# A Study on the Relevance of Chinese Agricultural Technologies to Smallholder Farmers in Africa

AFRICAN AGRICULTURAL TECHNOLOGY FOUNDATION
FONDATION AFRICAINE POUR LES TECHNOLOGIES AGRICOLES

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# Preface

In 2008, the Rockefeller Foundation commissioned the African Agricultural Technology Foundation (AATF) to conduct a study on the relevance of Chinese agricultural technologies in addressing the productivity constraints faced by smallholder farmers in Sub-Saharan Africa (SSA). This was in preparation to the fourth Forum On China–Africa Cooperation (FOCAC) meeting which was scheduled to take place in Cairo, Egypt in November 2009. FOCAC has emerged as the main mechanism for structured dialogue between China and African countries following the Beijing meeting in 2006 that was attended by 41 African heads of state. This was the first time that this many leaders attended a meeting outside of the African continent. The FOCAC ministerial meeting in 2009 therefore offers an opportunity for catalysing new thinking on Chinese–African engagement and highlighting policies and projects that can create economic opportunities for Africans. This meeting could provide an opportunity to introduce a new mode of engagement between China and Africa whereby, in addition to trade, any investments by China could be supplemented by access to relevant Chinese technologies to stimulate African agricultural development for poverty alleviation and attaining food sufficiency. In this regard, agriculture has become a priority in Chinese−African economic and technological cooperation. This is because Africa boasts of abundant agricultural resources, while China is a big agricultural country with mature and applicable agricultural technologies and therein lie broad prospects for Chinese–African agricultural cooperation.

AATF in its interaction with China realised that SSA countries are yet to fully harness the potential benefits of Chinese agricultural technologies. This can be attributed to the following reasons.

- Little research or analysis has been conducted on the use and applicability of Chinese technology in African agriculture.
- Absence of mechanisms or institutions that actively seek to take advantage of the Chinese technologies to advance development in African agriculture.
- African governments have not been aggressive enough in engaging China to develop African agriculture.

To acquire in-depth understanding of what the Chinese agricultural technologies have to offer Africa, AATF undertook a study to identify technologies available in China that can be used by African resource-poor smallholder farmers. AATF also understood that reversing the productivity gap in African agriculture required not only an understanding of the technological solutions to the constraints but most importantly access and transfer solutions.

The premise of the study was that the increase in agricultural productivity in China occurred largely through scientific and technological innovations. Agricultural productivity in SSA lags far behind most of the agricultural areas of the world, and there has not been a systematic application of science and technology that could improve the situation. The subsistence farming practised in Africa results in yields and incomes that are unpredictable, leads to environmental degradation, and ultimately leads to a lack of food security. Many of the farmers barely produce enough food to survive, let alone a 'cash crop'. Identifying ways to improve agricultural productivity in SSA has been the focus of many private, national and international organisations in recent years, and many publications describe the challenges and opportunities in addressing the factors that constrain agriculture in Africa.

AATF, with assistance from a selected number of consultants working in the agricultural sector, identified the constraints and their technological solutions. They went further to identify the strategies for the access and transfer of such technologies based on their experience, knowledge and discussions with the stakeholders from both SSA and China. This report provides a compressive overview of the Chinese agricultural technologies that can address many current and future constraints that affect agricultural productivity in SSA. It is hoped that a broad range of stakeholders will find the report's conclusions and recommendations to be of value in their efforts to improve agriculture and enhance the lives of people living in those regions.

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# Abbreviations and acronyms

| | |
|---|---|
| AATF | African Agricultural Technology Foundation |
| AGRA | Alliance for a Green Revolution in Africa |
| ASARECA | Association for Strengthening Agricultural Research in Eastern and Central Africa |
| ATDC | Agricultural Technology Demonstration Centre |
| BAAFS | Beijing Academy of Agriculture and Forestry Sciences |
| CAAS | Chinese Academy of Agricultural Sciences |
| CADFund | Chinese Africa Development Fund |
| CAU | China Agricultural University |
| CBO | Community Based Organisation |
| CCS | Centre for Chinese Studies |
| CGIAR | Consultative Group of International Agriculture Research |
| CIMMYT | International Maize and Wheat Improvement Center |
| CORAF | Le Conseil Ouest et Centre Africain Pour la Recherche et le Développement Agricoles |
| CRF | Control Release Fertiliser |
| EAC | East African Community |
| EAP | East Asia and Pacific |
| ECOWAS | Economic Cooperation of West African States |
| FAO | Food and Agriculture Organisation |
| FOCAC | Focus On China–Africa Cooperation |
| GDP | Gross Domestic Product |
| GFDI | Grassland Fire Danger Index |
| GMOs | Genetically Modified Organisms |
| IARCs | International Agricultural Research Centres |
| ICT | Information and Communication Technology |
| IIAM | Instituto de Investigação Agrária de Moçambique |
| IITA | International Institute for Tropical Agriculture |
| IMF | International Monetary Fund |
| IPM | Integrated Pest Management |
| ISAR | Institute of Scientific and Agricultural Research |
| IWMI | International Water Management Institute |
| MENA | Middle East and North Africa |
| MoA | Ministry of Agriculture |
| NARS | National Agricultural Research Systems |
| NARES | National Agricultural Research and Extension Systems |
| NEPAD | New Economic Partnership for African Development |

| | |
|---|---|
| NERCITA | National Engineering Research Centre for Information Technology in Agriculture |
| NERICA | New Rice for Africa |
| NGO | Non-Governmental Organisation |
| OECD | Organisation for Economic Cooperation and Development |
| PPPs | Public-Private Partnerships |
| SADC | Southern African Development Community |
| SAPs | Soil Absorbent Polymers |
| SSA | Sub-Saharan Africa |
| WDR | World Development Report |

# Executive summary

Agricultural productivity in Sub-Saharan Africa (SSA) has stagnated over the last three decades while that of other developing regions such as South Asia has grown considerably. The low agricultural productivity in SSA has entrenched poverty among smallholder farmers. Accelerating growth and overcoming constraints to African agriculture is therefore crucial not only for achieving food security and reducing perennial hunger but also for generating employment and trade. The productivity of smallholder farmers in Africa remains low due to numerous biotic and abiotic constraints. Technological innovations that could address some of the constraints may exist but smallholder farmers in Africa may not be aware of their existence. Further, some of the useful agricultural technologies are under intellectual property protection that controls their commercialisation. This limits wide dissemination of such technologies for the benefit of smallholder farmers in Africa.

