value products for African farmers, agro-industry and food wholesaling and retailing.

Marketing chains are also becoming more integrated in urban areas with the rise of supermarkets and convenience shops. Agricultural research will need to address the problems of an increasingly diverse array of crop, tree and livestock activities, and give more attention to post-harvest storage and processing properties, as well as rural to urban markets. The private sector should have an important role to play in these kinds of research (InterAcademy Council 2004, p. 194).

The impacts of the changing agrifood system or the so-called "supermarket revolution" are ambiguous. On the one hand, this revolution leads to lower food prices for consumers and creates opportunities for farmers and processors to gain access to quality-differentiated food markets and raise incomes. On the other hand, it can create challenges for small retailers, farmers and processors who are not equipped to meet the new competition and requirements from supermarkets. When supermarkets modernise their procurement systems, they require more from suppliers with respect to volume, consistency, quality, costs and commercial practices.

Supermarkets' impact on suppliers is biggest and earliest for food-processing and food-manufacturing enterprises, given that some 80% of what supermarkets sell consists of processed, staple or semi-processed products. But by affecting processors, supermarkets indirectly affect farmers, because processors tend to pass on the demands placed on them by their retail clients (Reardon/Gulati 2008).

For small-scale farmers, being competitive in supplying supermarkets is a major challenge that requires meeting strict standards and achieving scale in delivery. Therefore, *effective producer organisations are essential*. Governments and private sector can help small-scale farmers to expand and upgrade their range of assets and practices to meet the new requirements of supermarkets and other coordinated supply chains. Many producer organisations do not have the capacity to provide the technical assistance required for ensuring collective compliance with quality, quantities and timing. Well-targeted technical and financial support from donors, governments and non-governmental organisations is often necessary for producer organisations to overcome the initial hurdles (FAO 2004, p. 21; Reardon/Gulati 2008; World Bank 2007, pp. 22, 127-128).

Some farmer cooperatives have broken into lucrative and dynamic niche markets by obtaining certification for their products as "organic", "fair trade" and "environmentally friendly". Such products have a premium price and bring high returns to farmers. For small producers, organic farming offers the added benefits of reduced dependence on purchased inputs like pesticides and fertiliser and increased use of low-cost labour (FAO 2004, p. 21).

3.2.8 Education and Health

In this chapter, a short outline will be given on the importance of education and health.

Education

The vast majority of the 860 million illiterate adults (with a majority of women) and the 130 million children (mainly girls) who do not go to school live in rural areas in developing countries. Education levels in rural areas tend to be low worldwide: an average of four years for rural adult males and less than three years for rural females in Sub-Saharan Africa, South Asia and the Middle East and North Africa. Improving basic rural education has been slower than in urban areas (FAO 2004, p. 28; World Bank 2007, p. 9).

Hunger, illiteracy and lack of schooling affect many of the same areas, are facets of extreme poverty and are closely interlinked. Hunger, malnutrition and food insecurity erode cognitive abilities and reduce school attendance. Conversely, illiteracy and lack of education reduce earning capacity and contribute directly to hunger and poverty (FAO 2004, p. 28).

Improving education can be one of the most effective ways to reduce hunger and malnutrition. Programmes that take aim simultaneously at lack of education and at malnutrition have achieved notable gains in several countries (FAO 2004, pp. 28-29). Investing in education has two sides – a demand and a supply side.

The demand for schooling responds to lower costs, both in school expenses (fees, clothing, books, etc.) and the opportunity costs of travelling over poor roads to distant locations and not having children to do productive work. Therefore, free primary education is often not enough for poor children to attend school due to other costs (World Bank 2007, p. 218).

Furthermore, it is increasingly the quality of rural education that requires the most improvement. Education should include vocational training that can provide technical and business skills that are useful in agriculture and rural non-farm economy (World Bank 2007, p. 9).

Health

Agriculture affects health, and health affects agriculture. Agriculture supports health by providing food and nutrition for the people and by generating income that can be spent on health care. Yet agricultural production and food consumption can also increase the risks of water-related diseases (malaria) and food-borne diseases. Moreover, health hazards are linked with specific agricultural systems and practices, such as infectious animal diseases (avian flu, brucellosis) and pesticide poisoning. Pesticide poisoning alone is estimated to cause 355,000 deaths per year (World Bank 2007, p. 225).

Illness and death from AIDS, malaria, tuberculosis and other diseases reduce agricultural productivity through the loss of labour, knowledge of productive adults and assets to cope with illness. Because the majority of the world's poor work in agriculture and the poor suffer disproportionately from illness and disease, taking an integrated view of agriculture and health is necessary to address poverty and promote agricultural development. Therefore, *better coordination of the agriculture and health policies can bring big dividends for productivity and welfare* (World Bank 2007, p. 10, 225).

3.2.9 Gender

Gender, that is socially constructed relations between men and women, is an organising element of existing farming systems worldwide. In many poor countries, women do most of the farm work – planting, weeding and harvesting crops – as well as tending livestock. Additionally, they spend long hours fetching water, collecting firewood, preparing meals and caring for children and sick relatives. Women are increasingly left as the sole caretakers when husbands migrate to cities in search of work, are caught up in conflicts or die from HIV/AIDS or other diseases. Women are not only poor in terms of money, but also in terms of time (IAASTD 2008a, p. 21; IFAD 2008a).

In many poor countries, women cannot own land, obtain credit to buy land or make decisions to improve land. Less than two per cent of land in the developing countries is owned by women. When women have access to land, it is often of poor quality – too small, difficult to reach and with little irrigation. Land is an extremely valuable asset, and secure access to land is a powerful way to reduce poverty. Insecurity of tenure discourages women from investing time and resources in sustainable farming practices. This is especially true for agroforesty technologies due to the delay between investment and returns (IFAD 2008a; IFPRI 2005).

Within the household, market orientation can differ with the gender of the cultivator, and women are often more likely to be engaged in subsistence farming and less likely to cultivate cash crops. In Ghana, women resisted the introduction of high-yield cassava plants because large quantities of this crop would be processed and sold in bulk to distant markets – traditionally a responsibility of men (IFAD 2008a; World Bank 2007, p. 78).

Women have more limited access to credit, markets and technologies. They also may not have the money to buy fertiliser or improved seed. Microfinancing has opened access to loans for millions of poor people, especially women, but it has not yet reached most agricultural activities, except high-turnover activities such as small livestock and horticulture (IFAD 2008a; World Bank 2007, p. 13).

Many countries have reformed their legislation to better protect women's rights. National law can require that a woman's name is put on land records along with her husband's, and can establish the right of widows and daughters to inherit land. Nonetheless, male dominance in religious and customary law often prevents rural women from inheriting or controlling land. Women's property rights are often determined in practice by the interpretation and implementation of laws at the local level (IFAD 2008a; Quisumbing/McClafferty 2006).

Gender is a determining factor of ongoing agricultural restructuring. Current trends in agricultural market liberalisation and in the reorganisation of farm work, as well as the rise of environmental and sustainability concerns are redefining the links between gender and development. The proportion of women in agricultural production and postharvest activities ranges from 20 to 70%; their involvement is increasing in many developing countries, particularly with the development of export-oriented irrigated farming, which is associated with a growing demand for female labour, including migrant workers.

Whereas these dynamics have in some ways brought benefits, in general, the largest proportion of rural women worldwide continues to face deteriorating health and work conditions, limited access to education and control over natural resources, insecure employment and low income (IAASTD 2008a, p. 21).

Therewith, shifts in household strategies that are intended to lead out of poverty are not gender neutral. An understanding of how resources are allocated within households can profoundly affect policies associated with the design and implementation of development projects (Quisumbing/McClafferty 2006; World Bank 2007, p. 84).

Studies of IFPRI show that empowering women and reducing gender disparities are keys to ensure food and nutrition security in the developing world. Important findings in this context are (IFPRI 2005):

Targeting women in agricultural technology dissemination can have a greater impact on poverty than targeting men.

Equalising agricultural inputs between men and women results in significant gains in agricultural productivity.

Educating women is a key method for boosting agricultural productivity, especially in Sub-Saharan Africa.

Gender disparities in property rights threaten natural resource management.

Targeting programmes to women benefits the whole household, but particularly girls.

There is no single path to strengthening women's property rights.

One of the eight Millennium Development Goals calls for achieving gender equality and empowering women. Empowering women is crucial for reaching many of the other goals, including the prime goal of reducing by half the proportion of poor people by the year 2015 (IFAD 2008a).

IAASTD comes to the conclusion that “urgent action is still necessary to implement gender and social equity in AKST policies and practices if we are to better address gender issues as integral to development processes. Such action includes strengthening the capacity of public institutions and NGOs to improve the knowledge of women’s changing forms of involvement in farm and other rural activities in AKST. It also requires giving priority to women’s access to education, information, science and technology and extension services to enable improving women’s access, ownership and control of economic and natural resources. To ensure such access, ownership and control legal measures, appropriate credit schemes, support for women’s income generating activities and the reinforcement of women’s organisations and networks are needed. This, in turn, depends on strengthening women’s ability to benefit from market-based opportunities by institutions and policies giving explicit priority to women farmer groups in value chains. … Finally, if we are to better recognise women as integral to sustainable development, it is critical to ensure gender balance in AKST decision-making at all levels and provide mechanisms to hold AKST organisations accountable for progress in the above areas.” (IAASTD 2008a, p. 21 et seq.).

3.2.10 Governance

The success of development policies for agriculture is depending on many governance issues, such as political stability, government effectiveness, regulatory quality, rule of law and control of corruption. Strengthening governance matters in all discussed areas. A comprehensive overview can not be given within the framework of this report. Instead, corruption in irrigation is discussed as an example.

Irrigation systems can be captured by large users. In Mexico, for example, the largest 20% of farmers reap more than 70% of irrigation subsidies. Moreover, corruption in irrigation exacerbates food insecurity and poverty. Irrigation systems that are difficult to monitor and require experts for their maintenance offer multiple entry points for corruption, leading to wasted funding and more expensive and uncertain irrigation for small-scale farmers. One particular problem is the regulation of irrigation with groundwater resources.

As a result of weak regulation, large users in places such as India or Mexico can drain groundwater supplies with impunity, depriving smallholders of essential resources for their livelihoods.

In India, the total corruption burden on irrigation contracts is estimated to exceed 25% of the contract volume, and is allegedly shared between officials and then funnelled upwards through the political system, making it especially hard to break the cycle of collusion (Transparency International 2008, p. XXV).

A recent and promising approach to understanding corruption in irrigation is to look at it as the provision of a service that requires effective institutions and the alignment of stakeholder interests to function properly. Addressing rent-seeking and corruption then becomes a matter of redesigning institutions in order to remove deficiencies and uncertainties in agreements among stakeholders while increasing transparency and incentives for compliance (Transparency International 2008, p. 69).

From such a perspective, the major entry points for corruption in surface or canal irrigation include the following (Transparency International 2008, pp. 69-70):

Subsidy capture: Public irrigation subsidies are usually justified on the grounds that irrigation supports national food security and farmers who are unable to pay market prices for water. For individual farmers or landowners, irrigation is attractive as long as their personal financial benefits outweigh the much lower subsidised costs they face. This leads to the temptation for farmers and their representatives and cronies to overestimate projected benefits, underestimate construction costs and lobby governments to pay for projects that do not necessarily deliver net benefits to society, but that deliver a major subsidy to landowners. Businesses that design, build and operate systems can also be tempted to bribe key government officials. Policy capture is difficult to prove, but the existence of powerful, politically well-connected large-scale farmers who manage to secure the bulk of irrigation subsidies in many countries makes policy capture a plausible premise.

Corruption in construction: Procurement and tendering are particularly prone to corruption when products cannot be standardised, as is the case with constructing large-scale irrigation projects. Because every large dam is essentially a one-off product, cost estimates among competing contractors can vary greatly, offering the opportunity to include bribes in quotations with little risk of detection. As with all construction projects, corruption in irrigation can result in favoured contractors winning contracts, contractors not being held accountable for poor performance and inferior work and contractors colluding to overcharge.

Corruption in maintenance: Though the amounts may be smaller and more standardised than new construction projects, irrigation maintenance tends to be much less stringently monitored. Some forms of maintenance, such as de-silting a canal, are extremely difficult to monitor, since the results can be literally ‘under water’. So the corruption risks are in fact greater. In addition, since maintenance funds are usually provided as part of an agency’s annual budget cycle and are subject to the discretion of maintenance engineers, spending can be based on corruption opportunities rather than actual maintenance needs.

Corruption in operation: Opportunities for corruption depend on how irrigation systems are organised. Irrigation researchers tend to recommend systems that have more opportunities for manipulations, in order to allocate water more precisely to where it is needed. At the same time, manipulation translates into corruption opportunities. Officials or ditch riders who operate gates can be bribed to open gates further or keep them open longer than intended. Systems with fixed structures can also be manipulated by widening ostensibly permanent outlets, though the ‘evidence’ of tampering remains visible to inspectors passing by. Some farmers may bribe officials in order to increase their water allocation. But they are also vulnerable to hold-up and extortion by the same officials, since they have a major stake in seeing the crop through. Water shortages caused by drought and other factors can motivate irrigation officials to extract side payments from farmers.

Fee collection is another entry point for corruption. When charges are based on the surface area irrigated, field-level officials can be tempted to charge for the full area but only record part of it in the official records. Because government records of irrigated areas tend not to be public, and the government does not have the capacity to audit collection officials on a large scale, such fraud can easily go undetected. And, when the government decides which areas can be irrigated through zoning processes, officials can be bribed to turn a blind eye to the illegal irrigation of land outside proper zones (Transparency International 2008, p. 70).

Corruption is not confined to the field level. Enrichment from corruption can significantly boost incomes for local irrigation officials. Appointments to these lucrative jobs then become coveted and themselves vulnerable to corruption. Higher-level officials sell jobs to the highest bidders, and appointees have little choice but to extract side payments from farmers in order to recoup their ‘investments’. Patronage for irrigation jobs thereby perpetuates corruption and trickles up the administrative hierarchy (Transparency International 2008, p. 70).

Fighting corruption in irrigation means strategically restructuring incentive systems rather than piecemeal reforms. Key elements are (Transparency International 2008, pp. 75-77):

For policy capture, remedies are tied to broader reforms of political participation and empowering marginalised groups to engage in the political process. The more widespread use of diagnostics that help expose inequities implicit in water subsidies may be a useful sector-specific contribution to this endeavour.

With regard to groundwater overuse, policing is next to impossible. But indirect measures, such as higher prices for electricity and fuel that power pumps, may shift the calculations of large users towards more responsible use while doing little harm to smaller users, who cannot afford large pumps in the first place. Such measures can be expected to be deeply unpopular, however, and hark back to the problem of policy capture, which also besets irrigation subsidies.

Tackling the webs of corruption in canal irrigation requires institutional reform. By far the most common solution to break the hold that irrigation engineers have over operation and maintenance has been transferring irrigation management from the government to groups of farmers, known as water user associations (WUAs). Known as irrigation management transfer (IMT) or participatory irrigation management (PIM), this strategy has gradually become conventional wisdom for World Bank projects that address irrigation system reform. Guidelines for the process have been established. All the same, IMT and PIM do not usually address the issue of corruption directly, and few studies exist to demonstrate their impact.

Establishing water user associations is considered a useful tool for addressing corruption. Bundling small, marginalised voices into a collective, formally recognised user group is intended as a step towards empowerment and better protection against extortion and corruption.

3.3 Strategies for development

The high importance of agriculture for development is a common outcome of the current international assessments. Increasing productivity in agriculture is seen as a key element to achieve the Millennium Development Goals. Strengthening of agricultural knowledge, research and development and extension, and their sharply increased public funding are broadly recognised recommendations (IAASTD 2008a, p. 7; Pardey et al. 2006b, p. 6; World Bank 2007, p. 14).

In line with the complex issues and the broad assessments, a number of strategies and many different strategy elements are proposed in the reports. Beyond the common demand for higher recognition and investment in agriculture, the strategies for development show different emphases and priorities (see also Giger et al. 2008). Some important examples are given to illustrate these different emphases and priorities.

General focus

According to the *World Bank report*, agriculture-for-development agendas should be based on four policy objectives (World Bank 2007, p. 19):

Improve access to markets and establish efficient value chains

Enhance small-scale farmer competitiveness and facilitate market entry

Improve livelihoods in subsistence farming and low-skill rural occupations

Increase employment in agriculture and the rural non-farm economy

The agenda for agriculture-based countries (mainly in Sub-Saharan Africa) focuses on improving smallholder competitiveness in medium and higher potential areas, where returns on investment are highest, while simultaneously ensuring livelihoods and food security of subsistence farmers (World Bank 2007, p. 20).

For the transforming countries (mainly in Asia) with the widening rural-urban income disparities, the focus is seen on the generation of rural jobs by diversifying into labour-intensive, high-value agriculture (especially horticulture, poultry, fish and diary products) linked to a dynamic rural, non-farm sector. Export markets for non-traditional products should be developed (World Bank 2007, p. 20). In urbanised countries, the main challenge is seen in linking small-scale farmers to modern food markets and making them competitive in supplying supermarkets, for which effective producer organisations are seen as essential (World Bank 2007, p. 20).

The World Bank report has provoked *critics from Non-Governmental Organisations* (NGOs): Main points of criticism are the continuing focus on liberalisation and economic efficiency, the insufficient consideration of power structures and the non-including of food sovereignty (Hein 2008; Oxfam 2007; Patel 2007). Moreover, a look back and the drawing of lessons from past policies is missing (Murphy/Santarius 2007).

In contrast to the World Bank, a fundamental shift in agricultural knowledge, science and technology (AKST) is demanded by *IAASTD*. This should include science, technology, policies, institutions, capacity development and investment so that development and sustainability goals can be met successfully. Such a shift should recognise and give increased importance to the multifunctionality of agriculture, accounting for the complexity of agricultural systems within diverse social and ecological contexts. It would require new institutional and organisational arrangements to promote an integrated approach to the development and deployment of AKST. It would also recognise farming communities, farm households and farmers as producers and managers of ecosystems. In terms of development and sustainability goals, these policies and institutional changes should be directed primarily at those who have been served least by previous AKST approaches, i.e. resource-poor farmers, women and ethnic minorities. IAASTD points out the importance of local and traditional knowledge. Large and middle-scale farmers are seen to be continuing important and high pay-off targets of AKST, especially in the area of sustainable land use and food systems (IAASTD 2008a, p. 6).

International trade

The *World Bank* sees further trade liberalisation as substantial for developing countries trade and agricultural output growth. Its assessment is that urbanised countries, particularly those in Latin America with competitive advantage concerning many of the currently protected products, will benefit most. By removing their current level of protection, industrial countries would induce annual welfare gains for the developing countries estimated to be five times the current annual flow of aid to agriculture (World Bank 2007, pp. 11, 117).

IAASTD comes to the conclusion that trade policy reform to provide a fairer global trading system can make a positive contribution to sustainability and development goals. Supportive trade policies can also make new AKST available to the small-scale farm sector and agroenterprises. The assessment is that agricultural trade can offer opportunities for the poor, but that current arrangements have major distributional impacts among, and within, countries which in many cases have not been favourable for small-scale farmers and rural livelihoods.