It is against this background, that the African Agricultural Technology Foundation (AATF), with support from the Rockefeller Foundation, commissioned this study in November 2008 to identify the relevance of Chinese agricultural technologies to addressing productivity constraints faced by smallholder farmers in SSA. This study was in preparation to the fourth FOCAC meeting scheduled to take place in Cairo, Egypt in November 2009. FOCAC has emerged as the mechanism for structured dialogue between China and African countries.

This study highlights smallholder farmer constraints in SSA and assesses the available Chinese technologies that can potentially solve the constraints. It recommends a strategy for adoption of these technologies for the benefit of Africa's smallholder farmers. The study also examines the involvement of China in SSA agriculture. The study reviewed existing literature on constraints facing the smallholder farmer in Africa, available Chinese agricultural technologies and experiences on agricultural technology. This study is also informed by a visit to China where interviews, field visits, workshops and presentations from and with Chinese experts were conducted.

The study identified numerous constraints to agricultural productivity in SSA, including but not limited to poor soils, drought, limited access to improved varieties, lack of irrigation facilities, poor water harvesting and management, high pests and diseases incidence, low mechanisation, poor research and extension, and ineffective government policy on agriculture.

The Forum on China-Africa Cooperation (FOCAC) was first established during the ministerial conference in Beijing in 10-12 October 2000. Beijing Declaration of the FOCAC and Program for China-Africa Cooperation in Economic and Social Development were adopted with four commitments; continued assistance to African countries, reduction and exemption of debt worth 10 billion RMB Yuan owed by those heavily indebted poor countries and the least developed countries in Africa, provision of a special fund for competent Chinese companies to invest in Africa and set up an Africa Human Resources Development Fund.

In 2003 during the second ministerial conference of FOCAC held in Addis Ababa 15-16 December, the Action Plan (2004-2006) made commitments including: increased assistance to African countries; training of up to 10,000 African personnel in different fields in three years; tariff-free market access to some commodities from the least developed countries in Africa; expansion of tourism cooperation with Africa; sponsorship of an international art festival focusing on African arts and the 'Voyage of Chinese Culture to Africa'; and increased people-to-people exchanges with Africa.

In 2006 during the third ministerial conference which was turned into a special summit that was held in Beijing 4-5 November 2006, declarations of Beijing Summit and FOCAC Action Plan (2006-2009) were adopted by 49 heads of state and government from China and African countries. Chinese President Hu Jintao announced the Chinese government's decision to take the following eight measures to assist the development of the African countries in the three-year period from 2006 to 2009:

1. Double China's 2006 assistance to Africa.
2. Provide US$ 3 billion of preferential loans and US$ 2 billion of preferential buyer's credits.
3. Set up a China-Africa development fund that will reach US$ 5 billion to support Chinese companies to invest in Africa.
4. Build a conference center for the African Union to support African integration.
5. Cancel debt matured at the end of 2005.
6. Open up China's market to Africa by granting zero-tariff to 440 items of commodities that are exported to China from the African least developing countries.
7. Establish three to five trade and economic cooperation zones.
8. The last measure includes another eight small items: train 15,000 African professionals, send 100 senior agricultural experts to Africa, set up 10 agricultural technology demonstration centers, build 30 hospitals, build 30 malaria prevention and treatment centers and provide anti malaria medicine, build 100 rural schools, dispatch 300 youth volunteers and increase government scholarships from 2,000 per year to 4,000 per year by 2009.

Thus, there has been progress in the implementation of the 2006 FOCAC commitments on agricultural development by both the Chinese government and the respective African governments. In addition to the agreement by the governments in 2006 to build ten agricultural demonstration centres in Africa, four more have been signed up and construction is at different stages of completion in the respective countries. The Chinese president and several ministers have visited Africa as a follow up to the FOCAC commitment. However, African countries need to focus more and prioritise mutually beneficial projects.

The study established that there is an array of useful Chinese agricultural technologies ranging from the basic to the cutting edge type of technology (for example 'marker assisted' breeding and recombinant gene technologies). The Chinese technologies include but are not limited to germplasm improvement through conventional breeding and molecular techniques, use of fertilisers, efficient water use systems, irrigation, dryland farming techniques (mulching, soil absorbent polymers, organic matter use, special equipment and land improvement), pests and diseases control, mechanisation, weather forecasting and information technology systems. This range of agricultural technologies has been credited with the increase of productivity in China. It was established that a number of the Chinese agricultural technologies could be useful in addressing the constraints faced by African smallholder farmers.

The study identified key Chinese agricultural technologies that may be used to improve productivity in SSA. These include improved crop varieties, like high fertiliser use efficiency super rice hybrid, with yields as high as 13.5tonnes/ha that may be suitable for the rice growing regions of SSA; multiple-disease resistant high-yielding wheat; multiple disease resistant high yielding maize that may be suitable for the maize production areas; slow release fertilisers; dryland technologies, water conservation and harvesting techniques, supplementary irrigation, micro-irrigation and plastic mulch; land management practices and policies; re-organisation of a moribund agricultural extension system; technologies for reducing post-harvest losses; mechanisation with appropriate technology to increase labour productivity; and integrated aquaculture farming that focuses on joint production of fish, livestock and crops.

From the Chinese experience, it is evident that facilitation through creation of an enabling environment and required facilities is critical in exploiting the potential impact of agricultural technologies. Their successful deployment will depend on the capacity of information systems, research and extension, farmer groups, markets and infrastructure.

This study proposes that to facilitate technology access and delivery, FOCAC could be used as a conduit for disseminating agricultural technologies. This forum should also focus on invigorating agricultural production in Africa as the foundation for economic growth. The China–Africa Development Fund (CADFund) should also be used for investment projects in agriculture and awareness on the existence of the fund and how to access it should be created. This will immensely benefit both the African farmer and the Chinese investor. Other ways of transferring the Chinese agricultural technologies may include public-private partnerships, collaborative research and extension, policy intervention, capacity building and infrastructure development and the creation of efficient markets.

It should however be borne in mind that the environment or infrastructure required for some of these technologies to thrive may be lacking or different from what exists in Africa. Secondly, a quick review of the agrarian reform in China suggests that the policy environment which enabled agricultural growth in China is far removed from the situation in Africa today. Poor infrastructure, socio-economic and policy environments are seen as the overriding constraints in Africa. Finally, if the agricultural production is to go beyond subsistence, it is imperative that market infrastructure be developed to bring positive change in the socio-economic circumstances of the smallholder farmers in SSA.