Some developing countries with large export sectors have achieved aggregate gains in GDP, although their small-scale farm sectors have not necessarily benefited and in many cases have lost out. The small-scale farm sector in the poorest developing countries is a net loser under most trade liberalisation scenarios that address this question. The conclusion from this assessment of distributional impacts is that IAASTD calls for differentiation in policy frameworks and institutional arrangements if these countries are to benefit from agricultural trade. IAASTD sees growing concern that opening national agricultural markets to international competition before basic institutions and infrastructure are in place can undermine the agricultural sector, with long term negative effects for poverty, food security and the environment. Increasing the value captured by small-scale farmers in global, regional and local markets chains is seen as fundamental for meeting development and sustainability goals (IAASTD 2008a, p. 19; IAASTD 2008b, p. 31).

Modern biotechnology

The *World Bank* assessment is that genetically modified plants, or transgenic crops, have been taken up more rapidly in commercial farming, but there is still considerable potential for improving the productivity of small-scale farming systems and providing more nutritious foods to poor consumers in developing countries. Investments in R&D on transgenic crops are concentrated largely in the private sector, driven by commercial interests in industrial countries. The public sector should be leading the R&D on smallholder food crops, because the private sector cannot appropriate benefits of research on these crops. The World Bank criticises that the public sector has underinvested in agricultural R&D in general and in modern biotechnology specifically. Furthermore, the slow progress in regulating possible environmental and food safety risks has restrained the development of GM plants that could help the poor. The conclusion in the World Bank report is that the potential benefits of these technologies will be missed unless the international development community sharply increases its support to interested countries (World Bank 2007, pp. 15, 177-179).

The *IAASTD* comes to a much more sceptical assessment. For modern biotechnology, there is seen a significant lack of transparent communication among actors, assessment lagging behind development and uncertainties about benefits and harms. In this context, Intellectual Property Rights (IPR) are seen as ambivalent, because they attract investment in agriculture, but can also concentrate ownership of agricultural resources. Especially in developing countries, IPR instruments such as patents may drive up costs, restrict experimentation by the individual farmer or public researcher while also potentially undermining local practices that enhance food security and economic sustainability. In this regard, there is particular concern about present IPR instruments eventually inhibiting seed-saving, exchange, sale and access to proprietary materials necessary for the independent research community to conduct analyses and long-term experimentation on impacts (IAASTD 2008a, p. 14).

4. THE RESULTS OF THE CASE STUDIES

In this chapter, the main results of the case studies are presented. Detailed information and the in-depth analysis can be found in the case studies (see annexes 1-6).

4.1 Rainwater Harvesting

The availability of water is the precondition for human life and agriculture. Agriculture has been identified as a priority sector in reducing poverty. In dry regions with irregular and scarce precipitation and ephemeral rivers and without shallow groundwater of appropriate quality the local water demand for small-scale farming can be balanced by Rainwater Harvesting (RWH).

This chapter is based on the case study by Klaus-Dieter Balke (see annex 1).

Characteristics

The technologies of RWH are decentralised water distribution systems including the collection, filtration and storage of local rainwater and surface runoff. Corresponding to the local conditions (climate, morphology, soil, etc.) many various techniques can be applied. RWH methods make it possible to supply human beings and cattle with water, to enlarge the productive land, to increase the crop yield, and – finally – to reduce the rural migration to urban areas. Moreover, erosion and desertification can be diminished. Under appropriate circumstances RWH delivers water for reforestation and groundwater recharge, too.

An important RWH method that can be applied in nearly every kind of landscape is the collection of water in cisterns. In mountainous regions rain and surface runoff can be collected in the retention areas of micro-dams, in infiltration trenches and hill catchments (Example in figure 6). In flat regions subterranean embankments and catchments, micro and macro catchments, field irrigation and graded strip catchments are often in use. A special technique, applied in high mountains near the sea, is fog harvesting.

RWH technologies are simple to install, to operate and to maintain. They are very sustainable, particularly in combination with Conservation Agriculture, because rainfall can not be over-exploited. In certain cases RWH methods can also be used for the restoration of degraded land. Most of the natural material for RWH constructions (rocks, soil) is of local origin. Often, catchment areas and cultivated sectors cover fallow land. The introduction or improvement of RWH systems should be combined with Conservation Agriculture in order to increase the water use efficiency and the soil fertility. For combination with Agroforestry systems, infiltration trenches parallel to the contour lines can be used.

The plants to be cultivated in a RWH scheme should have a limited water demand, a short vegetation period and a tolerance to drought and waterlogging. Trees are relative sensitive to moisture stress during the establishment stage compared with their ability to withstand drought once their root system is fully developed (Mishra, 2006).

For each region the most appropriate crops must be chosen according to the natural conditions (availability of water, soil composition, etc.), the demands of the plants and the acceptance by the population. As fertilisers natural plant remnants or manure should be used, chemical fertilisers only if necessary and in small quantities.

In regions with RWH-fed agriculture, a variety of plants is cultivated, such as almonds, apricots, barley, beans, cabbage, cassava, citrus, dates, figs, groundnuts, lentils, lettuce, maize, melons, millet, olives, onions, peaches, peas, pepper, sorghum, squash, tomatoes, wheat, etc.; sheep and cattle are fed as well.

Figure 6: Micro dams in Tunisia

Quelle: Case study „Rainwater Harvesting“, annex 1, p. 12

Current relevance and use

The methods of RWH can be applied in every climatic zone with water deficiency. They are especially important for emerging countries and developing countries in the south-west of North America, some regions in South America, in large areas of North Africa, Sub-Sahara and Southern Africa, Middle and Near East, the Arabian Peninsula, and widespread areas of Asia.

Resulting from climate change, it must be expected that the regions currently affected by droughts will extent in the future. The negative consequences of a declining yield – caused by longer dry periods - could be reduced by the introduction and adaptation of RWH techniques which are already approved in other, yet drier regions.

The enlargement of the worldwide area cultivated by RWH technologies can contribute to the mitigation of climate change impacts.

Restricting framing conditions

The infrastructure is often on a very low level in poor and remote areas where life depends on RWH agriculture. If a surplus of crop yield can be sold, it must be considered that the farmers need access to a market place in the surroundings. Otherwise, additional income can not be achieved.

Sometimes political forces must be convinced that RWH techniques do not represent primitive methods but are very important for the food production, especially in dry and poor regions.

RWH methods are especially applied by small-scale farmers whose financial means are very limited. In order to improve their situation it is necessary to run RWH development projects including financial aid from governmental or international sources, probably combined with mini-credits for the farmers.

Potentials for improvement

Nowadays, RWH installations are often not as efficient as they could be, sometimes far below their potential, and they need to be improved. In such cases, repair, re-introduction, adaptation to the recent situation and improvement for better efficiency is necessary. The management of the scarce water resources in order to supply as many consumers as possible and to avoid difficulties between them must be taken into consideration. To avoid difficulties, the farmers should undergo an information and training programme.

The introduction or improvement of RWH techniques must be realised in cooperation of external experts from international organisations and the competent government, and the local farmers or community groups.

Each RWH project has to consider and respect ownerships, land rights and water laws (indigenous laws, Islamic laws, laws derived from western laws or no special laws), cultural, social and socio-economic backgrounds. A water association can be founded by the users as a framework for the cooperation. Also some families, ethnic, self-help or religious groups can establish a co-operative.

RWH technologies are sustainable and environmentally friendly. River water and groundwater are not consumed. According to the recommendations of Conservation Agriculture (see chapter 4.2) the tillage is practised in a careful way in order to keep a favourable soil structure, for fertilising plant remnants or – only in limited cases – very small quantities of chemicals are applied The additional vegetation consumes CO_2. Moreover, erosion is inhibited or stopped.

Difficulties may arise in a watershed if RWH plants utilise water in the upstream area causing a reduction of available water for the farmers living in downstream areas. In such cases a just water management must solve the distribution problem.

Effects for small-scale farmers

Examples demonstrate that the crop yield of rainfed cultivation can be doubled or even quadrupled by using techniques of RWH because the catchment areas deliver an additional quantity of water to the cultivated areas so that the plants can consume water over a longer period of time. Such results also require the optimum time of planting, the choice of appropriate crops, a good management of soil fertility, pest control and crop rotation (Hatibu & Mahoo, 2000). Regarding the application of pitting methods the crop yield may increase by 40% (Prinz et al.)

Compared with other methods to produce usable water such as deep wells or the desalination of salty or polluted water by reverse osmosis, ultra-filtration or evaporation RWH techniques are much cheaper and easy to maintain. For the preparation of a catchment area local material (rocks, loam) can be used free of cost, the work can be done by the farmers themselves. The construction of a well is expensive, especially if the well must be sunk into deeper aquifers, a boring company must be charged and construction material such as bricks, pumps and pipes is needed. The methods of water desalination require sophisticated equipment, energy to drive the process, trained personnel and, moreover, the remnants such as brine or salt must be removed.

4.2 Conservation Agriculture

Prevention of soil degradation as well as preservation and/or enhancement of soil fertility are important requirements in sustainable agriculture. The productivity of soils is labile and endangered in tropical areas as well as in arid and semi-arid regions. The Conservation Agriculture development to date has been associated with rainfed arable crops. The Conservation Agriculture concept and principles are applicable to any farm size. They have the potential to rise productivity and therewith income, to protect the soil, enhance water resources and to contribute to climate change adaptation and mitigation.

This chapter is based on the case study by Theodor Friedrich, Amir Kassam and Francis Shaxson (see annex 2).

Characteristics

Definition and key elements

Conservation Agriculture (CA) is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. Conservation Agriculture is based on enhancing natural biological processes above and below the ground.

Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with, or disrupt, the biological processes. This definition of the UN Food and Agriculture Organization (FAO) is based on broad consensus across diverse stakeholders.

Conservation Agriculture is characterised by *three principles* which are linked to each other in a mutually reinforcing manner, namely:

Continuous no- or minimal mechanical soil disturbance (i.e. direct sowing or broadcasting of crop seeds and direct placing of planting material in the soil);

Permanent organic-matter soil cover, especially by crop residues and cover crops; and

Diversified crop rotations in the case of annual crops or plant associations in case of perennial crops, including legumes.

Translation of CA principles into technologies and farmer practices

CA systems utilise soils for the production of crops with the aim of reducing to a minimum the excessive mixing of the soil that is characteristic of tillage-based farming, maintaining crop residues on the soil surface to minimise damage to the environment and deploy diverse crop rotations and associations for enhancing soil and crop health, for producing more biomass of higher quality, for integrated insect pest, disease and weed control, for improved nutrient uptake and for biological soil tillage.

As a consequence, Conservation Agriculture pursues the aims:

To provide and to maintain an optimum environment of the root-zone to maximum possible depth;

To ensure that water enters the soil so that (a) plants never, or for the shortest time possible, suffer water stress that will limit the expression of their potential growth; and so that (b) residual water passes down to groundwater and stream flow, not over the surface as runoff;

To favour beneficial biological activity in the soil in order to (a) maintain and rebuild soil architecture; (b) compete with potential *in situ* soil pathogens; (c) contribute to soil organic matter and various grades of humus; (d) contribute to capture, retention, chelation and slow release of plant nutrients;

To avoid physical or chemical damage to roots that disrupts their effective functioning or limits their maximum potential for nutrient uptake.

In tropical and subtropical areas, the danger of erosion through rainfall is high, the soils are usually poor and eroded and the temperatures are high and thus decomposition is rapid. The type and number of land preparation operations determine the quantity of residues left on the soil surface.

It is therefore important to choose land preparation practices that protect the natural resources base and at the same time improve productivity and reduce production costs. Zero till or no-till practices are those activities in which the seeds are placed into the soil with the least soil disturbance possible. That means planting and sowing into the residues of previous crops and weeds.

CA can be practised in all sizes of farms and ecologies. Machinery, tools and equipment have been developed to cater for three levels of power usage: manual power, animal traction and motorised equipment. The success of CA depends on the effective management of operations dealing with: (a) land preparation, (b) cover crops and weeds, (c) direct seeding and (d) harvest and residues.

Involved knowledge: Integrating CA principles into production practices

At the production level, Conservation Agriculture cannot be reduced to a simple standard technology package because of the diversity and variability in agro-ecological and socio-economic conditions that are associated with farming in general and with less favourable areas and smallholders in particular. Thus, the interactions between the possible recommended technological components and the location-specific conditions of farming must be adequately taken into account.

Consequently, the standardised "best bet" production technologies approach tend to be of limited relevance and value for many farmers because CA practices tend to be knowledge-intensive and farmers themselves must become involved in fine-tuning the transformation and application of the principles into site-specific and farm-specific practices.

International cooperation

International cooperation has become stronger in recent years as illustrated by the biennial process of the World Congress on CA, as well as increasing numbers of regional workshops. An international multi-stakeholder meeting organised by the UK Tropical Agriculture Association (TAA) and hosted by Newcastle University in March 2007 was followed by a larger meeting hosted by FAO with technical support from TAA (FAO 2008a, 2008b). The outcome of the latter meeting was the concept of 'Community of Practice' (CoP) within development communities to formalise and strengthen the connections among like-minded persons who work in a variety of circumstances and collectively seek to improve both knowledge and practice of CA.

Potential advantages from CA

Potential for CA systems in the 21st century agriculture development is based on the large amount of field-based evidence from all continents regarding the role of CA systems in raising productivity and income, improving livelihoods and reducing production costs, increasing resilience of production, contributing to climate change adaptation and mitigation, enhancing water resources and protecting ecosystem services and environment.

In the case of Conservation Agriculture, the benefits can be grouped as:

Economic benefits that improve production efficiency;

Agronomic benefits that improve soil productivity; and

Environmental and social benefits that protect the soil and make agriculture more sustainable.

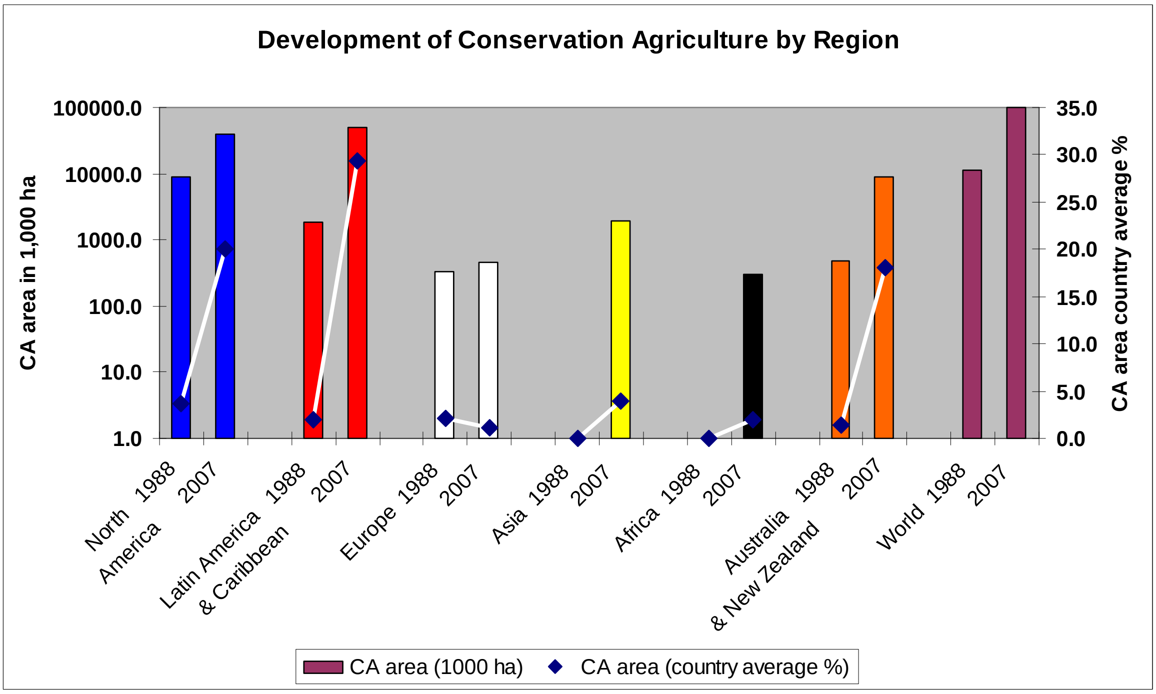
Conservation Agriculture as farming concept and a set of practices has a wide range of compatibility and complementarity with other resource-conserving approaches and technologies and is applicable in rainfed and irrigated farming systems, including Organic Farming (chapter 4.4). It is suitable for different crop types such as grain crops including rice, roots and tubers, vegetables, perennials and Agroforestry systems (chapter 4.5).

Current relevance and use

Worldwide, there are now almost 100 million hectares of arable crops which are grown each year without tillage in CA systems (Figure 7). The total area under Conservation Agriculture is still very small (about 6-7%) relative to areas farmed using tillage.

No-till agriculture in the modern sense originated in the USA in the 1950s, and from this time until 2007 the USA has always had the biggest area under no-till in the world. But it is interesting to note that, in the USA, no-till accounts for only 22.6% of all cropland hectares, as compared with the Southern Cone of *Latin America* where no-till becomes the majority agricultural system with 60% of the surface. Canada shows the fourth biggest area under no-till with 12.5 million ha. CA exists in Europe but it is not really widely spread. In Australia CA has been widely and quickly embraced by farmers.

Figure 7: Development of Conservation Agriculture over the last 20 years by world region in total area (ha) and as average percentage across the adopting countries of the respective region



Source: FAO, 2008a

Asian and African countries have begun to take up CA practices only in the last 10-15 years, but have already acquired many useful lessons with respect to adapting the principles of CA to a vast diversity of conditions and constraints. Among the most encouraging experiences has been the CA work developed in dry environments such as Tunisia and Kazakhstan.

CA is practised in all climate zones of the world where annual and perennial crops can be grown, from the tropics and subtropics to the temperate regions. CA concept and principles are applicable to any farm size (large land holdings, commercial farmers, medium-scale farmers, small-scale farmers) subject to availability of equipment.

Restricting framing conditions

The initial and primary restriction to the adoption of CA is the assumption that tillage is essential for agricultural production. Subsequent hindrances to its adoption include, to various degrees, those of intellectual, social, technical, environmental and political characteristics. Key restrictions for mainstreaming CA systems relate to problems with up-scaling which is largely based on the lack of knowledge, lack of expertise, lack of inputs (especially equipment), inadequate financial resources and infrastructure and poor policy support.

Insufficient financial resources at the farm and government level to support the change-over from tillage system to CA are a key restriction in the change process. If farmers do not have secure rights to the use and produce of their farmland (as in the case of renting land, sharecropping etc.) there is the likelihood that the farmer would be unwilling to invest time, effort and money into improving it if/when the owner might decide to take it back and profit himself from the benefits of the other's work. This could prove to be a severe disincentive and dampener of enthusiasm for adopting CA. This potential problem is widespread in many parts of Africa.

Even in the face of looming problems posed by complexities of climate change effects and their interactions with increasing demands for production from the land, a number of governments are not yet fully enthused by the possibilities of Conservation Agriculture. The effectiveness of such backup will depend on coherence of purpose and approach between the different agencies of government involved in encouraging the spread of CA.

Restrictions to adoption of CA among farmers themselves may include resistance to change, and the fear of ridicule. Where the local tradition is that the cattle and other animals of the local community are entitled to graze on all harvested fields as well as on common lands, there are likely to be conflicting views between traditionalists and those who would start CA on their croplands. Ecological restrictions may be imposed by climatic conditions, together with land characteristics.