# Chapter One
# Introduction

## Background

Sub-Saharan Africa (SSA) is the only region on the globe today where poverty and malnutrition continue to increase in percentage and in absolute numbers (Sachs, 2005). Over half of the hungry people are subsistent farmers who cannot grow enough food to feed their families consistently and escape poverty. Conway and Toenniessen (2003) report that about 31% of the above 400 million smallholder farmer household members, comprising mainly women and children, are undernourished. African agriculture therefore remains a key sector for developing initiatives to increase efficiency, growth and, most importantly, to fight hunger in SSA.

The problems of agricultural productivity growth in SSA are compounded by the nature of the environment, crops, pests and diseases, farming systems, climate change, low irrigation capacity and unfavourable policy regimes. The productivity of smallholder farmers in SSA remains low due to numerous biotic and abiotic production constraints. Technological innovations that could address such constraints may exist and those that are being developed are increasingly coming with patents that control their commercialisation thereby limiting wide-scale dissemination of such technologies for the benefit of smallholder farmers in SSA. Accelerating growth and overcoming constraints in African agriculture is therefore crucial not only for achieving food security and reducing perennial hunger but also for generating employment and trade.

The African Agricultural Technology Foundation (AATF) was founded to facilitate public–private partnerships for the access and delivery of appropriate technologies to the resource-poor smallholder farmers in SSA. Thus, the quest to increase Africa's agricultural productivity and reduce rural poverty has been at the centre of AATF's objectives and strategic vision. AATF notes with concern that whilst agriculture is the backbone of many economies in SSA, it is characterised by a low technological innovation and little, if any, improvement in yield per unit area of land has been recorded in the past 40 years. It has become imperative for AATF to explore tested, high-performance and suitable technologies from across the globe that can be adopted by smallholder African farmers and that could supplement those being developed by both public and private sector institutions in Africa.

In recent years, China has become a major global player in trade and industry. Between 1999 and 2008, China–Africa annual trade increased from US$ 6.5 billion to US$ 106 billion, making China Africa's third largest trading partner after France and the USA.

China's economy is expected to become the second largest economy in the world by 2016. Chinese agriculture, which is dominated by millions of smallholder producers, has recorded large improvements in productivity in the past 30 years. Total grain production in China quadrupled between 1949 and 1998, despite the fact that over the years the per capita farmland has decreased; for example the Ministry of Agriculture (MoA) (China, 2008) indicates a decrease from 0.139 hectares per capita in 1978, since the onset of agricultural reforms, to 0.093 hectares per capita in 2006. Experts attribute the increase in agricultural productivity in China to favourable institutional and policy changes, rural infrastructure and economic development and innovative agricultural technologies. The presence and importance of the development of public and private institutions that focus on agricultural technology development in China has also been noted.

Through the Chinese Academy for Agricultural Sciences (CAAS), a consortium of over 30 agricultural research institutes, and China's National Agricultural Research Systems (NARS), researchers generate a significant number of agricultural technologies that increase smallholder productivity. Through CAAS, China generates substantial revenues through technology transfer and agri-business.

To acquire in-depth understanding of what the Chinese agricultural technology landscape has to offer Africa; AATF undertook this study to identify technologies available in China that can be used by African resource-poor smallholder farmers. This study thus provides a thorough review of potentially available Chinese agricultural technologies that could be useful in mitigating productivity problems in African agriculture. Efforts to improve agricultural productivity in SSA are critical since they do not only lead to enhanced food security, but they also create employment and increased trade through a multiplier effect. The study also focuses on identifying current levels of Chinese engagement in mitigating productivity problems in agriculture in SSA.

Since 1960, China has supported several African countries to develop their agriculture, improve livelihoods and achieve economic and social progress. In a bid to support African agriculture, China made some commitments at the 2006 FOCAC meeting to provide 100 agricultural scientists and ten agricultural demonstration centres in Africa by 2009. This study reports on the progress on these commitments and also documents current levels of Chinese involvement in agriculture in SSA within and outside the said commitments.

## Rationale of the research

Agricultural productivity in SSA is stagnating or declining, a stark contrast to the situation in other developing regions of the world such as in China. Reversing the productivity gap in African agriculture requires not only an understanding of the attendant significant constraints but also most importantly access to solutions. Dixon et al (2001) intimate that there is overwhelming evidence showing that increased productivity and agricultural growth are fundamental for rapid reduction of poverty.

Many experts feel that what is missing in SSA agriculture is a credible inventory of scientific breakthrough and technological innovation especially of a high impact nature targeted at smallholder farmers. It is apparent that the increase in smallholder agricultural productivity in China is driven to a substantial extent by productivity enhancing agricultural technologies. Thus the Chinese agricultural technologies might expand the range of technological solutions that could enable smallholder farmers in SSA to quickly increase their productivity.

The average developing world cereal yields which were estimated at 1 tonne per hectare in 1961 increased to 4.5 tonnes per ha in the East Asia and Pacific (EAP) region, 2.3 tonnes per ha in the Middle East and North Africa (MENA) region, yet remained at 1 tonne per ha in Sub-Saharan Africa (WDR, 2008; Binswanger-Mkhize, 2008), while in China it increased to about 4.5 tonnes per ha (MoA, China). The agricultural technology gaps between SSA and the other regions that have managed to raise agriculture productivity are quite significant. For example it is estimated that in 2000, while improved crop varieties covered 84% of the area under cereal cultivation in the EAP region and 61% in the MENA region, they only covered 22% in SSA (Binswanger-Mkhize, 2008). Another input use statistic of note is that in 2002, fertiliser use in the EAP region was estimated at 190kg per ha of arable land, 73kg per ha in the MENA region, while only at 13kg per ha in SSA.

Evidently, as shown by Figures 1 and 2, there has been something that the Chinese have managed to do which the Africans have not done.  The food production per capita income for China has increased, whilst that of Africa has declined meaning that there is a lot of agricultural development taking place in China.

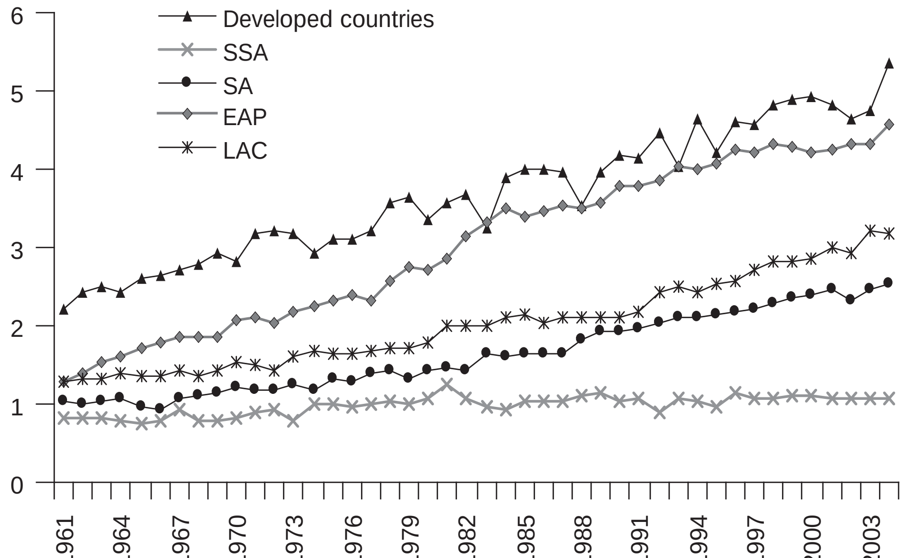


Figure 1: *Production of cereals (tonnes) between 1961 and 2003 (Source: FAO, 1996)*

China has taken the initiative to help African agriculture as signalled by the thrust and commitments of FOCAC. African heads of state therefore, should be fully informed on what relevant agricultural technologies are available in China that has potential for positive impact on African agricultural productivity so that their transfer to Africa can be pursued in various ways. These ways could include multilateral arrangements such as FOCAC, bilateral arrangements, public–private sector and private–private sector arrangements. This report therefore outlines the productivity constraints in Africa and the agricultural technologies available in China, the technologies that could be useful and applicable to address smallholder farmer constraints in SSA and strategies for access and transfer of the identified technologies to SSA.

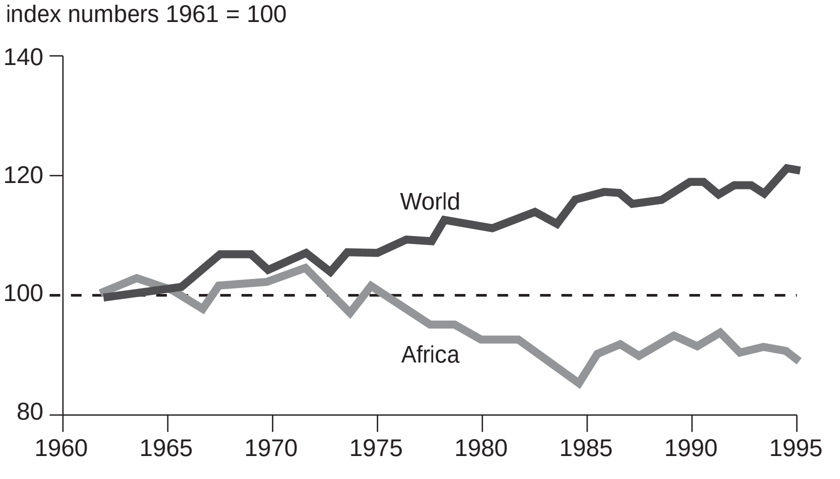


Figure 2: *Food production per capita in Africa and the world (1960-1995) (Source: FAO, 1996)*

## Objectives

The overall objective of the study was to identify relevant Chinese agricultural technologies that can address productivity constraints affecting smallholder farmers in SSA.

The specific objectives included the following.

1. To assess the constraints of smallholder agriculture in SSA.
2. To assess the level of Chinese involvement under FOCAC in supporting smallholder farmers in SSA.
3. To assess agricultural technologies that are available to Chinese smallholder farmers that can be used within the African smallholder farming community to address productivity constraints.
4. To come up with criteria for selecting Chinese agricultural technologies which are suitable for smallholder farmers in SSA.
5. To come up with strategies for access and transfer of Chinese technologies to smallholder farmers in SSA.

# Methodology

## Area and scope of study

This study on constraints identification was carried out in SSA focusing on the regional areas of east, west and southern Africa. The focus countries included Tanzania, Ethiopia, Kenya, Ghana, Burkina Faso, Nigeria, Malawi, Mozambique and Zambia. Information was sourced from National Agricultural Research Systems (NARS), government departments, continental and regional bodies (EAC, ECOWAS, NEPAD, ASARECA, SADC and CORAF), Non-Governmental Organisations (NGOs), community based organisations (CBOs), agricultural universities and private organisations. The investigation covered key stakeholders involved in smallholder agriculture in the focus countries. The second part of this study examined technologies used in the Chinese agricultural sector, the assessment of which technologies would be useful to SSA smallholder agriculture and structuring ways of making them available and accessible to smallholder farmers in SSA.

### Research design and data collection methods

The methods used included desk research and key informant presentations, interviews, field visits and workshops. A review of existing documentation and materials on SSA agriculture was used to identify and assess the constraints to agricultural productivity faced by smallholder farmers, and the Chinese involvement in African agriculture.

Key informants interviewed included employees of ministries of agriculture in the respective countries, employees of NARS, farmer organisations, government agencies, universities, Non-Governmental Organisations and community based organisations involved in agricultural development. On the Chinese part, interviews covered Chinese agricultural policies and technologies, progress made in agricultural technologies and Chinese smallholder agriculture. Chinese agricultural technology transfer experiences to smallholder farmers and technology transfer critical success factors and strategies for Africa to access Chinese technology.

Respective African country embassy personnel were also interviewed on FOCAC commitments, bilateral agreements on agriculture and technology transfer possibilities. Some smallholder farms in China were visited and the smallholder farmers were interviewed to get information on the technologies and intuitions. Academies of science and universities were also visited to familiarise with agricultural technology research infrastructure, structures, ongoing funding, extension and commercialisation of useful research findings.

# Chapter Two
# Constraints to agricultural productivity in Sub-Saharan Africa

## Smallholder agriculture in Sub-Saharan Africa

Whilst agriculture is the mainstay of SSA economies, it is characterised by a number of biotic and abiotic constraints. Agriculture in SSA has been largely confined to low productivity subsistence farming and has been considerably dependent on rain and inefficient farming systems such as shifting cultivation, where land is temporarily cultivated with simple implements (such as hand-hoes) until its fertility decreases and then abandoned for a time to allow the soil to regenerate. In addition, most of African arable land generally has been allocated through a complex system of communal tenure and ownership rather than through individually acquired titles, and peasant farmers have had rights to use relatively small and scattered holdings. This system of land ownership has tended to keep the intensity of agricultural production low and has inhibited modernisation. According to Binswanger-Mkhize (2008), agricultural productivity in SSA is not only low but relatively behind technologically, and also impacted negatively by slow development of input and output markets and associated smallholder services, coupled with inadequate safety nets to deal with extreme poverty, risks and fluctuations.