Potentials for improvement

Conventional, tillage-based ways of treating soils have resulted in damage to their inherent productive capacity and their biologically-based sustainability as favourable rooting environments. Conservation Agriculture is a fundamental change in the agricultural production system, is aimed at self-sustaining improvements of the overall health of the soil/plant ecosystem and provides a more benign and beneficial alternative.

By avoiding tillage, the loss-rate of CO_2 from soil to atmosphere is greatly reduced; permanent cover of mulch materials both sustains the soil biota, raises soils' retention/release capacity for water and plant nutrients, and protects the surface from extremes of rainfall and temperature; rotations limit pest build-up, favour nutrient-cycling in the soil and increase levels of soil organic matter at different depths. In these ways CA improves and sustains soil health on land already in good condition, can regenerate land in poor condition and favours the self-repeating sustainability of soil processes.

Effects for small-scale farmers

Land degradation is not so much consequent on poverty *per se* as it is on failure or inability to apply what is already known about the functioning of such systems. Even those rural poor who cannot fully meet their basic needs can benefit from application of CA's principles. They cite: reduction in labour to produce greater crop yields per unit area; improvement in family members' health due to being able to include vegetables in the diet; reduction or elimination of periods of hunger during the year; greater food security; chances to make off-farm sales of surplus produce.

These benefits were initiated with near-nil investment through altered usage of already-available materials and energy, and then provided extra cash for re-investment in the enterprise next season. Where some resources were scarce relative to the land area, their concentration in limited proportions of the farm, as opposed to spread thinly everywhere ensured at least some crop plants were advantaged and matured fully.

There are growing risks to continuing with tillage agriculture, but entrenched insistence on its continuation (as by powerful voices of some input- and equipment-makers) could jeopardise firm encouragement and support by governments of CA's spread. Interested farmers risk becoming disillusioned if adequate practical advice, equipment or inputs are not available.

A government needs to make firm and sustained commitment to encouragement and support of CA, expressed in policies which are consistent and mutually reinforcing across the spectrum of government responsibilities and, as necessary, sufficiently flexible to accommodate variability in local characteristics. Facilitation should include tapered financial and logistical support as appropriate and necessary, for the number of years needed for farmers to have made the changeover and become familiar with the functioning of CA. Formal recognition should be given to the public goods value of environmental benefits generated by adoption of CA. The education system, from first grade to post-graduate, should be permeated with understanding of well-managed CA as an optimum expression of sustainable productive agriculture.

4.3 System of Rice Intensification

The System of Rice Intensification (SRI) is an innovation in rice production systems that is still evolving and ramifying, but already it is raising factor productivity and incomes for more than 1 million small farmers producing rice around the world on over 1 million hectares. SRI addresses the major constraints affecting the livelihoods of small and poor farmers: their limited resources of land, labour, water and cash, as well as losses from pest and diseases and adverse climatic conditions. SRI does not require rice farmers to commercially purchase and use any external inputs, since its benefits derive from changes in the ways that existing resources are used for rice production, which reduces their commercial input-dependence. At the same time, SRI concepts and methods can be adapted by larger rice producers, so they can help meet the basic food needs of the urban poor and national population.

This chapter is based on the case study by Norman Uphoff and Amir Kassam (see annex 3).

Characteristics

The System of Rice Intensification (SRI) is basically a set of modified practices for managing rice plants (including its phenology) and the soil (including soil biota and aeration), water and nutrients that support their growth. These changes in often age-old cultural practices were assembled and integrated by Fr. Henri de Laulanié, S.J., who spent half a lifetime in Madagascar working with small and poor farmers there to improve their rice productivity and output so as to alleviate their families' hunger and poverty (Uphoff 2006). The crop husbandry methodology that he developed inductively can be justified in terms of principles that are well-grounded in agronomic science (Uphoff 2007).

Key elements

The main operational elements of SRI, each having good agronomic rationales, are:

Young seedlings: If establishing the rice crop by transplanting, young seedlings, 8-12 days old instead of the usual 3-4 weeks, are used.

Careful transplanting: Transplanting should be done very carefully but quickly, taking special care to protect the young roots.

Wider spacing: The recommendation is one plant per hill established in a square pattern. The aim of the wider spacing in a square pattern is to give both roots and canopy more room to grow, for taking up nutrients and capturing sunlight.

Aerobic soil conditions: Using very young seedling has been shown in factorial trials to be the single most important contributor to higher SRI yields (Randriamiharisoa/Uphoff 2002), but the second most important is keeping the paddy soil *moist but not continuously saturated*. This avoids the suffocation and degeneration of rice plant roots (Kar et al. 1974) and also supports more abundant and diverse populations of aerobic soil organisms that provide multiple benefits to the plants (Randrimiharisoa et al. 2006).

This can be done by applying small amounts of water daily, with several period when the field is allowed to dry for 3-6 days during the vegetative growth stage, or by alternate wetting and drying (AWD) for periods ranging from 3 to 8 days.

Active soil aeration: When paddy fields are not kept continuously flooded, weed growth becomes a greater problem. Weeds can be controlled by manual weeding or chemical herbicides, but neither gives as good results with SRI practices as the *use of a soil-aerating hand weeder* which churns up the soil as it buries weeds conserving their nutrients as they decompose in the soil.

Enhanced soil organic matter: Finally, SRI involves enhancing the soil organic matter as much as possible with compost or mulch to 'feed the soil' and the life within it so that the soil biota will help feed and protect the growing plants.

The System of Rice Intensification can be fully organic since resulting plants are more resistant to pests and diseases; but if not enough biomass or labour is available to supply the soil with organic matter, mineral fertilisers can be used. Also, agrochemicals can be used for pest control but are usually not needed or uneconomic. Generally the best yields and highest incomes with SRI methods come from organic crop management. They are successful with both traditional, local varieties and with new, improved varieties and hybrids, so these methods can be used within the full range of subsistence to 'modern' agricultural production systems. The key is to enable the rice plants and the crop as a whole to express their full genetic potential under the soil-water-nutrient management conditions that enhance and maintain soil fertility and its productive capacity. So, in this regard SRI is compatible and convergent with Conservation Agriculture. The source of the benefits described above is that SRI practices, taken together, produce larger, longer-lived plant roots and more abundant, diverse and active soil biota to support a greater number of panicle-bearing tillers that have higher number of spikelets and seeds, and mature synchronously and early (Figure 8).

Figure 8: Malian farmer in Timbuktu region comparing SRI rice plant on right with plant grown conventionally on left. Trials in 2007 and 2008 gave yield of 9 tons/ha with SRI practices compared to 6.7 tons/ha with best management practices

Source: Case study „System of Rice Intensification“, annex 3, p. 64, picture courtesy of Dr. Erika Styger

Complementary elements

The SRI recommended practices are modifications of irrigated rice cropping systems, not the whole system, so there are a number of other activities involved, having some modifications to suit the core practices:

- land preparation including possibly raised bed and/or zero-till;
- nursery management under unflooded conditions;
- seed selection and priming;
- soil solarisation where pathogens are a problem; and
- soil enrichment with micro-organisms as an innovation still being evaluated.

SRI is still evolving, so innovations and modifications like direct-seeding or mechanical transplanting are being introduced by farmers. Also, possibilities exist for increasing organic matter from biomass produced in-situ within the rice-based cropping system using high biomass cover crops and crop rotations as is the case with Conservation Agriculture systems.

Defining System of Rice Intensification

Not being a conventional standardised 'technology' and being still 'a work in progress', as well as requiring learning by farmer based on 'trial-and-error' approaches, no fixed or narrow definition is possible or desirable. SRI concepts and practices are being extended to other crops so 'SRI' is not even just for rice. Essentially, SRI is a suite of practices, based on sound scientific principles, for enhancing the growth and performance of both plant roots and soil biota, to produce more healthy and productive plant phenotypes (phenomena) from any genotype (initial genetic potential). The result is more profuse growth of tillers (stems), leaves, panicles (ears of grain) and grains themselves. SRI is better understood as a matter of degree than of kind; SRI is better regarded as a 'menu' rather than a 'recipe.' Rather than try to decide what is or what is not SRI, we suggest considering to what *extent*, and how *well*, the recommended practices were used, and with what results. SRI practices such as timing and spacing, and increasingly in-situ biomass production, are always to be adapted to local conditions and cropping systems.

Although SRI was developed for improving production of irrigated rice, its concepts and methods are being extended to *rainfed* rice production and also to *other crops* such as wheat, finger millet and sugar cane. Thus, the eventual impact on the agricultural sector of SRI ways of thinking and cultivating could become quite broad.

Involved knowledge

SRI is an innovation based on new knowledge, or rediscovery of old knowledge, rather than on purchased material inputs, utilising available land, labour, water, natural resources and cash more productively. The specific knowledge involved is discussed in the case study.

Key actors

From its inception, SRI has been a farmer-centred innovation. Its success depends upon farmers' motivation and skill for using the insights originating in Fr. Laulanié's work but being continuously expanded and ramified. SRI has been extended by a full range of institutions, from national to local levels, working with farmers in the dissemination and application of SRI concepts and practices: government agencies, non-governmental organisation (NGOs – initially the most active on behalf of SRI), universities and research institutions, also private sector organisations (e.g. Syngenta in Bangladesh, Nippon Koei in Indonesia). In general, SRI can be characterised as a 'civil society' innovation.

International actors

There has been some donor agency support in a number of countries, but so far most of the initiative occurred at national, intermediate and local levels, with communication and coordination support coming from Cornell University in the U.S. The international community generally has been slow to respond to SRI opportunities, and there has been some controversy surrounding SRI. But the evidence of SRI's benefits and wide applicability is increasing season by season, and country by country, so SRI is becoming more and more of an international phenomenon and an opportunity to be harnessed for poverty alleviation and strengthening food security and sustainability.

Potentials for sustainability

Because SRI reduces the demand for water in agricultural production and also the use of agrochemical inputs, it has benign environmental impacts. But raising the biological and economic productivity of land, labour, water and capital all at the same time, it enables farmers to produce more with less, by mobilising the services and benefits of soil biota. While not exactly a 'free lunch' (see listing of costs and constraints below), it points the way to greater sustainability of agricultural production in general, and of production intensification.

Current relevance and use

SRI is now demonstrated and spreading in all world regions except Europe and North America, and its methods have proved to be productive in a wide variety of agroecosystems: from the tropical coastal regions of West Africa to the interior, arid climate of the Timbuktu region in Mali, on the edge of the Sahara Desert; from 100 meters asl in the terai region of Nepal up to 2,700 meters in that country. Although developed for the benefit of small farmers in Madagascar, SRI being a biologically-based innovation is scale-neutral. In Sichuan and Zhejiang provinces of China, extension services report that SRI methods are being taken up most quickly by larger farmers, because these help them save labour as well as seed, water and money.

Four years ago, there were less than 30,000 hectares of SRI use outside of Madagascar, whereas today this area is over 1 million hectares. Where government agencies have gotten involved in SRI dissemination or where NGOs have had sufficient resources for their extension activities, the spread has been quite rapid. Most of the uptake of SRI methods has been, not surprisingly, in Asia, where 90% of the world's rice is produced.

Except for Madagascar, the country of SRI origin, there has been no major spread of the new methods in Africa, but that the methods can raise yields with lower water and other input requirements has been shown in many Sub-Saharan African countries.

Limitations and constrains

The main objective limitation/constraint is *water control* to be able to apply smaller but reliable amounts of water; where fields are inundated, the benefits of SRI will not be achieved because plant roots will die back and only anaerobic soil organisms can survive. *Labour availability* is essential because initially the methods require more time while these are being mastered; over time, SRI can become labour-saving. *Biomass availability* to enrich the soil organic matter content and/or make compost is important, although if there are limitations of biomass as a source of nutrients or labour time to produce compost, mineral fertilisers can be used with the other methods. *Crop protection* is sometimes needed, although SRI plants have considerable natural resistance against pests and diseases. *Farmer skill and motivation* is the most important requirement since SRI involves more intensive and knowledgeable management, while reducing the intensity of other purchased inputs. Then there are *other factors* including access to simple, reasonably inexpensive implements that enhance labour and soil productive capacity, market development where increases in supply may exceed local demand and appropriate land tenure.

Potentials for improvement

The System of Rice Intensification is being continually improved, particularly at farmer initiative, although the scientific community has growing interest in and involvement with SRI. The benefits obtainable for small farmers as well as for the environment are driving this continuous innovation. Potential for further improvement exist in minimising puddling or doing away with it altogether, introducing direct seeding, in-situ biomass production through high biomass mulch and cover crops, and transforming the total rice-based cropping system to Conservation Agriculture. There are opportunities for development-oriented research to improve equipment and practices for direct seeding, for weed management, for residue and soil cover management, for nutrient and water management and for cropping pattern management. In irrigated rice, there are potentials for significant water savings through SRI, and in case of irrigation expansion for rice production, SRI-based systems offer higher return to investment to the farmers and at the scheme level to governments. Policy support to promote SRI has been slow in coming but this is beginning to change. Policy and institutional changes can be accelerated if the scientific and donor community can be made aware of the full potential of SRI methods for sustainable production intensification, reducing energy and production costs, responding to climate change, saving water and reducing the consumer price of rice.

Effects for small-scale farmers

SRI's alternative management practices can improve soil fertility and water retention by inducing better root development in plants and building up soil organic matter and soil biota.

These elements contribute to SRI's higher total and factor productivities. Also, by reducing the need for agrochemical inputs (inorganic fertilisers and chemical protection), SRI can improve soil and water quality, also easing future water crises by reducing irrigation and crop water requirements. Thus, the overall unit cost of production is relatively lower than under the conventional irrigated system. As a bonus, there is higher outturn of milled rice when unmilled paddy grain is processed because of less chaff and fewer broken grains.

All this sounds 'too good to be true', but these various effects have been documented in a diverse set of countries, now up to 35 across Asia, Africa and Latin America. SRI has been spreading rapidly beyond its country of origin, Madagascar, over the past decade despite relatively little donor support. Farmer uptake of SRI in some rice-producing areas, including areas of severe poverty such as eastern and northern India and northern Myanmar, is proceeding at unprecedented rates.

Because SRI is a biologically-driven innovation, rather than being based on introducing certain genotypes or increasing purchased external inputs, there can be wide variability in results. These are affected by climate and soil conditions as well as by varietal differences and by differences in farmer skill and attention. Also, the crop response to SRI methods depends in part on the starting point – whether rice production is currently low-input/low-output or more 'modernised' with higher levels of inputs and better yield results. So, averages are not very meaningful. But generally speaking, SRI methods are seen to have the following impacts compared to their conventional counterparts:

Depending on current yield levels, *output per hectare* is increased usually by 50% or more, with increases of at least 20%, and sometimes 200% or more.

Since SRI fields are not kept continuously flooded, *water requirements* are reduced, generally by 25-50%.

Although external commercial inputs can be used with SRI methods, the system does not require purchase of new varieties of seed, chemical fertiliser or agrochemical inputs.

The minimal capital costs make SRI methods *more accessible to poor farmers*, who do not need to borrow money or go into debt, unlike many other innovations.

Costs of production are usually reduced, usually by 10-20%, although this percentage varies according to the input-intensity of farmers' current production.

With increased output and reduced costs, *farmers' net income* is increased by more than their augmentation of yield.

4.4 Organic Farming

The fundamental distinction of Organic Farming from conventional agriculture consists in its focus on input optimisation rather than output maximisation. It aims at more efficient nutrient use and re-use by optimising the scope of nutrient recycling. Fertilisers are primarily used for the regeneration and maintenance of soil fertility. Findings and knowledge from the field of ecosystem analysis are therefore considered and applied to the concept of Organic Farming. This also implies the recognition of agricultural enterprises as entities with a certain level of closure (comparable to organisms).

Likewise, enterprises operate on a high level of economic autonomy, which is particularly relevant in terms of food security.

This chapter is based on the case study by Heide Hoffmann (see annex 4).

Characteristics

A distinctive feature of Organic Farming is the fact that it acts according to principles which are opposed to essential fundamentals of our society today. While one of the principles of a market economy is undamped growth with the most efficient use of resources possible, Organic Farming restricts itself. I.e. farmers work according to strict legal guidelines. The objective is to create typical agro-ecosystems where a natural development of economic plants and farm animals is possible. At the same time the use of system-unspecific methods and means, especially readily soluble mineral fertilisers, synthetic pesticides and performance stimulants and thus maximum proceeds are renounced.

Organic Farming is thus at first a legally defined production method for food and may also be part of a lifestyle, e.g. a movement with agro-political and ideological-philosophical influence. In addition, Organic Farming 'by design' (producing organic food with certification for a special market) can be distinguished from organic farming 'by default' where farmers in developing countries applies no agrochemicals because they have no resources to buy external inputs and/or follow traditional production methods. For the latter, data on concerned farmers and agricultural land use are not available.

Due to the self-restriction of the cultivation system and the respect for the cycle and system character, Organic Farming is especially suited for ecologically fragile ecosystems either in marginal locations or in areas with a high biodiversity. A special advantage is the fact that the principles and technologies of Organic Farming allow the integration of technical solutions of conventional farming as well as the further development of traditional land use systems.

The principles of Organic Farming are formulated in a very broad sense and include the way how people treat soil, water, plants and animals to produce, process and trade food and other goods (IFOAM 2009).

They also concern the way how people treat the man-made landscape, their behaviour amongst each other and how they shape the heritage of future generations. Organic Farming is not only about considering ecologic and economic coherences, but also about social aspects. Organic Farming is thus based on the principles of health, ecology, justice and welfare.

Organic Farming has overlaps with Conservation Agriculture, System of Rice Intensification, Agroforestry systems and Rainwater Harvesting. For example, the traditional Tassa method of Rainwater Harvesting can be combined in the Sahel region with an agricultural production with organic standards (Figure 9).

Figure 9: Tassa method – example of rainfed production in the Sahel region

Quelle: http://www.fao.org/DOCREP/006/Y4690E/y4690e1t.jpg

Key technologies

The Organic Farming production systems show similarities concerning their key technologies on all continents:

Use of a high biodiversity through crop rotation, Agroforestry systems and combination of plant and livestock production;

High ranking of compost and, if available, animal dung;

Often a high proportion of manual labour;

Openness towards new technical solutions (Organic Farming is not technology-hostile). The cultivation system allows the use of simple mechanisation solutions as well as the application of modern machines that may be combined with animal power up to the use of precision farming elements.

Key actors and international cooperation

Typical actors engaged in Organic Agriculture are the farmers themselves. In most countries it is referred to as a typical grass root movement where farmers often get support from NGOs and, in some cases, also by scientists. In Asian countries such as South Korea, Japan and China, Organic Farming is even supported by the government.

The IFOAM (The International Federation of Organic Agriculture Movements) is the umbrella organisation of the international cooperation in the field of Organic Farming. In form of a democratic grass root organisation, it unites currently 750 member organisations in 108 countries.

Current relevance and use

As a part of the environmental movement, Organic Farming had its start with different schools, smallholders producing for local markets, e.g. biodynamic farming in Germany or low external input sustainable agriculture in the United States (Low-External-Input-Agriculture (LEISA) and Low Input sustainable agriculture (LISA), see Reijntjes et al. 1992).