Productivity in agriculture has been declining due to several factors including lack of access to capital, soil degradation, poor access to markets and new technologies, low investments in agricultural research and decline in donor support in agriculture, inadequate training and extension services, extreme weather patterns in form of more frequent and prolonged droughts and floods, and crop pests (Eicher, 2003). Drought induced famine is an issue in SSA and more so in southern Africa. This situation is exacerbated by the fact that only 3.7% of arable land in SSA (excluding South Africa) has some irrigation in comparison to 31.6% in Asia (Rukuni et al, 1994). In addition, there is a problem of HIV/AIDS that has resulted in the reduction in life expectancy and productive capacity of farming households in SSA (Haggblade et al, 2004).

The smallholder farming systems of SSA are characterised by the following.

- Low input and output: low usage of inputs such as fertilisers, improved seed and other technologies. Consequently, the yields remain low compared to the developed countries.
- Subsistence: the bulk of the food grown is for domestic consumption with little produce being taken to the market.
- Low modern technology adoption: widespread use of inferior genetic

material and low mechanisation; reliance on animal draft power and human labour, and dependency on rainfall.
- Poor infrastructure: poor communication systems, unskilled human resources and lack of organised marketing systems.
- Strong linkage between crop and livestock subsystems; when one subsystem suffers the other is affected unlike in monocropping systems. The interdependence of different elements of the system has been highlighted elsewhere (OECD Development Centre, 1987).

Doward et al (2007) highlight the factors limiting smallholder agriculture in Malawi as being high levels of poverty, low productivity, increased vulnerability, seasonality, high dependence on maize, price fluctuation, land pressure, poor market development and infrastructure, fragility of casual labour markets and 'coping strategies' of poor people. In addition, emergency food aid which is common in eastern and southern Africa tends to distort local commodity prices, a situation that discourages local farmers. Ravallion (2008) says that the biggest lessons that Africa can learn from China is that growth in smallholder agriculture will require both market incentives and public investment. Therefore, any effort to overcome agricultural productivity constraints through transfer of agricultural technologies must be accompanied by investment in market development.

## Constraints to smallholder agriculture in Sub-Saharan Africa

Although crop production has been a major driver of rural development in most SSA countries, several other constraints have been highlighted. Aziz (1990) notes major crop production constraints as highlighted in Table 1.

### Poor soils and soil management

The soil, being the medium in which crops grow, is a very critical element in the farming system. Only 6% of the land in SSA has high agricultural potential (Tegene and Wiebe, 2003 quoted in Ehui and Pender, 2005). The major soil problems in SSA are nutrient deficiency, high acidity, high leaching, degradation and loss through erosion. For example, close to 5 million hectares of arable land in Ethiopia is acidic. Poor soil quality and low soil fertility has been identified as one of the most important constraints to improving crop productivity in SSA (NAS, 2008; Sanchez et al, 1997; Donovan and Casey, 1998; Scoones, 2001; Mekuria and Waddington, 2002; Sasakawa Africa Association, 2004). Soil in SSA is naturally low in nitrogen and deficient in phosphorous, sulphur, magnesium and zinc. In addition, low soil depth reduces crop anchorage and ability to extract nutrients and water (ECA, 2003).

The soils in SSA have low structural porosity and tend to easily compact and harden. Intensive row cropping, overgrazing and deforestation accelerate erosion of topsoil.

Table 1: Summary of major constraints in SSA smallholder farming

| Constraint | Details |
|---|---|
| Soils and soil management | Poor soil fertility and structure, erosion, poor soil fertility management practices, low fertiliser application, poor access to inputs |
| Water and water management | Drought, floods, climate change, very low access to irrigation |
| Biotic | Pests and diseases |
| Improved varieties | Lack of improved varieties, lack of knowledge of and access to improved varieties |
| Labour | Availability and expertise, effect of HIV/AIDS |
| Land and land tenure | Availability, size, control, usability as collateral |
| Energy | Low fuel and electricity availability, low mechanisation, shortage of draught power |
| Post-harvest | Poor post-harvest handling and storage facilities |
| Infrastructure | Transport infrastructure, high transport costs, communications, human resources, support institutions (such as research stations), markets |
| Constraints to animal production | Animal pests and diseases, low productivity and adaptability of breeds, nutrition |
| External factors | Policy environment, macro-economic situation, political stability, lack of credit and expensive credit, market prices, market access, lack of full appreciation of market requirements, absence of standards and quality control systems, irregular farm production, lack of market information, poor global commodity prices, poor extension coverage, low capacity of research and extension |

Source: Aziz, 1990

Decline in soil fertility is worsened by poor crop management practices and low nutrient application (Smaling et al, 1997). Sanchez (2002) reports that soil erosion and nutrient leaching lead to losses of up to 20kg/ha of the major soil nutrients (nitrogen, phosphorus and potassium). In many parts of Ghana, for example there are numerous problems associated with the declining productivity of the soil due to frequent soil tillage and removal of crop material/residue. Further in Ghana, 69% of the total land surface is prone to severe erosion which costs 2% of the annual Gross Domestic Product (GDP). Although the problem is in all the agro-ecological zones, the savannah regions are the most affected (MoA Ghana, 2007). Land degradation, soil fertility depletion and soil erosion are serious constraints to agricultural productivity in much of Nigeria.

Crop production can only improve if the fertility is improved through use of organic or inorganic fertilisers. Despite the acknowledgement of this fact, fertiliser usage in SSA remains very low; at just 8kg/ha in southern Africa (Henoa and Baanante, 2006;

Lal, 2007). For instance, for the period 2004–2005 the World Bank estimated fertiliser use in Ethiopia at 3kg/ha of arable and permanent cropland, 44kg/ha in Kenya, 13kg/ha in Tanzania and between 10–15kg/ha in Nigeria. In contrast, data from other developing regions estimate that in 2002, fertiliser use in the EAP region was estimated at 190kg/ha of arable land and 73kg/ha in the MENA region.

Access to fertiliser by smallholder farmers remains a big challenge due to limited coverage, lack of adequate institutional capacity, funds and poor infrastructure. Other challenges include high and fluctuating international prices, high transport costs from port to inland destinations, poor distribution of infrastructure, the absence of capital for the private sector to invest in distribution, business risks facing fertiliser importers, and inconsistencies in government policies. Such inefficiencies in the input supply markets result in high prices beyond the reach of the smallholder farmers.