Organic Farming systems exist worldwide on all continents. Organic Farming succeeded in establishing alternative production systems and created new markets worldwide.

According to the FiBL Survey 2008, more than 30.4 million hectares were managed organically by more than 700,000 farms worldwide in 2006. This constitutes 0.65% of the agricultural land of the countries covered by the survey (Table 6).

More than one quarter of the world's organic land is found in developing countries (8.8 million hectares). Most of this land is located in Latin America, followed by Asia, Africa and Europe. The leading countries in terms of organic land are China, Argentina, Uruguay and Brazil. The highest percentages of organic land are found in several pacific island countries, East Timor, Uruguay and Argentina. In these countries, the relative shares of organic land are comparable to those in Europe. These high shares can probably be attributed to a high potential for exports and several support activities in these countries.

In developing countries, the shares of grassland (more than half of the organic land in these countries) and those of permanent crops are, compared to Europe and North America, relatively high. This can be attributed to the fact that export plays an important role – either for meat products (mainly from Latin America) or for permanent crops. The most important permanent crops are export crops, such as coffee, olives, cocoa and sugarcane (Willer, 2008. In: Willer, Menzler-Yussefi, Sorensen, 2008, p. 40).

Table 6: Organic agricultural land and farms by continent in 2006

Continent	Organic land area (hectares)	Share of total agricultural area	Organic farms
Africa	417’059	0.05%	175’266
Asia	3’090’924	0.17%	97’020
Europe	7’389’085	1.62%	203’523
Latin America	4’915’643	0.68%	223’277
North America	2’224’755	0.57%	12’064
Oceania	12’380’796	2.70%	7’594
Total*	30’418’261	0.65%	718’744

Source: FiBL Survey 2008 in Willer, Yussefi-Menzler, Sorensen, 2008, p. 26

Due to the growing international demand for healthy food and its global trading there is a need for the standardisation of Organic Farming systems. This standardisation turns out as highly controlled certification based on precepts and rules for production.

Restricting framing conditions

There are also significant constraints on the potentials of Organic Farming for development. In part these are external such as the cost of certification, infrastructure problems, maintaining links with distant markets and the uncertainties of world markets. But there are internal constraints as well. The overarching priority for agriculture in developing countries is attainment of sustainable food security. Organic Agriculture has a huge potential in helping meet this objective.

Potentials for improvement

Experience has shown that Organic Agriculture has competitive potential, also on economic comparisons. Another aspect is the reduced drought susceptibility of Organic Farming, particular relevant for the fight against hunger in poor African regions.

However, even Organic Agriculture is not yet sufficiently sustainable and requires further development. The most frequent problems mentioned for organic production sites are: Lack of techniques, small fields, marginal soil conditions and dry climate.

From a technological perspective much potential remains unexploited, e.g.:

Improvement of the humus content and biological soil activity, leading to fostered nutrient cycles and dynamics. In agro-sylvan systems, for example, composting of wooden residues containing lignin might facilitate a jump in intensity.

The method of evolutionary plant-breeding could create varieties which not only dispose of a higher yield potential, but also of better drought and heat resistance. Participatory approaches including farmers in the process further allow a significant reduction of the timeframe of such breeding programmes.

Effects for small-scale farmers

In a recent study, Badgley et al. (2007) examined a global dataset of 293 examples and found that in developing countries organic systems produce 80% more than conventional farms. Moreover, contrary to fears that there are insufficient quantities of organically acceptable fertilisers, the data suggests that leguminous cover crops could fix enough nitrogen to replace the amount of synthetic fertiliser currently in use.

In a review of 286 projects in 57 countries, farmers were found to have increased agricultural productivity by an average of 79% by adopting “resource-conserving” or sustainable agriculture (Pretty et al. 2006). A variety of resource conserving technologies and practices were used, including integrated pest management, integrated nutrient management, conservation tillage, Agroforestry, Water Harvesting in dryland areas and livestock and aquaculture integration into farming systems. These practices not only increased yields, but also reduced adverse effects on the environment and contributed to important environmental goods and services (e.g. climate change mitigation), as evidenced by increased water use efficiency and carbon sequestration as well as reduced pesticide use.

The work relies on previous research, which assessed 208 sustainable agriculture projects. This research found that for 89 projects for which reliable yield data was available, farmers had achieved substantial increases in per hectare food production through adopting sustainable agriculture practices: The yield increases were 50-100% for rain-fed crops, though considerably greater in a number of cases, and 5-10% for irrigated crops (Pretty/Hine 2001 p. 48).

4.5 Agroforestry systems

Agroforestry systems are understood as land use systems which simultaneously combine deliberately interplanted annual crops and trees. Agroforestry consists of a set of reasoning and design principles rather than fixed planting schemes. Agroforestry aims to diversify and sustain production for increased social, economic and environmental benefits for land users.

This chapter is based on the case study by Carsten Marohn (see annex 5).

Characteristics

Definition and types of Agroforestry systems

Agroforestry systems *sensu strictu* are defined as land uses, which simultaneously combine deliberately interplanted annual crops and trees. These systems can be highly diverse in species composition and physical structure. Agroforestry design integrates and imitates generic principles and functions of natural ecosystems and adapts them to local conditions.

In ecology the principle of succession describes the colonisation of ecosystems through time. Natural succession is characterised by increasing biomass and diversity at decreasing growth rates. While monocropping systems rather resemble pioneering stages of vegetation in open areas, Agroforestry imitates complex successional stages of natural ecosystems in rather advanced stages.

A high biodiversity is hence a distinct feature of such systems. Although species composition is often altered intentionally and diversity levels mostly remain below those of natural forests, the habitat quality of Agroforestry systems in general remains high.

In summary, Agroforestry systems provide a variety of set-ups modelled on successional stages of forests with the purpose of minimising costs and inputs, maximising productive functions and self-sustenance while maintaining and enhancing essential environmental services.

There are countless Agroforestry systems that have been developed across the globe. Primarily they can be classified according to their main managed components into

Agrosilvicultural systems: Annual crops and shrubs/trees;

Silvopastoral systems: Pasture or cut fodder with animals and trees;

Agrosilvopastoral systems: Trees, crops, pasture/cut fodder and animals.

Furthermore, the systems can be differentiated according to their spatio-temporal arrangements, functions and organisational aspects. Finally land use intensity or management can be used as additional classification criterion.

Extensive systems, such as semi-nomadic types of forest clearings or selective planting along frequently used trails, have been applied since millennia. These traditional practices still today serve as models for near-natural, sustainable land use and can be considered as vital and primary source of nowadays' knowledge on Agroforestry.

Among the sequential and semi-simultaneous systems, *taungya* (interplanting of cash or food crops with forest seedlings in the early stage of reforestation schemes) is considered as progenitor of modern Agroforestry.

Especially in tropical areas, where increased human pressure requires to curtail the fallow period for soil regeneration, *improved fallows* with leguminous nitrogen fixing perennials are established as further development of traditional shifting cultivation. Soil recovery is mainly enhanced by the use of the multi-purpose woody leguminous species or the strategic use of fertilisers.

In spatially differentiated Agroforestry *hedgerow planting* is widely used. Though the hedges planted along contour lines provide multiple benefits (soil protection, fodder, fuel wood) farmers may refrain from establishing such systems due to the potential competition with the annual crops in terms of nutrients, water, light and space. *Windbreaks* and *shelter belts* along coastlines and riverbanks perform similarly, however partly without annual components.

Among the animal-based systems only a few silvopastoral systems may be considered as Agroforestry in a broader sense. This includes keeping livestock under fruit trees for fertilising, repressing grass and competing undergrowth and for easing the gathering of fruits. In agrosilvopastoral systems annual crops, perennials and livestock are combined in various sequential (e.g. *livestock-under-tree* following a *taunyga* system) or spatially differentiated set-ups (e.g. feed-damage protection through living fences).

Contrasting the afore-discussed systems, *intensive Agroforestry* is mostly characterised by higher biotic and structural diversity, which in return requires farmers' increased attention and management. *Homegardens* represent a prominent, wide-spread land-use system in many tropical regions. Their assemblages of multipurpose trees and shrubs with annual and perennial crops and various livestock, located within the compound, provide a variety of economic, ecological and social functions and values including food self-sufficiency, recreation or spiritual retreat.

Contrasting to home gardens, *multi-storey tree gardens*, usually located at some distance to the homestead, may spare the annual component. The system combines various multi-purpose trees and perennials in a forest-like system with at least two storeys.

For potentially smallholder-dominated commodity crops like rubber, banana, cacao or coffee, integrated cropping systems or cultivation in low intensity managed forests represents a viable setting. These can pose an alternative to large-scale high input estates, if recollection and marketing are assured.

Successional Agroforestry mimics natural transcourse of vegetative colonisation most closely, arguing that climax vegetation is best adapted to environmental conditions on site. This means that the crops and species used at a given time correspond with the plant communities of the respective successional stage, e.g. pioneers, early and late successional guilds (Figure 10).

Archaic Philippine Hanunóo systems, *rainforestation*, South American s*istemas multi estrato* (multi-strata systems) or Sri Lankan *analog forestry* are examples of natural succession accelerated by human intervention (e.g. synchronised plantings, pruning, weeding). Depending on the design strategy (ecotourism, carbon sequestration, agricultural crops etc.), exotic species along with the keystone native species are introduced under the condition of being analogous to the natural vegetation in structure and ecological function.

Figure 10: System habitus and some important products in a schematic Latin American successional Agroforestry system

Year 1	Years 2-3	Years 5-10	Years >20
Maize	*Inga spp.*	Cocoa, coffee	Cocoa
Beans	Pineapple	Peach palm	Brazil nut
Cassava	Papaya	Citrus, Annonaceae etc.	Vanilla
Maracuja	Div. bananas	Div. banana	Palm fruits and NTFP
Sesame	Coffee	Fast growing wood	Hard wood

Source: Case study „Agroforestry systems", annex 5, p. 27, illustration Yana/Weinert 2001

International cooperation and research

In consideration of its great potential but also a number of serious constraints and threats, there are a number of national and international actors dealing with Agroforestry in terms of research and development. However, only few institutions on international level have a special focus on this sector, which somehow reflects its negligence in the past. The World Agroforestry Centre (ICRAF) is entitled the world mandate for Agroforestry by CGIAR, but also Bioversity International, the FAO and the International Centre for Tropical Agriculture (CIAT) dedicate a number of programmes and projects to agroforestry-related issues.

Apart from these international agencies there are many national and regional R&D institutions in developing countries as well as university institutes worldwide focusing on Agroforestry, not to forget innumerable NGOs.

Research in Agroforestry still focuses on the biophysical aspects of such systems, only recently socio-economic issues are discussed on a broader scale. As land use and land use change has become a major topic for research, so has computer modelling, which allows to run scenarios and to assess their implications efficiently. Several models for Agroforestry exist, they range from inter-species competition on a plot level to environmental functions in the landscape. On the socio-economic side, the bulk of publications is on cost – benefit calculations, considering subsistence as well as cash crops and non-market benefits. Neglected fields are tenure and gender-related issues.

Potentials for sustainability

Agroforestry offers a great potential for sustainability, although it has some limitations and constraints.

The effective and efficient use of the natural resources available is commonly perceived as an important key to sustainability. In Agroforestry design, this is achieved by complementary structuring of annual and perennial plants in different storeys. In doing so, a variety of ecological niches can be productively explored whereas inter- and intraspecific competition are ideally minimised.

An appropriate set-up requires to consider the specific demand for light, water and nutrients of each component in their successional, seasonal and spatial variability. Another key principle applied is the establishment and maintenance of a tight nutrient cycle. This includes the nutrient fixation through leguminous trees, the safety net function of deep-rooting trees against the loss of nutrients as well as the nutrient pump function, i.e. circulation of minerals from deeper soil horizons through roots and leaf litter onto the soil surface, where these nutrients are available to shallow-rooting plants.

Additional beneficial effects result from the physical water retention function (reduction of direct run-off and evaporation) through a permanent vegetation cover, increased leaf litter, humus and improved soil structure. Multi-strata canopies can contribute to a significant reduction of microclimatic extremes and ensure an extended availability of soil water. This in return favours vegetation, root penetration as well as a perpetual microbial colonisation with positive feedback effects on the nutrient cycle. In fact, comparative studies prove that Agroforestry systems in terms of water use efficiency can be significantly superior to monocropping systems.

Accumulation of soil organic matter (SOM) and the maintenance of a high soil humus content is another core element of sustainable land use represented in Agroforestry. A high soil humus content both stabilises the soil structure against erosion and stores nutrients. Quality and quantity of SOM depend on species composition, their biomass production and input through litter, human activities such as pruning, mulching or manuring, but also on decomposition rates. In Agroforestry the annual and perennial components of vegetation can provide both the permanent source of SOM and the protective function against wind and water erosion, a function that may be enhanced by appropriate management practices, such as terracing or hedgerows.

Current relevance and use

In general, the distribution of Agroforestry systems can be clustered into three agro-ecological zones, namely

humid lowlands with shifting cultivation, taungya, plantation-crop combinations, intercropping systems and multi-strata tree gardens;

semiarid lowlands with silvopastoral systems, windbreaks and shelterbelts, multi-purpose trees for fuel/fodder and multi-purpose trees on farmlands and

highlands with soil conservation hedges, silvopastoral combinations and plantation-crop combinations.

In *Sub-Saharan Africa*, tree-based agricultural systems could potentially cover an area of almost 1 billion hectare (over 40% of the land area). Currently, only 9% of this potential has been realised. Tree crops for export, in particular cocoa and coffee, play a dominant role, but tree fruit exports have distinctly increased in the past decades. Africa is particularly struck by HIV/AIDS, climate change as well as population growth, coupled with proceeding deforestation and land degradation. Agroforestry to a certain extent could thwart these problems, but development and spreading of tree crop systems is impeded by lacking inputs, poor market access and market price fluctuations.

Various strategies, such as diversification, improved planting materials, post-harvest technologies, credit schemes and the promotion of farmer associations have been recommended to tackle these challenges.

In *South-Asia*, tree-based systems are established on 112 million hectare but could be potentially doubled. These systems play a major role in semi-arid parts of the Indian subcontinent but can be found dispersed all over the region. The main challenge agriculture (including Agroforestry) in general faces is water management, which shall be tackled with diversification strategies.

In the *East Asia-Pacific region* (including China and Mongolia) the potential for tree-based systems is estimated at more than 1.1 billion hectare with around 14% of the area being currently under such type of land use. In China, Agroforestry has a long tradition and plays a major role in the context of reduction of wind erosion. Large shelter belt schemes cover more than 11 million hectare in the northern and central regions. In other parts of the country, different systems of intercropping agricultural crops with trees or so-called farmland-forest-networks are very popular and add up to another 15.5 million hectare. Recently, rubber plantations are increasing in some regions of Asia such as Southern China and Vietnam. While smallholder jungle rubber on peat soils in Sumatra is considered a system relatively close to nature, the sustainability of large-scale plantations or extension on wide areas is controversially discussed. Although rubber plantations are counted as Agroforestry systems by some, they do not fulfil the criteria defined above and are rather opposed to the approach on diversified resilient systems.

For *Latin America and the Caribbean*, estimations indicate a potential of some 1.2 billion hectare of tree-based systems extending over a very wide range of agro-ecological zones with less than 9% of the potential area currently cultivated in such forms. This entails a large spectrum of problem areas but also potentials. It is thus not surprising that a wide range of management and development strategies is offered by the key actors.

Restricting framing conditions

The great variety of agro-ecological zones, political and social settings does not allow a general ranking of constraints that have to be overcome in order to better tap the potentials of Agroforestry. However some of the major obstacles shall be mentioned.

If their generic principles are carefully customised, Agroforestry systems are flexible and highly adaptable to biophysically limiting factors such as water, light and nutrients, as well as to changing climate conditions. This relates in particular to the structural and biotic design, such as adequate spacing, vertical structuring and proper species-site matching.

Regarding the financial resources required, Agroforestry systems can, due to optimised resource use, be more easily adapted to the low input conditions prevailing in many developing countries and small-scale farmer communities. Quality and high yielding planting material is sometimes declared a limiting factor, especially if food-security or improving market supply is an issue. Yet genetic erosion through spread of clones, improved cultivars or genetically modified organisms imposes a serious threat to agrobiodiversity and may imply risks.

In the initial period after establishment, negative cash-flow is a common phenomenon. Consequently, small farmers, usually short in income, rather give preference to those systems that require low financial investment for establishment while providing short-term positive cash flow.

In terms of labour demand peaks of labour occur especially in the phase of establishment, but later on natural self-regulation capacities, modern work saving techniques, staggered maturity periods and the longevity of the use system as such allow to keep labour input at a reasonable level.

Insecure or illegal legal land tenure is a basic problem of many developing countries. It does not only obstruct rural development but often abets forest encroachment and land degradation. It acts a disincentive to investment and sustainable land use, especially for tree-based systems, which require a secure long-term perspective. A number of studies further suggest that land use practice established also depends on plot size and biophysical characteristics.

Apart from its relevance for self-sustenance, Agroforestry has the potential to supply markets with a variety of food and non-food products thereby creating income for farmers. In view of the expansion potential of tree-based systems, the provision of market information to assess demand and supply chains, modern processing and storage technologies as well as physical market access (roads, transportation) are essential elements for the strategic planning prior to the implementation of a land use system. Their absence in many rural areas is a major bottleneck for development, which adds to a widespread lack of organisational structures, credits and business skills.

The peculiarities of Agroforestry predetermine its products for niche markets with price premiums, which in return commonly require compliance with international standards. To take these chances and gain access to premium markets does not only presume producers' conviction and advanced skills, but also demands to overcome organisational challenges and to master high transaction costs.

Due to the weak delineation against forestry and agriculture, policies and governance are often little conducive to the further development of Agroforestry. Legal uncertainties in terms of land tenure rights as well as of administrative sovereignty, over-regulation, bureaucracy or arbitrariness can be identified as major shortcomings. Another limiting factor is that Agroforestry – due to its intermediary position between land use systems – may fall between categories eligible for funding.

Last but not least, knowledge and information are a key condiment to the adoption of Agroforestry practices and to creating collective and individual ownership and benefits. This implies to consider the local settings, integrate local and traditional knowledge and to provide extension and long term supervision. In this context special attention must be given to disadvantaged groups.

National and international key actors have identified most of the constraints compiled here as focal areas for future research and action which reflect their mid and long term strategies. The related programmes mainly address the implementation of gene banks, increased productivity, marketing, mitigation of and adaptation to climate change as well as payments for environmental services.

Potentials for improvement

Agroforestry systems require in-depth knowledge and extended practical know-how and experience on plant characteristics, uses and compatibility. Although the principles may be generic, care needs to be taken in transferring exact copies of one practice to different environments: The success of Agroforestry practices is strongly interrelated with the evolution and tradition of local knowledge; on the other hand, integration of local knowledge foments acceptance, ownership and thus the potential for sustainability. Adapted systems can represent an integral element of a viable socio-economic system in its specific cultural environment. Hence, Agroforestry systems can disprove the perception of traditional practices and knowledge being backward and underdeveloped. This prejudice is to a certain degree attributable to the fact that Agroforestry is a low-input land use practised by mostly poor smallholders – a rather unattractive market for industries and easy to be discredited.