## Climatic variability: Drought and flooding

Climatic variability is a particular problem in the arid and semi-arid ecological zones. Rainfall variability in Africa is reported to be roughly twice that in temperate regions. Drought consists of inadequate total rainfall or dry spells in the main rainy season that impact negatively on production. Thus, even in years when precipitation is adequate overall, rain can start late or finish early, with disastrous consequences for agriculture.

Droughts are a permanent feature in countries such as Botswana, Zimbabwe, Mali and Burkina Faso. In Burkina Faso drought is a common phenomenon occurring every two years. Smallholder agriculture is particularly vulnerable to these droughts, specifically in the north which is part of the Sahel, a belt of semi-arid land separating the Sahara desert from tropical vegetation. Persistent drought in east and west Africa is well documented and has been primarily attributed to changing Atlantic sea surface temperatures. Nearly 80% of Kenya is arid or semi-arid, and water is a major constraint in these regions. Similarly, there are large swathes of land that are arid or semi-arid in both Tanzania and Ethiopia, with limited water sources.

Early warning systems such as weather forecasting in most SSA countries are often underfunded, hardly functional, outdated and inaccurate. Therefore, little is known about the anticipated length, severity and origin of drought, making it difficult to enlighten and prepare the farming communities. This unpreparedness brings with it severe effects on crop and livestock productivity. Smallholder farmers in SSA are thus at the mercy of unreliable rainfall, which may seem adequate but presents huge challenges due to the uneven distribution during the crop season.

Table 2: Frequency of relatively severe droughts in southern Africa countries from 1963-1993

| Country | Period | | | Total |
|---|---|---|---|---|
| | 1960–72 | 1973–81 | 1982–93 | |
| Botswana | 0 | 1 | 7 | 8 |
| Lesotho | 2 | 2 | 2 | 6 |
| Mozambique | 0 | 0 | 2 | 2 |
| South Africa | 2 | 1 | 8 | 11 |
| Swaziland | 0 | 0 | 4 | 4 |
| Zimbabwe | 2 | 1 | 6 | 9 |

Source: FAO, 1996

On the other hand, flooding (for example as caused by tropical cyclone Eline in 1999/2000) destroyed crops in Mozambique and Zimbabwe, creating a rather uncommon occurrence in southern Africa (although there were similar disasters in the 1970s). The Limpopo River flooded in 1977 and 1978, the Inkomati River in 1977 and the Zambezi River in 1978 with catastrophic consequences to Mozambique. Tropical cyclone Justine caused widespread damage in the northern coastline area of Mozambique in 1979. Damage from the 1978 floods in the Zambezi valley was estimated at approximately US$ 63 million with thousands of families having to move to higher grounds (SADC, 1992c). Other agricultural hazards that have adversely affected crops such as tobacco and cotton include hailstorms and excessive late season rain.

## Water resources development and management

In SSA, only 5 million hectares accounting for about 4.9% of total cultivated area is under irrigation compared with 40% in South Asia, 55% in China and 65% in Japan. More than 3 million hectares of the estimated 5 million hectares of irrigated land are in just two countries; Madagascar and the Sudan (Wiggins, 2000). In addition, water harvesting, conservation and management in rainfed areas is not adequately practiced.

Studies have reported that yields can be increased fourfold through efficient water management (Camara and Heinemann, 2006) and there is potential for SSA to improve productivity through irrigation (IWMI, 2007). Larkins et al (2007) emphasise improved water management by the use of organic matter, water harvesting techniques, prevention of soil erosion, and use of tied ridges and terracing. Therefore, where feasible, development of smallholder irrigation in SSA should be seriously considered.

The areas under irrigation in the last decade and potential irrigable areas in some of the southern African countries are shown in Table 3.

Table 3. Area under irrigation and potential irrigable area using the existing water resources

| Country | Area irrigated (ha) | Potential irrigable area (ha) |
|---|---|---|
| Botswana (1990/91) | 1,300 | 39,000 |
| Lesotho (1991/92) | 1,900 | 20,000 |
| Mozambique (1991) | 45,000 | 2,400,000 |
| South Africa (1996) | 1,300,000 | 1,600,000 |
| Swaziland (1990) | 46,000 | 86,000 |
| Zimbabwe (1995) | 120,000 | 370,000 |

Source: Author's Research, 2009

## Biotic constraints

Biotic constraints to smallholder agriculture can be broadly classified into pests, diseases and weeds, which affect the crops at various stages of growth. Pests and diseases can reduce crop yield by up to 70% and also destroy biodiversity. The devastating invasions of desert locusts every ten years in west Africa's Sahel region has destroyed crops and caused famine in several west African countries.

Haggblade (2007) cites reports by Otim-Nape (2005) on the decrease of cassava production by up to 75% within five years following an outbreak of a new strain of cassava mosaic virus (CMV). Chitundu (1992) reports a decline of over 30% in cassava output in Zambia following an outbreak of the cassava mealy bug in 1983. Other pests and diseases that attack specific food crops include *Striga* in maize, millet and sorghum; pod borers and brown blotch in pulses; fungus; aflatoxin in groundnuts; and nematodes in banana and water melon, aggravating the food insecurity situation in Africa. Table 4 lists some of the main diseases and pests of the major crops in SSA.

Table 4: Some pests and diseases associated with main crops grown by smallholder farmers in SSA

| Crops Affected | Pest, disease or weed | Sources |
|---|---|---|
| Grain and legume crops | *Striga* (witchweed), *Cynodon dactylon*, *Echnochloa spp*, rust and vector borne viral diseases | Ejeta and Gressel (2007) |
| Rice, millet and sorghum | Quelea bird (*Quelea quelea*) | Dogget (1988) |
| Maize, cotton and rice | Stem borer and bollworm | NAS (2008) |
| Stored grains | Weevils, borers, *Aflatoxin spp,* fungus | Gressel et al (2004) |
| Root crops such as cassava and sweet potatoes | Weevils, nematodes and viruses | Kahn (1984), Terry and Perreaux (1984) |
| Legumes | Diseases such as bean mosaic, angular leaf spot, anthracnose, common blight, rust, cowpea mosaic and *cercospora* leaf spot | Allen and Ndunguru (1984) |

Source: Author's Research, 2009

Often smallholder farmers use inadequate pests and diseases control methods, both in the fields and in storage (Charman, 2004). Other factors have also been cited for example Akobundu (1980b) lists major constraints to herbicide usage as inadequate knowledge of herbicide recommendations and usage, poor timing of herbicide application, inappropriate application methods, scarcity of small affordable packs of herbicides, unreliable extension services and an acute shortage of professionally trained weed scientists.