Notwithstanding, advanced scientific knowledge and modern technologies can vitally contribute to enhance the spread and adoption of suitable Agroforestry practices, by providing spatial information, improving the knowledge and data base for land use planning, site and impact assessment, modelling, scenario analysis, participatory approaches, marketing and profitability studies.

Beyond the fact that most Agroforestry systems are at least partially subsistence-oriented, economic viability as part of sustainability deserves careful attention, in particular because the options for profit generation are important drivers of development in rural areas.

Compared to conventional agriculture, labour is a distinguishing input factor of Agroforestry. Being primarily a smallholder land use system with a high degree of autarky, labour peaks mainly occur in the initial time after establishment before the canopy closes and trees can outcompete weeds. On the other hand, inputs for maintenance later on require low input of labour force. As Agroforestry systems are even observed in densely populated areas such as Java, the land size available is usually not a limitation for the occurrence of Agroforestry systems but a determinant for their design.

Diverse agroforests – along with staple food, fruits – provide farmers with cash income opportunities through a wide range of repeatedly or sequentially marketable products such as resins, fire wood, fruits, animal fodder, medicinal plants, timber and animal products.

Effects for small-scale farmers

The purposeful structural and organismic diversification – a mixture of crops and ‘unprofitable’ plants – increases the systems’ self-regulation capacities and thus their overall resilience against pests, diseases and abiotic stress. To the same extent this diversification minimises economic risks for farmers in case of crop failure, decaying market prices or consumer demand.

With the increasing influence of globalised markets on smallholders' incomes and livelihoods, a diversified portfolio of annual crops and perennials, in particular trees, does not only create a certain resilience against market failures, but also increases self-sufficiency and options for self-supply with a variety of healthy food (i.e. fruits), timber, fodder, fuel wood or medicinal plants.

Various case studies illustrate that, in the long run, Agroforestry systems often prove to be superior to conventional systems in terms of common economic indicators (e.g. Net Present Value, Benefit-Cost-Ratio). However, these examples can hardly be generalised without taking into account the local settings like site, design, varieties or socio-economic settings.

Agroforests can be considered as appropriate setting for self-sufficiency. This also implies their ability to mitigate economical and ecological risks, which can be strongly interrelated. This quality is gaining increasing relevance in the context of climate change.

On a macroeconomic level, Agroforestry products account for a significant share (up to 50%) of agricultural exports earnings in many developing economies. On a global scale, the potential of Agroforestry to provide environmental services recently adds a new dimension, which goes beyond conventional economic criteria and approaches: The internalisation of environmental services like biodiversity and management of genetic diversity, soil and watershed conservation, carbon sequestration, among others could, if monetised, potentially add significant value to these systems and create local economic benefits for development.

4.6 Transgenic Crops

Even after 20 years of research and 12 years of cultivation, there are as yet no transgenic varieties that are specific to developing countries. It is controversial whether the reasons for this lie primarily in the technology itself, in the interests of the technology owners, or were caused by (overly) strict licensing conditions. There are, however, adapted HR and Bt varieties, mainly as a result of hybridisation into regional varieties.

This chapter is based on the case study by Arnold Sauter (see annex 6).

Characteristics

Genetically modified (synonyms: transgenic or genetically engineered) plants do not represent a homogeneous, distinct production system. The genetically engineered change to a plant variety may affect other elements of cultivation (e.g. plant protection or tillage) to very different degrees. Undoubtedly, developments in the area of intellectual property rights and the establishment of biosafety regimes can be regarded as the biggest "systemic" effects on agriculture overall, whereby different risk philosophies (e.g. in the USA and the EU) and national differences have a strong influence here.

Genetically modified plants are the products of using recombinant DNA techniques in plant breeding. Recombinant DNA techniques, also known as genetic engineering or (more familiarly but less accurately) genetic modification, refer to the modification of an organism's genetic make-up using transgenesis, in which DNA from one organism or cell (the transgene) is transferred to another without sexual reproduction. Genetically modified organisms (GMOs) are modified by the application of transgenesis or recombinant DNA technology, in which a transgene is incorporated into the host genome or a gene in the host genome is modified to change its level of expression (FAO 2004, p. 8).

The *crop yield*, both of individual parts and of the plant as a whole, is determined multifactorially as a complex feature and up to now genetic engineering has only been able to exert a minor influence on it. Improving the plants' resistance to influences that *reduce* the crop yield or quality (such as diseases and pests or lack of nutrients and water), i.e. the creation of resistance or tolerance in order to *secure crop yield,* can be partly procured through individual features or just a few characteristics and is thus in principle more accessible to genetic engineering.

In addition to the varieties grown up to now that are resistant to insects and herbicides, there has been intensive research for many years above all into variants that are resistant to viruses and fungi. Up to now, a number of virus-resistant varieties have been licensed and grown on limited acreages, including peppers and tomatoes in China and pumpkin and papaya in the USA. Similarly, resistance or tolerance to cold, drought or salinity that can be used by genetic engineering has also long been the subject of research and has moved more into the limelight of the current debate, without any concrete results being foreseeable here.

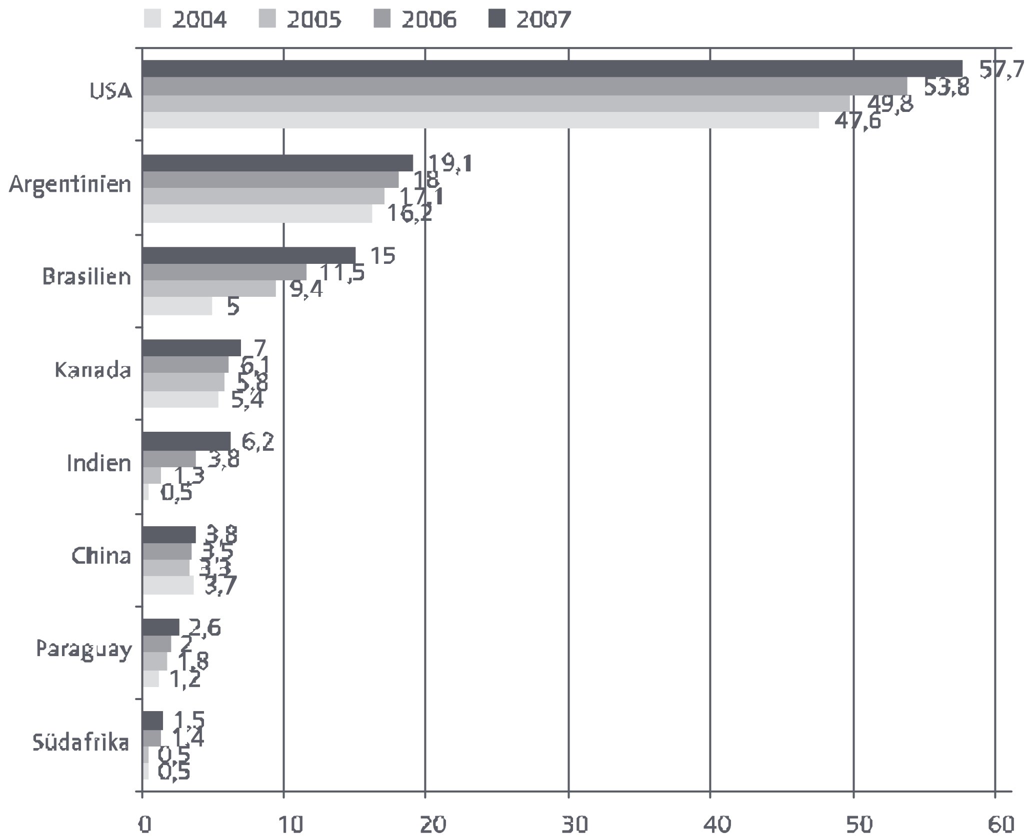
In the area of *quality characteristics* of plants, genetically engineered modifications with the aim of obtaining new, industrially practicable substances such as "plant-made industrials" or "plant-made pharmaceuticals" are a central feature of many R&D projects, but so far any concrete use has been of little significance. In this regard, there are hardly any perceptible aspects specific to developing countries, with the exception of the biofortification approach, i.e. the (genetically engineered) enrichment of basic foodstuffs with vitamins or essential minerals. Relevant projects are being pursued for the target group of poor populations in Africa and Asia and have been promoted for some time on a larger scale by the Bill and Melinda Gates Foundation; the example of "golden rice" which has achieved particularly good progress is discussed in depth in the case study.

Although research into genetically engineered breeding approaches may also be conducted in a decentralised fashion in publicly financed institutions and in smaller companies, the real development of genetically modified plants in fact predominantly takes place in a few large seed companies, many of the most important of these are also important producers of agricultural chemicals. Locally, the large companies work together to some extent with resident seed companies in which they often have shares.

Current relevance and use

In 2007, the estimated global acreage of genetically modified crops was around 114 million hectares (representing approx. 5% of arable land worldwide). Genetically modified crops were grown in 23 countries (James 2007). Twelve years after the commercial introduction of transgenic plants, more than 99% of the acreage still displays only two genetic traits (herbicide tolerance and/or insect resistance) and consists of four crops: soybean (51%), maize (31%), cotton (13%) and rapeseed/canola (5%). The global acreage of genetically modified crops has grown continually, in some important emerging countries as well. A total of 88% of genetically modified crop acreage is located in the countries of North and South America (Figure 11).

Figure 11: Countries with the largest area under GM crops (in million hectares, 2004-2007)



Quelle: James (2004, 2005, 2006 and 2007)

The cultivation of any other genetically modified plants is only very limited and they thus play hardly any economic role (e.g. virus-resistant varieties or altered colours for decorative flowers) or are still at the development stage (crops resistant to abiotic stress such as drought or salinity; plants for the production of functional foods, pharmaceuticals and industrial chemicals, also called molecular farming).

Commercial cultivation has up to now almost exclusively taken place in the so-called emerging countries and is quite predominantly restricted to two cash crops: HR soybean in South America (Argentina, Brazil, Paraguay, and Uruguay) and Bt cotton in India and China. In addition there are HR and/or Bt corn acreages, above all in South Africa, Argentina and in the Philippines. Taken as a whole, the role of this cultivation is hardly ever for the purpose of ensuring food security or for local markets. However, in India and China Bt cotton is grown almost exclusively by an estimated 11 million small-scale farmers.

In some cases, these plant products which are processed and exported for fodder and textile manufacture are of great economic significance. Cotton, for instance, is China's most important agricultural product overall in terms of value, and about 70% of it is obtained from transgenic varieties/breeds. In Brazil, soybean is the central agricultural product, with about a 10% share of the entire export of the country, and in 2007 about two-thirds of it was produced with the aid of transgenic varieties.

An important role in distribution is played by the governments and licensing and monitoring authorities involved according to their basic attitude to genetically modified plants and through the thoroughness and efficiency of their work.

In addition, in terms of acceptance by farmers, an important role is played by the nature and intensity of opposition movement to the use of genetically modified plants which is encountered in practically all countries. These often proceed from environmental organisations, globalisation critics and representatives of small-scale farmers, the landless and indigenous population groups. There are particularly strong opposition currents in Latin America (where there is also a particularly large amount of genetically modified plants grown, especially HR soybean), in India and in some African countries. The authoritarian Chinese nation allows less leeway here.

Restricting framing conditions

Although there were and still are a large number and variety of overall research and development projects on transgenic plants for the particular benefit of agriculture in developing countries – in the countries in question, in international agricultural research centres and in some cases in cooperation with institutions in industrial countries –, these seem as ever to be mainly at early stages. It is widely assumed that worldwide up to now comparatively few resources have been used, from which it is inferred that the actual potential of transgenic plants has not yet been properly determined for developing countries. Proponents of a stronger use of genetically modified crops additionally emphasise that regulatory and administrative licensing and cultivation conditions in connection with continuously inadequate capacities in science administration have prevented further successes in development. It is indisputable that, regardless of type and implementation, specific regulation of transgenic plants makes its research and development more expensive than that of non-transgenic, conventional plants or varieties, and this is an obstacle in any case.

Therefore, considerable economic power and comprehensive research capacities are necessary to make a successful national, proprietary development of transgenic varieties realistic – worldwide this has only been achieved in China in the stricter sense. In some countries, R&D on and with genetically modified crops is strongly dominated by international companies (e.g. Brazil and probably India, too), or the extent of the activities and capacities is (very) limited. Important barriers and hurdles are the patenting of many procedures and products as well as unclarified regulation in some cases, which makes the prospects for the success of an R&D commitment hard to calculate.

Particularly in small or poor countries, the available capacities in terms of science and infrastructure are insufficient for autonomous agricultural research in general and for genetic engineering development in particular. In these countries it must thus be clarified what kind of cooperation (with private companies, international institutions/organisations, public R&D in industrial countries) is particularly promising and desirable in search for the best possible solutions for country-specific problems. The participation of smallholder representatives and other social groups has so far been mostly low or hardly developed in the formulation of research requirements and the search for new (technological) agricultural strategies.

At the level of distribution of existing transgenic varieties, restrictions may proceed from insufficiently developed seed markets, which is still true for many of the poorer developing countries. This restriction is, however, not specific to genetically modified plants in the stricter sense but applies to all varieties of protected and traded (high-performance) varieties.

In the area of risk regulation, regulation strategies and policies are still considered to be inadequate or completely lacking in many countries. Even developed legislation is of little use, however, if the political and economic balance of power stands in direct opposition to an application. And where the social debate on the use of transgenic seeds is conducted very intensely, there is often only poor development of comprehensive risk communication on the part of the authorities.

Effects for small-scale farmers

Due to insufficient data, it is currently impossible to carry out a final evaluation of the size and distribution of profits in terms of business and economics which have been achieved by cultivating transgenic plants in developing and emerging countries. Studies which claim to be able to do this are not backed up scientifically and are based on unstable projections. The studies published to date on the economic results of Bt cotton cultivation in China are, for instance, based on the data from just a few years and just a few hundred hectares (out of an overall acreage of 5.5 million hectares) and demonstrate enormous fluctuations; for Brazil, no publications at all exist on the cultivation results, only estimations. It is undisputed that, particularly in China and India but also in the Philippines and in South Africa, transgenic varieties are predominantly grown by small- and medium-scale businesses. This observation, however, does not permit any conclusions to be drawn with regard to cultivation results or to the size or distribution of profits.

Serious scientific overview studies point out the basic problem that the actual or possible benefit and profit from the use of transgenic seeds is influenced in many ways by regional and operation-specific factors, including the existing or previously used cultivation technique, pest intensity, the strongly fluctuating price of seed, the competitive varieties and many other factors. Of course, by observing individual cases and taking the specific conditions into comprehensive consideration, and by comparing the alternatives in varieties and cultivation techniques, it is possible to quantitatively determine how the cultivation of a specific (transgenic) plant variety has developed under certain conditions within a defined time period and which economic (and ecological) implications arise here.

The influence of individual factors, e.g. the characteristic transferred by genetic engineering, on the individual effects and the overall yield will, however, not allow an exact determination in most cases.

Further socio-economic effects of a widespread use of transgenic varieties can be observed at two levels: in the seed market (including the design of protection systems for intellectual property) and in the circumstances of agricultural structure such as the size of operations and ownership structure. In view of the position of power – to some extent a kind of monopoly – held by the large biotech seed companies in the field of transgenic varieties, which in part comes up against poorly developed, decentralised seed markets, pressing questions arise regarding the options for guiding further development.

Critics of the spread of HR soybean in Brazil, for instance, assume that any possible economic advantage does not benefit the agricultural family businesses and traditional producer communities. These, they say, are increasingly exposed to the danger of marginalisation as the orientation of Brazilian agriculture towards global markets becomes increasingly strong, and this is further fired by the spread of HR soybean. The beneficiaries in agriculture, they maintain, are large farms and cooperatives, and the clear losers are vendors of produce explicitly free of genetic engineering, including the organic farmers whose market is jeopardised by the risk of contamination from transgenic soybean. In addition to this, the dominance of Monsanto's HR soybean can be seen to exert a bad influence on the number on small- and medium-sized seed producers in Brazilian soybean cultivation and their range of varieties.

Ecological and health risks

In considering which risk aspects, planes of impact and chains of effect are particularly relevant for or indeed specific to developing and emerging countries, two dimensions can be distinguished: The type and size of the risks are marked strongly by the conditions of geography and natural space, their controllability by "development-related" and institutional parameters. With regard to the parameters of *geography and natural space*, questions regarding biological diversity come up more strongly in some developing and emerging countries than they do in European countries, for example, especially when they house so-called centres of biological diversity that are regarded as particularly important and worthy of protection or other regions that are the source of agricultural crop plants.

With regard to the *development-related* parameters, one important topic consists of questions pertaining to their regulation or establishment and realisation; here it is virtually regarded as a consensus in the debate that in many or most developing and emerging countries there continues to be great deficiency in terms of institutions and capacities. On the part of the users, the effects of using high-performance transgenic seeds can be influenced particularly by the level of education and knowledge as well as by the amount of capital in the businesses. It is crucial for the possible effects on environment and health that Good Agricultural Practice is observed, e.g. in using pesticides. New varieties can also lead to changes in land usage over a wide area and thus have effects on the ecology.

The dominant topic here in the risk debate on the implementation of transgenic varieties in developing and emerging countries are, however, the related socio-economic and to some extent also socio-cultural questions, e.g. with regard to the effects on traditional crop-growing methods and seed markets.

Potentials for improvement

A central point of contention in the debate on genetically modified plants is that concerning their potentials for sustainability. Several subpoints (of contention) can be distinguished:

The question of the basic concept constituting sustainability: Basically, in most countries there is no clear and practicable concept for setting in motion a scientific, social and political agreement over the aims, strategies and channels of sustainable agriculture – this is also true for the industrial countries.

The question of how the various effects of using Bt and HR plants really look like: Basically the problem exists that there are many diverse influences on the possible benefit in the sense of harvest yield and resulting profit to be derived from using transgenic seeds, e.g. by the cultivation technique currently or previously used, by the intensity of pests, by strong fluctuations in seed prices and by competing varieties, to name but a few.

The question of how these should be evaluated: In considering Bt varieties as a possible option for plant protection – but not as an option which can be used indefinitely for dealing with the pest problem –, which must be seriously weighed against other options, many of the particular risks expressed in the debate are put into perspective (effect on non-target organisms, other ecotoxicity, resistance problems). At the same time, it must be required that the standard used to compare Bt varieties should not just be conventional practice but that other innovative, knowledge-based options, e.g. from the field of integrated plant protection and organic farming should also be taken into consideration. An evaluation of the environmental effects of HR varieties appears even more complex as there are numerous and indirect effects emanating from their implementation on the cultivation technique (reduction in tillage, fuel savings) and land use (crop rotations, increased acreage). These would have to be considered in the framework of a comprehensive impact assessment and evaluation in addition to the “direct” effects of the herbicides used and saved on humans and the environment and be weighed against these.

To carry out a higher-level evaluation, it would be necessary to include a weighting as to which legally protected goods (e.g. health, soil fertility, biological diversity, CO_2 emissions, rural development, resource distribution) have priority (which in turn can only be inferred from the developmental aims of a region or a country) and what contribution can be provided here by genetically modified varieties compared with alternative options. Basically it must be assumed that the overuse of an option, i.e. here the concentration on one single or just a few crops in terms of acreage and crop rotation contravenes the principles of Good Agricultural Practice and in the long run causes great problems.