## Poor post-harvest handling

Most farmers in SSA are affected negatively by the lack of appropriate harvesting, processing and storage technologies. This leads to losses of about 25–35% of the total yields. In addition there is little value addition to the products and due to lack of proper value addition infrastructure and the short shelf life, most products are spoilt before getting to the market. For instance, post-harvest handling in Mozambique, including on-farm storage, is reported to be typically poor. Ahmed (1981) reports that higher uncertainty stalks smallholder farmers as they are more likely to get low prices for their crops due to inappropriate storage. They therefore are unable to hold their grain crops until market prices are more favourable.

The combination of low productivity and post-harvest losses has led to losses of up to 10% of the total grain production and 20% of the total tuber production in Nigeria.

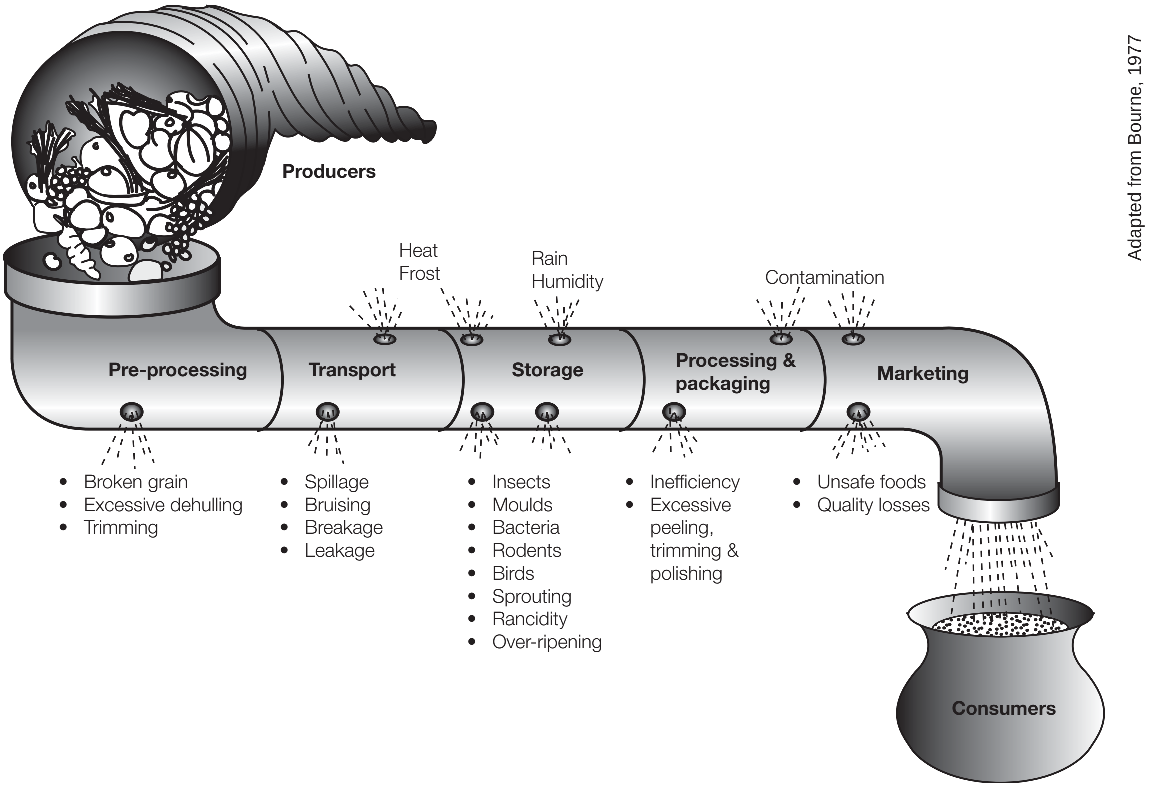


Figure 3: *Typical food pipeline 'leaks' illustration*

Agro-processors have inadequate equipment, face unstable market conditions, poor infrastructure, unfriendly government policies and lack of steady supply of raw materials. Figure 3 shows a schematic representation of how losses in food grains occur at different levels in the food value chain.

The study revealed that the leaks especially during storage are cause for major concern to smallholders in SSA. Fresh produce was indicated as seriously affected by factors such as lack of post-harvest handling skills and facilities, absence of ready markets coupled with transportation difficulties. The post-harvest technologies of fruit and vegetables involve physiological and phytopathological processes; therefore issues of disease and pest control are critical both in the field and during post-harvest.

## Lack of access to improved crop varieties

SSA smallholder farming is characterised by low use of improved crop varieties. Public funding for most breeding programs is either insufficient or nonexistent (NAS, 2008). Since smallholder farmers use low capital, it implies that only wealthy farmers can access improved varieties. Improved hybrid varieties are mainly driven by multinational companies in eastern and southern Africa, making them inaccessible to most smallholder farmers. This situation is exacerbated by agricultural policies which are often rather fragmented. Tschirley and Abdula (2007) report that Mozambique external input use is rare and seed for planting is typically saved from own production or bought in local markets, resulting in uneven colour (yellow grain mixed with white grain).

The institutional weaknesses in research and breeding coupled by breeding resources and technologies have led to poor quality germplasm. Where the seed is available, it is too expensive for the ordinary smallholder farmers to access. There is need to increase access to improved germplasm for smallholder farmers in SSA.

## Labour shortage and inefficient draught power

Africa is the least mechanised region in the world and use of human labour is very high. Such limited mechanisation means limited cultivation on small farms leading to low productivity. Reports indicate that only 13% of smallholder farmers use draught animal power as mechanised technologies are simply too expensive for them (Charman, 2004). Animals are the major source of draught power for the smallholder farmers in most countries. However, it should be noted that some countries like Swaziland have mechanised. Smallholder farmers in SSA without draught power have smaller farms; plant their crops late, get less crop yields and incomes compared to those who own draught animals. This perpetuates the vicious cycle of poverty. Their problems are worsened by the frequent droughts and outbreaks of livestock diseases resulting in the loss of draught animals.