It is often urged that local or native knowledge should be taken into account or indeed have an influence in developing genetically modified plants, e.g. to define breeding aims tailored to the user and produce customised varieties. However, there are few reports of concrete examples.

Actors in European development cooperation (in Germany, for example, also in national development cooperation) mainly doubt that genetically modified plants can contribute to sustainable agriculture, but the USA thinks differently. The World Bank (2007), FAO (2004) and the Nuffield Council on Bioethics (2003) regard the potential of GMP for sustainable agriculture as given, while IAASTD (2008) is much more sceptical. A recent TAB report concludes that a potential evaluation on the basis of the available information is not possible and argues for an examination of the options without predetermining the results and with a view to finding solutions.

4.7 Conclusions

The results of the case studies will be compared in this chapter to work out common lines and differences. Contribution to production aims, adaptation und introduction, and role of framing conditions and restrictions are discussed. The focus is always on the suitability for small-scale farmers in developing countries.

Production aims and interconnections

Agricultural production systems should fulfil different general aims to be sustainable and economically valuable. The approach and the extent to contribute to these aims are discussed and compared.

Preservation and improvement of soil fertility

Sustaining and improving soil fertility are a key element of Conservation Agriculture, System of Rice Intensification, Agroforestry systems and Organic Farming. For protecting the long-term fertility of soils, common objectives are

maintaining and increasing soil organic matter levels and various grades of humus,

encouraging biological soil activities,

maintaining and rebuilding soil architecture and

providing crop nutrients by using relatively insoluble nutrient sources which are made available to the plant through soil micro-organisms.

Key procedures to achieve these objectives are permanent soil cover and diversified crop rotations. Permanent soil cover can be accomplished especially by crop residues, cover crops and composts. In the context of crop rotation, important elements are legumes for N-fixation, mixed cropping (especially in Organic Farming and Agroforestry) and plant associations in case of perennial crops.

Partly, careful mechanical tillage which respects soil organisms and soil structure are seen as sufficient to protect the long-term fertility of soils (Organic Farming, System of Rice Intensification).

Continued no or minimal mechanical soil disturbance – also called non-tillage – is a specific characteristic of Conservation Agriculture. This key element of CA implies direct sowing or broadcasting of crop seeds and direct placing of planting material in the soil. Non-tillage, and therewith the principles of Conservation Agriculture, can also be integrated and is partly used in System of Rice Intensification, Agroforestry systems and Organic Farming.

The overall aim of all these systems is an intensification by higher biological productivity without necessarily increasing external inputs (readily soluble fertiliser, pesticides).

Another common point is that these production systems represent longer-term strategies which demand more or less far-reaching changes in production practice and whose benefits normally materialise only with some time-lag.

Most case examples (Conservation Agriculture, System of Rice Intensification, Agroforestry systems and Organic Farming) represent complex agricultural production systems. Therefore, a high level of knowledge and information is requested. The common approach is to formulate fundamental principles and to highlight key elements. But for the concrete application, these have to be translated case by case into production technologies and farmer practices. A standardised best approach is not possible due to the diversity and variability in agro-ecological and socio-economic conditions associated with farming in general and with less favourable areas and smallholders in particular. Local and indigenous knowledge and traditional elements are important in optimising the available resources in a productive dialogue without simply continuing traditional practices.

The available GM crops can only partly and indirectly contribute to soil fertility. This is the case, if non-tillage (or even Conservation Agriculture) is introduced in the context of herbicide tolerant GM crops.

New GM crops with drought and/or salt tolerance would potentially be helpful for maintaining and increasing soil fertility, but their successful development and market introduction is still unsure. Even if available in the future, the plantation of these GM crops alone will not be sufficient. They have to be integrated in complex systems of soil preservation, especially under the associated vulnerable soil conditions.

Retention and better use of water

Rainwater Harvesting (RWH) is an important set of techniques to achieve a balanced water supply for small-scale farmers in dry regions with irregular and scarce precipitation and ephemeral rivers and without shallow groundwater of appropriate quality. Rainwater Harvesting for better water collection, storage and distribution has to be combined with improved water use in the agricultural production systems. Examples for combinations with Conservation Agriculture and Organic Farming are given in the case studies.

A better use of so-called "green water" is closely connected to the preservation and improvement of soil fertility (e.g. Conservation Agriculture). A good soil condition ensures that rainwater enters the soil better, achieving higher infiltration rates, water is retained in the soil and plants suffer less water stress, residual water passes down to groundwater and stream flow and not over the surface as runoff.

In the System of Rice Intensification, permanent water cover and saturated paddy soils are changed to minimum or alternating water applications and moist paddy soil with aerobic soil conditions. The results are optimised conditions for root growth and soil biota. In consequence, the water requirements for the irrigation are significantly reduced.

Better water use efficiency is also an important characteristic of Agroforestry systems. Beneficial effects result from an improved physical water retention function (reduction of direct run-off and evaporation through a permanent vegetation cover, increased leaf litter, humus and improved soil structure) and a significant reduction of microclimatic extremes (through multi-strata canopies).

Once again, longer-term and complex strategies are requested, as Conservation Agriculture, Agroforestry systems or Organic Farming. Their general strategies and principles have to be adapted to local conditions, using local knowledge and incorporating needs of the addressed farmers. Therefore, local developments and adaptations of technologies and strategies are most needed.

Improvement of plant productivity

Most case studies (Conservation Agriculture, System of Rice Intensification, Organic Farming, Agroforestry systems) address higher plant productivity by improved growing conditions (see above).

In some cases higher yields are documented for GM crops used today. But an overall yield improvement is scientifically not well evaluated, in many cases unsure and controversially discussed. Higher yields for future GM crops have to be proved first, and are thus yet unsure.

The GM approach is concentrated on a restricted number of cash crops. Complex system improvements (Conservation Agriculture, System of Rice Intensification, Organic Farming, Agroforestry systems) demand breeding progress of a broad range of annual and perennial crops. Molecular breeding (so called "smart breeding") is of high importance for breeding progress in and for developing countries.

Especially for small-scale farmers, future breeding results should not be associated with a higher demand for external inputs and be aimed at an improved utilisation of agro-ecological production potentials.

Pest management

The complex agricultural production systems (Conservation Agriculture, System of Rice Intensification, Agroforestry systems and Organic Farming) include different forms of integrated pest management. Their aim is to improve the biological regulation of pests and to reduce or eliminate the use of pesticides. Diversified crop rotations and plant associations are key elements to reduce pest pressure. The successful development, adaptation und introduction of integrated pest management is knowledge- and information-intensive.

In contrast, pest management approaches with the current GM crops are in itself simple strategies. GM crops with insect resistance are incorporating an “insecticide” in the plant and GM crops with herbicide tolerance are combining a plant tolerance with a specific herbicide. But nonetheless, these GM crops make more or less complex resistance management strategies necessary. In consequence and overall, no simple solution of pest problems can be expected.

Distribution of work

A tendency for higher work demand is associated with Organic Farming and Agroforestry systems, and is required in the initial years for Conservation Agriculture and System of Rice Intensification. A temporary additional work demand can also be the consequence when building-up or restoring of Rainwater Harvesting systems.

Specific GM crops (especially with herbicide tolerance) can reduce the work demand.

Complex systems with broad crop rotation (Conservation Agriculture, Organic Farming) or high crop diversity (Agroforestry systems) implicate a better distribution of work and reduce work peaks.

Vulnerability of production

The reduction of production risks is of eminent importance for small-scale farmers. Risk aversion is essential for them due to the lack of resources. Complex approaches (Conservation Agriculture, System of Rice Intensification, Agroforestry systems, Organic Farming and also Rainwater Harvesting) have the highest potential to reduce production risks. On the other side, these production systems demand a high level of information, adaptation to local conditions and (some) initial investments with delayed returns. This is a major obstacle which has to be solved to convince small-scale farmers.

The effects of GM crops on vulnerability are discussed controversially (e.g. Bt.-cotton in India). In this context it is unclear, how far GM crops increase or decrease the change processes of agricultural structures. In the case of GM crops, the distribution and sale of seeds with simple messages by powerful international companies and in many cases the lack of independent advice and extension services represent a problem, from the small-scale farmer's point of view.

For reduced vulnerability, higher yields by breeding also remain of relevance and importance in the future. This applies for a broad range of crops which are relevant for developing countries.

Adaptation, implementation and spreading of improved production systems

All analysed agricultural production systems are suitable for different farm types, from smallholders to large farmers.

Some differences can be seen regarding the starting point for agricultural production system changes. Large-scale and/or larger-scale farmers can be important promoters for production changes (Conservation Agriculture, in same cases also in Organic Farming). Other new approaches are more centred on small-scale farmers (System of Rice Intensification, Agroforestry systems).

The System of Rice Intensification was characterised as a "civil society innovation" (Lines and Uphoff 2006) and was explicitly developed to benefit smaller, resource-limited farmers (in Madagascar) – starting mainly with a collaboration of farmers and later with an important role of Non-Governmental Organisations (NGOs). In Organic Farming, organic exporters are partly operators of Organic Farming initiatives in developing countries. Other initiatives are organised and/or supported by NGOs.

In a number of situations, local, traditional and/or indigenous knowledge and practices are important starting points and contributions for Rainwater Harvesting und Agroforestry, but examples exist also in Organic Farming und Conservation Agriculture. In Agroforestry, indigenous and local knowledge is an important source regarding species selection, tree-site matching, preferred uses and cultural acceptance. This includes the farmer-to-farmer approach, which generally requires external input for logistics and travel funds. On the other hand, some traditional and well-established ways of farming have to be overcome (Conservation Agriculture, System of Rice Intensification).

Participation processes and "ownership" as well as the inclusion of farmer organisations and cooperatives are of high relevance in all complex systems (Conservation Agriculture, System of Rice Intensification, Organic Farming, Agroforestry systems, Rainwater Harvesting). For learning by seeing and doing, Farmer Field Schools (FFS) are strongly recommended. Visiting demonstration plots and farmer-to-farmer communication are usually the most effective way to overcome resistance. It is very important that the persons – farmers, researchers, extension personnel, government decision-makers – are able to see results for themselves and talk to people like themselves who have validated the methods through hands-on practice.

Thus, networks for sharing information, cross-visitation among farmers, end-of-season workshops to share and consolidate experience and to document and disseminate improvements in the standard recommendations made, etc., reflecting local conditions, are all important.

Therefore, successful adaptation and introduction needs a nucleus of practical knowledge and a learning system to be built up in the farming, extension and research community. This knowledge and learning system should put out and demonstrate evidence of relevance and feasibility to stakeholders and should be used for training students, researchers, extension agents and farmers as well as sensitising institution leaders and decision-makers.

A type of research which is seldom undertaken, but which can pay dividends in good interactions between farmers and those who would advise them is that of "Operational Research". It is aimed at investigating, in the field and with farmers, how improved practices (whether defined by researchers and/or by farmers) actually have their effects in the field and how farmers perceive and manage them. Farmers and researchers become partners in such investigations, to the mutual benefit of both (see case study "Conservation Agriculture", annex 2, pp. 58-60).

Extension can also play a crucial role in bridging initial gaps in equipment, planting material or starting costs. This is often the case in rural areas, where credit is not available. Empowerment of socially disadvantaged groups can be another important task of extension. In practice, women are often executing the farm work, but they are not always the household decision makers. In this case special efforts are needed to address the appropriate target group, without causing social turbulences (see chapter 3.2.9).

Framing conditions and restrictions

Successes with the analysed agricultural production systems are dependent from adequate framing conditions.

Political system

Societal and political commitment is a key issue for all new agricultural production systems (Conservation Agriculture, System of Rice Intensification, Organic Farming, Agroforestry systems), which demand important changes of traditional or introduced agricultural production methods.

A government needs to make firm and sustained commitment to encouragement and support, expressed in policies which are consistent and mutually reinforcing across the spectrum of government responsibilities and, as necessary, sufficiently flexible to accommodate variability in local characteristics. Facilitation should include tapered financial and logistical support as appropriate and necessary, for the number of years needed for farmers to have made the changeover and become familiar with the functioning of the new production system.

Land rights

For all longer-term improvements and investments (Conservation Agriculture, System of Rice Intensification, Organic Farming, Agroforestry systems, Rainwater Harvesting), secure land rights are an essential precondition. Owner-operators, using family labour, have usually more success with the new methods than sharecroppers or agricultural labourers who have less or no stake in the outcome of their crop management. Measures to give land rights or ownership to agricultural producers lacking these would give a boost to the new complex production systems.

A specific problem of Conservation Agriculture, relating to the efficacy of soil cover, crop residues and/or cover crops/green manures, is that posed by communal grazing of individuals' fields after harvest. This has the double effect of both compacting the soil surface layer and eating-off the residues which otherwise would be a protective cover and a substrate for biotic activity in the soil. Some (inadequate) counterbalancing benefit may be expected from the manure which is deposited during the process.

Financing and inputs

Conservation Agriculture, System of Rice Intensification, Organic Farming and Agroforestry systems aim at a reduction of inputs or on low-input systems. Rainwater Harvesting can be build up with local materials.

Nonetheless, some initial investments are needed in Conservation Agriculture (for equipment for direct seeding or planting, for breaking of hard-pans), Organic Farming (for certification), Agroforestry (for planting material) and Rainwater Harvesting (for construction tools) which can be a relevant hurdle for small-scale farmers and are demanding public support. The lack of even small amounts of money to buy services, inputs and/or equipment can have proportionately larger negative impact on the small resource-poor farmer than it would have on a farmer with more resources and credit-worthiness.

Additionally, any extension effort will require some expenditure for personnel, transportation, materials etc. But major programmatic expenditures are not needed in the low-input production systems because purchased inputs are not required or used only restrictedly.

Contrary to this, the cultivation of transgenic crops is dependent on functioning seed and input markets. The GM crops currently used are associated with input-intensive cash crop production systems which demand external inputs as fertiliser and pesticides. Therefore, the introduction of GM crops is critical for small-scale farmers, if an adequate financing of the GM seeds and the associated inputs is not assured.

The longer-term development towards higher energy and input prices demands an input-reduced, biological productivity-based intensification; especially for small-scale farmers this is of high importance.

Availability of food markets and lacking infrastructure

Agriculture for development implies an increasing access and integration of small-scale farmers in food markets. An important incentive to improve agricultural production and to increase productivity is to sell at least part of the production. But large numbers of small resource-poor farmers are practising subsistence farming, with little to sell outside (or even within) their local communities. These farming communities often lack market access within reasonable distance. This is a problem of any agricultural development, not only of the new production systems based on biological productivity enhancement with low input. Overall, without market access and moving from subsistence to a market-oriented production it will be difficult to improve rural livelihoods.

The ongoing supermarket diffusion (see chapter 3.2.7) leads to higher demands on quality and documentation, which are difficult to achieve by smallholders. Producer cooperatives are seen as the necessary answer. At the same time such cooperatives can be helpful for introducing information about and organising support for learning intensive systems as Conservation Agriculture, System of Rice Intensification, Organic Farming and Agroforestry systems.

A special problem of Organic Farming are the expenditures for certification. Organic food producers in regions like Asia, Africa and Latin America are strongly export-oriented and therefore dependent from international markets for their products. They are advised to become less reliant on exports and to develop local markets to spread the business risk of organic food production.

A specific problem of transgenic crops can be the documentation requirements for traceability and labelling, to get access to European (and other) markets.

Lacking infrastructure like roads, electricity and telephone in rural areas impede market access, information on prices and demand as well as opportunities for local value addition (e.g. processing).

5. OPTIONS FOR ACTION

5.1 Need for action

Around half of the world's population is living in rural areas. Sub-Saharan Africa and South Asia have some 75% of its population in rural areas, North Africa and Central Asia some 50%. Agriculture is in the centre of their life. At the same time, the vast majority of farmers in developing countries are small-scale farmers. An estimated 85% of the farmers in developing countries produce on less than 2 hectares. Most of the poor in developing countries (75%) live in rural areas. Due to the large share of agriculture in poorer economies, strong growth in agriculture – with small-scale farmers in the centre of attention – is critical for fostering overall economic growth and for poverty reduction, as the overview on agriculture in developing countries showed (chapter 3.1).

In the past, agricultural productivity growth in developing countries has contributed remarkably to the net increase in global food availability. But people have benefited unevenly from the yield increases across regions. Furthermore, the increasing yields and productivity were based on input-intensive production systems, in connection with improved varieties. In many cases these production systems cause negative environmental impacts because of the promotion and use of intensive tillage-based production systems and the excessive use of pesticides and mineral fertiliser. In the same way, environmental shortcomings of some of the traditional tillage-based agricultural practices associated with poor socio-economic conditions create a vicious circle of soil degradation, due to the loss of organic matter and soil porosity, in which poor small-scale farmers have to deforest and use new often marginal lands. Thus, far-reaching changes in agricultural practice are needed in developing countries.

In agricultural science and technology, the knowledge gap between industrial and developing countries is widening. Overall, a pervasive underinvestment in agricultural R&D is described. The funding of research by governments, donors and international financial institutions declined since the 1980s. The share of agriculture in official development assistance (ODA) also declined sharply over the past two decades. In almost all Least Developed Countries (LCD), ODA is the main catalyst of investment in agriculture.

In the last years, a number of international assessments pointed out the high importance of agriculture for economic development, for food security and livelihoods, and for ecosystem services. Increasing productivity and output in agriculture through effective technologies and environmentally friendly production practices is seen as a key element to achieve the Millennium Development Goals (MDGs). The strengthening of agricultural knowledge, research and technology development, farmer-based innovation and extension as well as their sharply increased public funding are broadly recognised recommendations.

A fundamental shift in agricultural knowledge, science and technology (AKST) is demanded by the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD).

This should include science, technology, policies, institutions, capacity development and investment so that development and sustainability goals can be met successfully. Such a shift should recognise and give increased importance to the multifunctionality of agriculture, accounting for the complexity of agricultural systems within diverse social and ecological contexts. It would require new institutional and organisational arrangements to promote an integrated approach to the development and deployment of AKST. It would also recognise farming communities, farm households, and farmers as producers and managers of ecosystems. In terms of development and sustainability goals, these policies and institutional changes should be directed primarily at resource-poor farmers, women and ethnic minorities (IAASTD 2008a, p. 6).

Starting from the importance of agriculture for development and the need for agricultural productivity growth, different agricultural production systems (and their technologies) were assessed in the STOA project "Agricultural Technologies for Developing Countries" (see chapter 4). Of the assessed production systems, Conservation Agriculture, System of Rice Intensification, Agroforestry systems and Organic Farming can be described as complex agricultural production systems of intensification with higher agro-ecological and biological productivity, without necessarily increasing external inputs (mineral fertiliser, pesticides). They have the potential to address especially the needs and possibilities of small-scale farmers.

Sustaining and improving soil fertility are common key elements (of Conservation Agriculture, System of Rice Intensification, Agroforestry systems and Organic Farming). Main principles are diversified crop rotations, plant associations in case of perennial crops (especially in Agroforestry), permanent soil cover and minimal or no mechanical soil disturbance. At the same time, a better retention and use of water can be achieved. Another component is the integrated pest management. Additionally, technologies of Rainwater Harvesting can contribute to balance the water demand of small-scale farmers in dry regions with irregular and scarce water supply.

They represent a different approach in comparison to conventional agricultural production systems (and technologies) – the so-called Green Revolution – which made important contributions to meeting world food needs during the 20th century. But input-intensive production systems are not the only, or necessarily always the best, means for increasing agricultural productivity under the economic and environmental conditions of the 21st century. It becomes increasingly clear that Green Revolution approaches bring about large and rising economical and ecological costs. To the extent empirically justified, it will be beneficial for reasons of poverty reduction, food security, input-use efficiency, environmental quality, and human health to move away from the currently prevailing, energy-intensive and input-dependent approaches on the one side and traditionally based over-exploiting land uses on the other side and to orientate agricultural policy and practice more on agro-ecological conditions and the efficient use of biological production potentials.

Low-input intensification refers to achieving higher crop yields without or with restricted additional external inputs, combined with an improved soil and water management. In such systems, the external input use is low relative to the high external inputs needed in intensive tillage-based systems or relative to European or Eastern Asian standards. Conservation Agriculture, System of Rice Intensification and Agroforestry do not exclude the use (or some additional use) of external inputs such as mineral fertiliser. In the contrary, programmes for higher mineral fertiliser use will not succeed without improved soil management. With improving quality and health of soils (especially with increasing soil organic matter), the focus is on the higher efficiency of input use. Where the decline in production potentials of soils has to be reversed, a higher factor and total productivity can be achieved only over time, once the soil conditions for rooting, water retention etc. have been improved sufficiently. Labour considerations can make it necessary to consider some form of mechanisation which means more energy use. This energy can come from renewable sources such as animal traction or local biofuels.

With its specific restrictions of agrochemical use, Organic Farming is so far a special case, which also includes social aspects in its principles and produces for a special market (with higher prices). For this reason, it is not applicable in all cases. With emphasising common points of the discussed production systems, it is not said that they are identical, eliminating all differences.

Development and introduction of low-input intensification is also discussed in the context of climate change which will disproportionately affect developing countries and the poor. Adopting agricultural systems to climate change is urgently needed because impacts are already evident and these trends will continue even if Greenhouse Gas (GHG) emissions are stabilised. The recognition of the links between tillage- and input-intensive farming and climate change processes make it vital for the world’s farmers to raise their output using methods that do not demand inputs based on fossil fuels and do not further compromise the natural resource base of agriculture and diverse ecosystems.

Low-input production systems have potentials for resolving current global issues affecting agriculture and the environment – e.g. slowing climate change through reduced fossil fuel use, reduced gaseous emissions, increased carbon sequestration from residue retention and build-up of soil organic matter, improved soil quality and health, reduction of the impacts on food security of seasonal weather volatility, contributions to watershed repair through reduced runoff, improvements in water quality and reduced siltation, reduction of desertification due to reduced erosion and increased permanent ground cover. However, means and capacity for advocacy and change are at present inadequate.

In contrast, transgenic crops are until today restricted to a small number of cash crops and are mainly working in the frame of high-input production systems. The ability of transgenic crops to increase yields, to address food security and to be useful for small-scale farmers is discussed very controversially. Pest management approaches with the current GM crops are in themselves simple strategies. But nonetheless, these GM crops make more or less complex resistance management strategies necessary.

The complexity of transgenic crops lays mainly outside the agricultural production system, in demanding risk assessment and management as well as regulation strategies and policies which are still considered to be inadequate or completely lacking in many developing countries.

The common approach (of the analysed agricultural production systems with low additional external inputs) is to formulate fundamental principles and to highlight key elements. But for the concrete application, these have to be translated case by case into production technologies and farmer practices. A single standardised best approach is not possible due to the diversity and variability in agro-ecological and socio-economic conditions associated with farming in general and with less favourable areas and smallholders in particular. Local and indigenous knowledge and traditional elements are important in optimising the available resources in a productive dialogue, without simply continuing traditional practices.

The acceptance of modified agricultural production methods and improved livelihoods can only be achieved if market access for the increased production is built up at the same time and the food chain requirements are met. The successful development, introduction and use of agricultural technologies and their integration into adapted practices in developing countries depend on many framing conditions. For example, longer-term investments like soil improvements depend on secure land rights. Better infrastructure is another important element in the process of alleviating poverty and providing opportunities for rural citizens in developing countries, because inter alia agricultural development is related to access to markets and services.

The following options for action concentrate on the development, adaptation and introduction of the agricultural production systems Conservation Agriculture, System of Rice Intensification, Agroforestry systems, Organic Farming and Rainwater Harvesting – in other words, on possibilities of intensification by higher agro-ecological and biological productivity, with low external inputs. The options for action describe possibilities for European development policies and development cooperation at different levels and for a number of issues.

5.2 Policy commitment

Issues like soil fertility and soil productivity capacity, unless they result in catastrophic dimensions of erosion, do not inspire or attract policy makers. They might take note of concerns of soil degradation but then move over to the next agenda item. Even in the face of looming problems posed by the complexities of climate change effects and their interactions with an increasing demand for agricultural products, a number of governments are not yet fully enthusiastic about the possibilities of low-input intensification.

Political and societal commitment is a key factor for the introduction and spreading of agricultural production systems like Conservation Agriculture, System of Rice Intensification, Organic Farming and Agroforestry systems, which demand important changes of traditional or introduced agricultural production methods. The aim should be to bring the appropriate production system into the mainstream of agricultural activity.

The global and national urgencies are such that it is not appropriate just to let the adoption take its own course, even though Brazilian experience with CA shows that this can occur.

Without political commitment and strong, subject-specific backing of national governments, changes in agricultural production systems will be slow in most cases. The effectiveness of such backup will depend inter alia on coherence of purpose and approach between the different agencies of government involved in encouraging the spread of low-input intensification.

Support policies in developing countries must be enabling and flexible, rather than unitary and prescriptive. Allowing the design of location-sensitive programmes which draw on a range of policy tools will ensure that policies are designed which both accommodate and promote the location-specific nature of Conservation Agriculture, System of Rice Intensification, Organic Farming and Agroforestry systems, each strengthened by methods which improve efficiency of rainwater and/or irrigation water use. As these production systems work with principles to be adapted to local conditions, support policies need to be formulated on a similar appreciation.

On the one hand, Non-Governmental Organisations (such as farmer organisations, local NGOs) could contribute to achieve such a political commitment in developing countries. On the other hand, institutions and networks on regional and international level could play an important role in collecting, evaluating, sharing and disseminating knowledge and practices, thus facilitating and supporting the reformulation of agricultural policies on the national level. Furthermore, consumers and marketing organisations (retail chains) are important vehicles for pushing for more awareness in the importance of improved agriculture and food markets.

5.3 Incorporation into European development policies

Ownership of the developing countries (respective partner countries) is a core principle of the Paris Declaration on Aid Effectiveness (OECD 2005). It means that "partner countries exercise effective leadership over their development policies and strategies and co-ordinate development action", which was underlined by the General Affairs and External Relations Council (GAERC 2006). So in the first place, developing countries have to take initiatives to incorporate Conservation Agriculture, System of Rice Intensification, Organic Farming, Agroforestry systems and Rainwater Harvesting – depending on the local conditions – into their development strategies and policies.

Development cooperation is at the same time an issue of dialogue and partnership. Donors do not simply align to a partner country strategy; they assess it from their point of view and influence its substance by negotiating with the partner country government (see Mürle 2007, p. 13). European actors in development policy should be an advocate for giving agriculture high priority and for low-input intensification focused on small-scale farmers.

In the context of agricultural technologies for development, three levels of goals and commitments are of high relevance:

- Millennium Development Goals
- Agriculture as main rural development tool, with focus on small-scale farmers
- Low-input intensification based agro-ecological and biological production potentials

With the European Consensus on Development, the European development policy is focused on the Millennium Development Goals and poverty reduction (EU 2005). The importance of agriculture for development and the key role of small-scale farmers therein are internationally, and in the EC development policy in general, recognised and now have to be implemented in the European development cooperation. Many donors still have to increase the financial support and the number of agricultural programmes in practice to fulfil the policy statements. A number of projects and activities of different European actors on low-input intensification is already on the way, but an overall strong commitment is still missing.

Development cooperation in the European Union

The common European development cooperation dates back to the EEC's foundation, but is a relatively young policy competency of the Commission. Already in 1957, the Member States established a fund for development of countries or regions beyond the European Economic Community (EEC), the European Development Fund (EDF). However, this fund was a purely multilateral fund, with the Commission as a trustee of Member States' monies.

Only since 1993, the European Union has a distinct treaty mandate for development cooperation. This competency, according to the Treaty of Maastricht, is supposed to complement the activities of Member States in this policy area. This has not been substantially amended in the following treaties (Amsterdam 1999, Nice 2002, failed Constitution, Lisbon 2007). The shared competency of Community and Member States implies that Member States have their own bilateral relations with developing countries and the lion's share of their aid is distributed bilaterally.

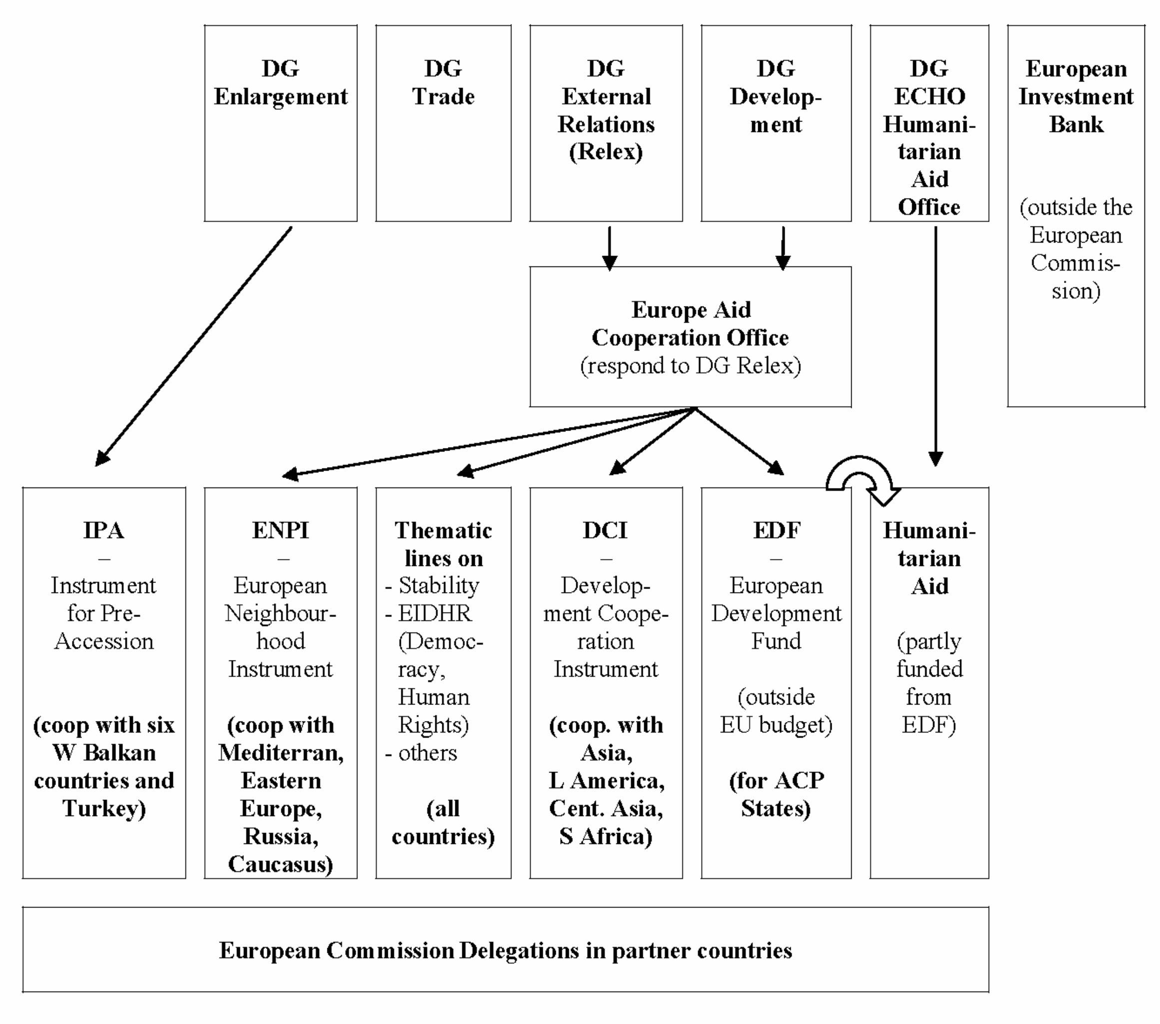
The development aid provided from the entire European Union (Member States and Commission) is administered by a very complex system. Even the Commission-administered funding comes from two different sources: the general budget and the EDF.

For development cooperations funded via the EU general budget, an overall spending of 50bn € between 2007 and 2013 is foreseen in the so-called Financial Perspective. The budget is subdivided into headings and budget lines, grouped by policy areas and by policy aims or instruments. This allocation is negotiated between the Commission, which has the sole right of initiative, the Council of Ministers and the European Parliament. The funding via budget is roughly divided into two rationales (see also figure 12): one part are financial instruments with global coverage, and the other part is distributed on a geographical basis (including the Development Cooperation Instrument (DCI) for developing countries that are not in the ACP group). Furthermore, the regional funds are subdivided into budget lines, which were regrouped into six sub-headings (e.g. food security) with the overall reform of the EU's assistance.

The European Development Fund (EDF) stands outside the EU treaties and is a multilateral fund for cooperation with former European colonies in Africa, the Caribbean and the Pacific (the so called ACP states). Every five years, the EDF is negotiated amongst the Member States – with a rather formal participation of the ACP states. The European Parliament can only express its opinion which Member States can follow or ignore. For the 10th EDF (2008 to 2013), an overall sum of 24 bn € was agreed between the EU Member States.

The organisation of the EU development cooperation has changed several times in the last few years. The geographical split between DG Development (for the ACP) and DG External Relations (for the rest of the world) is still in effect. Since 2001, EuropeAid is the agency in charge of implementing all EU external respective development cooperation policies (Figure 12).

Figure 12: Management structure of the European Commission's external relations



Source: Grimm 2008, p. 15

Integration into the complex system of European development cooperation

Financing from the EU accounts for more than half of the global Official Development Assistance (ODA), of which one fifth is administered by the European Commission (Grimm 2008). Therefore, the European Union and their Member States can play a major role in recognising the importance of low-input intensification in development cooperation.

The complex system of European development cooperation (see box) makes it necessary that donors in the Member States and at European level integrate improved agricultural production systems (as Conservation Agriculture, System of Rice Intensification, Organic Farming, Agroforestry systems and Rainwater Harvesting) into their development cooperation. An incorporation is not only demanded from the Commission but from many different donors. A need for advocacy can be seen.

For development cooperation funded via the EU general budget or the European Development Fund (EDF), the improvement of agricultural production systems can not only be placed under food security, but belongs as a cross-cutting issue also to natural resource conservation (soil, biodiversity, water) and mitigation of climate change. The improvement of agricultural production systems should be broadly integrated into the regional activities. This would support adapted approaches of applying the production systems principles to regional and local conditions.

Furthermore, the different European donors should adapt their funding instruments to cover the full period necessary for low-input intensification to become a permanent element of production systems (see chapter 5.4 and 5.5). 10-15 years are often required even if not started from scratch. This lapse of time is not uncommon in development cooperation and research programmes, albeit more than 3-5 years of firm financial planning are unrealistic (budget laws in EU and member states). In consequence, there is a strong demand for renewal and continuation of programmes.

Lead donor arrangements

The concept of leading donors should be applied. Lead donors are needed for the different agricultural production systems (Conservation Agriculture, System of Rice Intensification, Organic Farming, Agroforestry systems and Rainwater Harvesting), differentiated by regions and country groups. A farming systems approach is another possible sub-division for successful lead donor arrangements in agricultural technology development initiatives.

The aim of a division of labour is to achieve a high effectiveness in developing cooperation. Lead donor arrangements would enable donors to build up competence and good performance and would provide a clear partner with competence for developing countries.

For example in Agroforestry, the GTZ (German Technical Cooperation) targets decision-makers and researchers, rather than classical implementation ‘on the ground’. Other European development agencies like DFID or DANIDA closely coordinate their efforts with the World Agroforestry Centre, while at the same time conducting own projects, often emphasizing implementation of small-holder schemes including nurseries. The Bolivian section of DED (German Development Service) sees itself as a pioneer and leader in promoting and implementing successional Agroforestry systems. They identify external mid- to long-term support as important requirement to foster the entire project cycle from diffusion, generating acceptance, planning and implementation to the marketing of products. In this context processing of products from Agroforestry plots is given high priority to improve the income generation through value adding.

To reach sustainability, acceptance, transport and marketing issues need to be involved (see case study Agroforestry systems). Beside the production system itself, leading donor arrangements should therefore also include the complementary issues, especially initiatives for market access and development.

Integration into international programmes and processes

The European development policy – as a major donor for international agricultural research and other relevant international institutions and processes – should encourage the international recognition of the potentials of changing agricultural production systems. It should also contribute to the resources needed to operate the international initiatives and institutions on low-input intensification in agricultural production systems which are important for the collection and exchange of knowledge and practical experiences.

The European development policy should undertake initiatives to integrate the discussed agricultural production approaches into large scale programmes and processes related to food, the environment, climate change, poverty alleviation, national/regional programmes, including CAADP/NEPAD, AGRA, the operations of Conferences of the Parties on biodiversity, desertification and climate change, initiatives for food security and poverty reduction initiatives (PRSP), and the programmes of producer networks, large investors and International Financing Institutions (IFIs).

National and regional planning and programming

National and regional planning and programming of support to agricultural technology development are by nature most often complex processes which should involve many stakeholders (several ministries such as agriculture, research, water, environment, industry and probably trade) as well as non-state actors. To achieve larger production system shifts to be adopted on a large scale, national or even regional initiatives are needed. Furthermore, such concerted actions are necessary to integrate technological development and diffusion. And for such initiatives, incorporation into national programmes should be foreseen. That is the spirit of the Paris declaration, the appropriate scope of larger programmes which have to be pursued over many years, and which have to involve many actors.

A good example of how these ideas could in principle be enshrined into national programming is the CAADP initiative of NEPAD which explicitly has sustainable land and water development (pillar 1) and research (pillar 4) as 2 of their 4 main pillars, and peer learning as a cross cutting issue. Unfortunately, CAADP is not yet very operational, but it is the right approach.

5.4 Approaches for scaling-up

A single global strategy for up-scaling of Conservation Agriculture, System of Rice Intensification, Organic Farming, Agroforestry systems or Rainwater Harvesting will not work: The strategic approaches and principles must be tailored to countries, regions, farming systems or even local sites, reflecting specific technical, economic and social conditions.

Farmers and communities should be empowered to recognise in which way the principles can be applied and which technical approaches are appropriate to their own situations. And they should be supported to transmit their experience and ideas to others.

There are other concerns that farmers also have which have to be recognised, the most important being higher incomes through better sales of their products. If farmers are not provided with better income perspectives, in most cases other targets will be missed.

For up-scaling, a close partnership from the start among diverse stakeholders in adapting, promoting and supporting uptake – e.g. farmers and their organisations, research, extension services, service/input/credit providers, government agencies, NGOs etc. – should be ensured.

The introduction of principles should be done pragmatically, based on understanding of realities on the ground. Therefore, changes should be started by using locally-available inputs and based on local knowledge and beliefs whenever and to the extent possible. The start-up phase of adaptation needs special attention: If not skilfully organised and guided, failures are likely to occur, damaging the future willingness to change agricultural production approaches.

Irrespective of the need for local adaptation, some common approaches can be worked out.

Farmer-to-farmer extension and Farmer Field Schools

For learning by seeing and doing, Farmer Field Schools (FFS) are strongly recommended. Farmers should be supported to assume a leading role in the process of scaling-up. Visiting demonstration plots and farmer-to-farmer communication are usually the most effective way to overcome resistance. It is very important that farmers, researchers, extension personnel and government decision-makers are being able to see results for themselves, and to talk with persons like themselves who have validated the methods through hands-on practice. Thus, networks for sharing information, cross-visitation among farmers, end-of-season workshops to share and consolidate experience and to document and disseminate improvements in the standard recommendations made, reflecting local conditions, are all important.

Governments, NGOs and donor agencies should, as a matter of effectiveness as well as of reinforcing the values of participation and democratic self-governance, be facilitating the exchange of ideas and experience among farmers, enabling them to make further improvements upon any innovation introduced to or by them. For example in the case of SRI, individual farmers have spent their own time and money to spread knowledge to hundreds, even several thousand farmers, because they wanted others like themselves to be able to have the benefits of higher yield and income as well as to enhance both human and environmental health through SRI.

Diffusion of information can not only be based on willingness. As individual farmers get more effective and, often linked to that, market-oriented, they will get more time-restricted and ask themselves why they should support their competitors. If there are some economies-of-scale or other collective advantages (e.g. water management), then a continuation of support to neighbours can work. In other cases, monetary incentives for farmer-to-farmer extension are needed. In this sense, an example is the CARGILL “cotton made in Africa” project in Zambia where lead farmers were equipped and supported by the company to spread best practise technologies among neighbours, with a honorary based on the success rate.

Support for travel and other forms of communication (e.g. mobile phone networks) among farmers would greatly accelerate the spread and use and would also contribute to improvements year by year. Developing appropriate local, national and regional networks and task forces to facilitate capacity building, sharing of knowledge and active mutual learning are important.

Linking large-scale and small-scale farmers

In the case of Conservation Agriculture and Organic Farming, large-scale respective larger-scale farmers can be important promoters for production changes. The needs, technologies and potentials for uptake by large- versus small-scale farmers are distinct, and must be tackled in a different manner. Linking the learning and uptake processes of large and small farmers offers potential payoffs in speeding uptake, but effective and equitable links must be built. The potentials are linked to problems. Large-scale farmers often need good incentives because their opportunity cost of time is very high. Therewith, a support of inequity has to be avoided. Nonetheless, specific encouragements for larger-scale and more advanced CA and OF practitioners to advise and mentor small-scale farmers at earlier stages of adaptation and uptake should be included.

Share of knowledge

Collective knowledge and experience must be shared in introducing Conservation Agriculture, System of Rice Intensification, Organic Farming, Agroforestry systems or Rainwater Harvesting to new countries and in supporting the accelerated adaptation and uptake of these approaches in countries in which they have already been introduced. Knowledge management systems should be developed at the scales required to provide stakeholders with quality evidence on the performance, impacts, successes and failures, under their diverse conditions.

Focus groups should be linked through networks, forums and exchanges to share experiences and technologies, nationally and internationally. Also, exchange between different production system approaches should be organised so that learning from each other will be enabled.

For Conservation Agriculture, the concept of 'Community of Practice' (CoP) has emerged within development communities to formalise and strengthen the connections among like-minded persons who work in a variety of circumstances and seek collectively to improve both knowledge and practice. The participants in the FAO workshop in July 2008 proposed to establish a number of interconnected CoPs that can further the objectives of CA (FAO 2008a). The premises for a CoP are:

- The improvement of both theory and practice is greater from a *continuous interaction* between researchers and practitioners than from following the previous concept of a linear process where knowledge is generated and validated separately from practice, being subsequently 'extended' to practitioners;
- There is greater productivity from having *multi-sectoral cooperation* than having a standard 'division of labour' because different kinds of institutions (public sector, private sector, NGO, academic, grassroots, etc.) have respective comparative advantages to contribute to a collective enterprise and learn from each other; and
- There is great power in bringing together *like-minded individuals* who operate from diverse institutional bases, who have agreed on the general goal even if they contribute to different ideas and values of the means for achieving this; excitement and energy as well as information can be generated from heterogeneity that is encompassed within an 'envelope' of broad agreement leading to convergence of community members' perceptions and action.

This approach needs organisational and financial support, and could be a model for the other agricultural production system approaches.

Support by counsel and education

The availability of well-prepared advisers and facilitators is a key factor to minimise the potential negative effects of suboptimal performance in the early years of introduction. Extension efforts should be closely linked with farmer-to-farmer extension. Example farms have a positive effect especially in countries with a low level of education of farmers.

Tools which can provide awareness and often also information and knowledge, often neglected in extension, are radio, internet (via NGOs and farmer associations) and schools. Children in rural areas (most of whom realistically will spend at least part of their live as farmers), should be sensitised to agro-ecological issues.

For Organic Farming, official counsel should be taken over by public bodies, while specialised counsel should be given by Organic Farming organisations or associations themselves.

The potentials and principles of Conservation Agriculture, System of Rice Intensification, Organic Farming and Agroforestry systems scarcely feature in public education and training programmes, most of which continue to teach for example inversion tillage as central to sound agricultural practice. Funding and curriculum reforms are needed to strengthen the knowledge about principles, practice and potentials at various levels in education, training, research and development organisations, and as part of farmer training and empowerment.

Setting of standards and certification

The certification is a central element of Organic Farming, and an obstacle for small-scale farmers and associations. The recent expansion of organic production in developing countries with their specific agricultural constraints has not been adequately reflected in the standard setting by the organic community. For example, in areas where livestock breeding is disconnected from plant cultivation (many areas in Southeast Asia) it may be necessary to leave behind the strict principles of Organic Farming and allow the marginal use of particularly mineral N-fertilisers (elements of the LISA-Agriculture).

Furthermore, small-scale farmers and associations need support to cover the costs of certification and/or low cost certification schemes (e.g. with local personal) should be developed.

In Latinamerica, Agroforestry is dominated by NGO, with focus often on participatory smallholder approaches, including processing and marketing with certification efforts. A bias between perceived organic and certified organic is often an obstacle to successfully targeting the premium market segment. Beside the organic food certification, standards for environmentally-friendly produced food would be helpful to open up higher price market segments.

Development of market access

Agriculture for development implies an increasing access and integration of small-scale farmers into food markets but also into other markets, e.g. for forest products or fiber. An important incentive to improve agricultural production and to increase productivity is to sell at least part of the production. Enabling market access should be an integrated part of scaling-up strategies, where needed. The improvement of infrastructure such as the development of a road and path network also belongs to that. Assurance of product and process quality (especially stock-keeping and food conservation methods) is another need here.

For example after the successful establishment of organic production, when market-oriented production is becoming a reasonable objective, priority has to be set on the development of (yet inexistent) local markets for organic products. This implies the organisation of local product certification and the development of the required infrastructure for market accessibility.

Infrastructure and mobility regularly represent constraining factors since the demand for organic products generally evolves within well-suited societies found in urban and sub-urban areas. The establishment of product certification on the other hand will often be hindered by frequent illiteracy making daily documentation impossible for the smallholders concerned. Therefore, corresponding programmes facilitating education are needed to support product marketing initiatives.

Concerning the price policy in Organic Farming, a long-term rethinking is necessary. In the past, organic products yielded a significantly higher price than conventional products due to their higher quality and environmental benefits. Organic products should be cheaper or at the same price level as conventional products, if their consumption is to be made possible for poorer and lower-income groups (establishment of a regional and national market in developing countries).

Assessing benefits

As a support to introduction and up-scaling, it should be better demonstrated why low-input systems are better and more sustainable than conventional agriculture systems, which includes the generation of more rigorous information on the benefits to farm family livelihoods and the broader society.

5.5 Introducing financial support

Beside support for scaling-up initiatives and activities, financial support to small-scale farmers is needed for some initial investments and for compensating possible decreasing profits and risk during the adaptation period.

Incentives for changing production systems

Public support is needed especially during the conversion phase when some initial investments are needed, costs and risks of learning and adapting to local conditions arise, and a decrease in profits is possible.

For small-scale, risk-averse farmers especially, changing their production system and introducing low-input intensification could be stimulated by providing targeted incentives and fair cost-sharing and risk protection arrangements over several years. These may be perceived as a just compensation for the many eco-services that adoption is likely to generate for the benefit of society at large.

In Organic Farming, additional costs arise through the certification which may not be compensated by higher yields and prices. Public support for certification is therefore recommended.

Introduction of price premiums

Beside the price premiums for organic food, higher prices for food products from an environmentally friendlier production or with improved quality would support the uptake of low-input intensifications.

For example, the biggest incentive for System of Rice Intensification uptake, which would entail no cost to government, would be to introduce a price premium for SRI paddy, e.g., 10%, to be paid by millers or anyone who purchases paddy rice, justified by the fact (to be documented and monitored with some precision) that this unmilled rice (purchased by volume) produces about 15% more milled rice (by weight). There is no justification for millers pocketing this windfall which derives from the productivity of SRI methods and farmers' management efforts.

Farmers should get most of this gain as an incentive and a reward, thereby following practices that reduce water demand and agrochemical use, contributing to a cleaner and less-stressed environment as well as to healthier food products.

Food products from Conservation Agriculture and Agroforestry, which are produced environmentally-friendly similar to products from Organic Farming, should have market channels that remunerate farmers for the higher-quality food product. Such market incentives would make it more attractive for farmers to modify their production methods.

Incorporating external costs and benefits would justify higher prices. In principle, this can be done by subsidising low external technologies or inputs, or by taxing conventional technologies and inputs. But very good evidence, and very strong political will and public awareness are necessary to politically raise food prises.

5.6 Science and technology development

Technologies that can help to put low-input intensification into practice are mostly available. Their local adaptations to specific cropping systems and cultures across diverse agro-ecological and socio-economic situations are most important. Conservation Agriculture, System of Rice Intensification, Organic Farming, Agroforestry systems and Rainwater Harvesting are not a set of static technologies but dynamic systems that will differ depending on biophysical and socio-economic conditions and evolve over time. Even existing technologies have to be made operational (and economically viable), particularly in smallholder systems. R&D programmes must respond to this need. The contributions of numerous branches of the technical and social sciences, economic disciplines, stakeholders and interest groups must be combined in developing technologies and systems that are adapted to varied conditions and users.

Agricultural technology development can also – and maybe even better – be financed and supported via the research support instruments of the EC and its Member States. This is indeed happening already in numerous multi-party research projects. A serious problem with either research or development cooperation support is that they do not match and support each other very well. Weak points in science and research activities to be overcome are:

Scientific partners with bad connection to NGOs, farming communities, traders and in particular food transformation actors;

Priority setting by researchers, not by networks of stakeholders including farmers, traders, NGOs, enterprises;

Pure technology development, not taking into consideration larger innovation systems requirements such as intellectual property rights (not necessarily patents);

Lack of cooperation (from the start) with economic actors who can and are motivated to use scientific knowledge such as enterprises, input dealers, construction teams, business oriented NGOs, larger farmer associations;

Financing gap and all too often simple stop of support between technology development and full innovation adoption in the sense of widely diffused use.

For local adaptations a close interaction between farmers and researchers is needed. Despite the importance of local adaptations, some overall points for science and technology development can be worked out.

The European Initiative for Agricultural Research for Development (EIARD) could be a forum to discuss and coordination respective initiatives.

Production system research

Conservation Agriculture, System of Rice Intensification, Organic Farming and Agroforestry systems are complex systems, needing a better scientific understanding of their system dynamics. This includes a better understanding of management options and decisions, and of the processes of innovation and diffusion of practices and the dynamics of on-farm and collective decision-making with the objective of understanding if and how uptake can be accelerated. In the context of evaluating production systems, the refinement of crop choices and rotations as well as the combination of crop and livestock systems are further important issues.

Mechanisation

Improved machinery for land preparation, direct seeding and weeding are desirable for the discussed production systems. For example, improved local CA machinery would help to move beyond expensive imported equipment and create local manufacturing capacities and markets to meet the growing demand.

The special needs of small-scale farmers with little cash or credit to buy equipment have to be considered. In the case of System of Rice Intensification, efforts to mechanise transplanting and weeding would contribute to attenuating these two 'bottlenecks' for SRI use.

Biomass production and processing

Improving the agronomic effectiveness and labour efficiency of producing and applying organic matter is a key issue for Conservation Agriculture, System of Rice Intensification and Organic Farming. This applies for better use of crop residues on the field as well as for composting. Better tools and implements for cutting and distributing biomass on the field, collecting biomass, transporting it, shredding it to accelerate microbial decomposition, processing it into high-quality compost or mulch, and applying it, are needed. The designs of many cutters, carts, etc. used now in biomass acquisition and handling are decades, even centuries old.

There has been negligible ergonometric or other evaluation to arrive at more labour-efficient methods for getting biomass into the soil in forms that are agronomically efficient and produce as much as possible within the cropping system itself. The acquisition and use of crop residues methods and/or composting methods are extremely important for the preservation of soil fertility in tropical and subtropical areas.

Pest control

Pest management is currently considered one of the biggest weaknesses and/or obstacles for smallholders. With climate change creating conditions that will increase abiotic stresses and in turn biotic stresses on all crops, more attention needs to be paid to crop protection, including the relationship between insect and fungal dynamics on the one hand and crop nutrient and soil organic matter management on the other hand. Improved integrated pest management would contribute to increasing yields with reduced reliance on mineral fertilizers and agrochemical crop protection.

Water control

In the context of System of Rice Intensification, an adopted and improved combination of hardware (facilities for acquiring, distributing and, if necessary, draining water) and software (management capability for operating these structures) is needed for being able to maintain soil conditions that are mostly moist but also aerobic. With the growing scarcity and/or unreliability of water supply for agriculture, development and investments in gaining better control over water for the purpose of economising its use and making it more productive should be of high priority. For Rainwater Harvesting, effective water use is in the same way important.

Adaptation to climate change

For research as well as action, the adaptation to climate change is the major issue: Implications of climate change are a major source of setback for smallholder farmers and are a leading cause of farmers falling into poverty. The potentials of the discussed agricultural production systems to mitigate the effects of climatic variation and extreme weather events should be further investigated. To minimise drought effects, the various ways of making better use of rain (e.g. forms of Rainwater Harvesting) as well as improving and maintaining soil porosity and water-holding capacity of soils themselves, following soil improvement with organic matter should be further assessed. To quantify the potentials would be a first decisive step towards developing strategies to reduce susceptibility and increase resilience. Another important research need is the role of N_2O and CH_4 emissions from different systems.

Socio-economic research

Socio-economic research is less widespread than agronomic and biophysical issues. Dominant topics are economic comparisons with commonly practiced land uses regarding profitability. Relevant socio-economic issues to be more investigated are cost-benefit calculations, labour issues and risk (livelihood) strategies, biodiversity and environmental services as well as stakeholders' often diverging interests in land use, e.g. agricultural use versus conservation.

5.7 Assessing the agricultural potential of GM plants

Evidence suggests that for the evaluation of the future problem-solving potential of genetic breeding approaches it is not sufficient to consider existing developments, since the commercially available transgenic plant varieties as well at least as those at an advanced stage of development only represent a limited selection of possible breeding approaches. The study of genetic breeding approaches may be conducted in a decentralised way, even in publicly financed institutions and smaller companies, but the real development of genetically modified plants, by contrast, is conducted predominantly by a few large seed companies. Many of the most significant of these are also producers of important agricultural chemicals. In connection with the (literally) exclusive significance of patent-protected procedures in the genetic engineering of plants, it is thus glaringly obvious that the genetically modified plants available on the market represent those that fit best into the portfolio of these companies and by no means all those which could potentially be successful on the seed markets. If the development to date continues, it is to be expected that these few large biotech seed companies will continue to dominate to the same extent if not more, since they of course have a primary interest in successful and profitable varieties whose transgenic features fulfil their function for as long as possible for as many effectively paying users as possible. It cannot realistically be expected that these companies will of their own accord develop a variety specifically designed, for instance, for poor developing countries or regions.

Overall, even 25 years after the development of the first transgenic plant and after 12 years of widespread use of transgenic seeds, there is still great uncertainty:

- Does genetic engineering harbour dormant potential for sustainable agriculture in both industrial and developing countries?
- Is it even possible to elicit this potential, particularly when one considers the basic economic and legal conditions?
- Are there other options which are more promising in terms of ecological and social success and which are thus to be preferred?

There are many arguments in favour of steering towards a problem-oriented approach in search for potential future agricultural technologies and cultivation methods. With a view to transgenic plants, this means examining genetic engineering options without a predetermined result. Thus, with reference to the challenges of climate change and problems of water supply or other stress factors, it would be appropriate to first inquire the overall existing and foreseeable agricultural challenges and only then the means of possibly or necessarily adjusting cultivation methods. The contribution of plant breeding will be encountered here in some parts of the second inquiry. Only then options for green genetic engineering can be examined in a sensible way and in comparison to other approaches. The same is true for the problem of micronutrient deficits and many other examples.

5.8 European Agriculture

For the concerned promotion of production system changes in developing countries and the integration into development cooperation, own research capacities, knowledge bases and practical experience with low-input intensification in European agriculture are desirable. Based on own practices, experience and research and development activities, the recommended actions in development policies would be more credible and better founded.

The use and recognition of the discussed production system in Europe vary considerably. Organic Farming originates from Europe, is established by European regulation, and is encouraged by support schemes. Organic production and markets are continuously extending. Therefore, the EU has a strong and leading position in Organic Farming.

In contrast, the situation of the EU is weak for other production systems. For example, there is hardly any land under Conservation Agriculture systems in Europe. Environmental management custodian schemes in Europe do not promote the principles and practices of CA, and farmers have no incentives to switch from tillage-based systems to those based on minimal or no-till systems.

With the overall aim of a more sustainable agriculture in Europe, agricultural production and their intensification without increasing external inputs or even lower inputs is on the agenda.

Such transformations will lead to lower energy costs and agrochemical requirements, higher total and factor productivities as well as rehabilitation and conservation of biodiversity and the environment. Furthermore, the European agriculture also has to adapt better to climate change and contribute to climate change mitigation.

For the introduction of Conservation Agriculture and other production system changes, the broadening of crop rotation is a major problem because agricultural prices induce preference for a small group of crops and lead to restricted rotations. Further research and development is needed to address this problem.

Rice production is an important agricultural activity in the Mediterranean EU member countries and is still carried out with input-intensive production systems. There is an opportunity now for the EU to take a serious look at the extent to which rice production in Europe can benefit from SRI principles and practices.

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OVERVIEW ANNEXES

Annex 1: Case study "Rain Water Harvesting"

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Annex 2: Case study "Conservation Agriculture"

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Annex 3: Case study "System of Rice Intensification"

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Annex 4: Case study "Organic Farming"

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Annex 5: Case study "Agroforestry systems"

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Annex 6: Case study "Transgenic Crops"

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