Low mechanisation and draught power usage makes crop production in SSA smallholder farms very labour intensive. Land preparation, ploughing, planting, weeding, harvesting and processing is done using traditional hand held tools. Manual labour and hand hoe technologies account for 85% of farm operations. Labour shortage has been observed as a serious constraint to smallholder farmer productivity in SSA with particularly serious shortages reported in Malawi (Alwang and Siegel, 1999). Charman (2004) also cites a study by Whiteside and Carr (1997), where a considerable amount of agricultural labour in Malawi is provided by children (34% of children in the age group of 10–14), which in turn disrupts their education. This situation perpetuates a high rate of illiteracy and low skills in the labour intensive smallholder farming. They also report that whilst the agricultural sector dominates the labour market, higher urban wages in industry, service and construction sectors, and poor health (HIV/AIDS) threaten its supply. In addition, farm labour is often expensive and labour saving technologies such as the use of machinery, though available, are unsuitable for smallscale operations; they are too expensive and out of reach.

### Inadequate energy sources

The SSA region does not have sufficient supplies of electric power and cannot adequately support agricultural activities such as irrigation and post-harvest cold storage. The limited power generating capacity; poor distribution infrastructure for energy; and electric and hydrocarbon fuels such as gasoline impede rural development. The situation is worsened by the lack of focused efforts on development and utilisation of renewable and alternative energy sources.

## Constraints not related to technology

Highlighted below are constraints that are not related to technology as established by this study.

### Land availability and land tenure

In SSA only about 6% of the total land area is used to grow crops and 24% is under pasture (Du Guerney, 2002). This means productivity can only be increased by expanding land under crop production although it is constrained by land tenure systems. Although the situation varies considerably among countries, codified property rights regimes are still quite rare in Africa and most land falls under customary law (Van den Brink et al, 2005). Land under customary law is considered state-owned and becomes a scarce resource with the ever increasing population. In Ghana, for example, agricultural land is declining due to population pressure and urbanisation which reduces land for crop production and shift in farming area. For example there is a shift in cocoa production from the Ashanti, Eastern and Brong Ahafo regions to the Western region and replacement of yam by cassava in the transitional zone (MoA Ghana, 2007).

In Zambia and Tanzania, like in most other SSA countries, smallholder farmers have no individual ownership titles since land is communally owned. This limits access to formal credit, since the farmer cannot use land as collateral. This therefore reduces incentives to invest in land quality, maintenance or improvement. Acquisition of land rights could be an incentive for commercialisation of traditional agriculture in SSA. The inability of smallholder farmers to use 'their' land as collateral to borrow the much-needed short and long-term credit for investment in agriculture denies most of them access to improved technology like hybrid seed, fertiliser and equipment.

## Lack of appropriate infrastructure

The poor state of infrastructure (such as road transport networks, communication, human resources and support institutions like research stations) is one of the major challenges to improving smallholder agriculture in SSA. In most African countries, less than one-third of domestically produced food enters commercial marketing channels beyond the local area as distances from villages to major towns and to all-weather roads are long. Agricultural surpluses cannot easily be moved to deficit areas due to poor infrastructure (Mabeza-Chimedza, 2001). Roads and telecommunications are often not as well developed as they are in urban areas and transport operators are reluctant to work in these areas. Hine and Rutter (2000) estimate that for 51% of villages in Ghana, the walking distance to the nearest pickup point for motorised transport services is more than two kilometres and over ten kilometres for 10% of Ghanaian villages. Dorward and Kydd (2004) intimate that, in Malawi, poor infrastructure and telecommunications, coupled with poor road networks and transport services, lead to high costs of transporting goods and services in and out of rural areas.

## Inefficient markets

Access to markets and market information remains a challenge in the smallholder sector and constrains crop production in SSA. Horticultural crops are especially difficult to market at good prices if market information is not available, a situation that has constrained their production. Further, processing and storage facilities are virtually absent. Smallholder farmers are still not participating in cash crop production due to lack of capital, the knowledge required to produce these crops, and market information. The success of smallholder cotton production in Zimbabwe and smallholder tobacco production in the Zambezi Valley in Mozambique are good examples of how producer incentives can lead to improved production.

## Poor government policies

In some cases, respondents complained about lack of a clear direction in government policy on agricultural development. For example Ethiopia faces a lack of direction on how to foster and harness agricultural research results. Elsewhere, input subsidy schemes are encouraged. For example in Tanzania, fertilisers are subsidised but are usually insufficient because the cost of fertiliser vouchers is shared between the government and farmers in a manner that does not allow the farmers to purchase adequate amounts.

### Poor rural finance and government support

Smallholder farmers in SSA struggle to raise working capital and there is a large unmet demand for agricultural credit and rural finance. Thus as is typical in SSA, and as reported by Skelton et al (2003), in Mozambique, credit is in short supply and is costly to access. With inadequate short term financing, farmers find it difficult to buy seed and other inputs. In the long term, they are unable to invest in land improvement, irrigation development or improved technology. In contrast to conditions in Asia, there are few agricultural financial service providers in most of Africa (Collier and Gunning, 1997).

### Inefficient agricultural research and extension services

Support for agricultural research and development is lacking in most SSA countries. Institutional inadequacies in SSA have led to problems related to fragmented research systems, weak linkages among research institutions, universities and International Agricultural Research Centres (IARCs); ineffective coordination of research leading to wastage of resources and duplication of research effort; inadequate funding; and lack of conducive policies.

The state of extension services in SSA highlights a lack of information and expertise in production methods, new and more efficient technologies, information on the importance of management practices (such as crop rotation, use of herbicides and insecticides), requirements of the market, use of nutrients and livestock husbandry. Despite the huge need for effective extension for SSA smallholder farming, most of the extension approaches that have been tried have been met with limited success or have collapsed altogether.

## Constraints to beef cattle production

Smallholder beef cattle productivity in most SSA countries has remained low. Heifers calve late, with an average age at first calving of between 42 to 48 months instead of a possible 24 months, and calving percentage is between 40–50% (Zhou, 1997) instead of the possible 80%. The failure of the cattle enterprise to develop has been attributed to lack of financial support, inadequate grazing land, inappropriate research, low access to extension and veterinary services, poor breeds, disease incidence, poor management and reluctance by farmers to adopt a commercial approach to farming. Appropriate dairy breeds are not readily available and are often beyond the reach of smallholder farmers. Cattle production is affected by ‘overstocking’ and inadequate feed resource to sustain reproduction and increase in cattle population just as in Botswana and Lesotho. The increase in cattle population and frequent droughts has put pressure on grazing land. Crop by-products are also not processed into feeds to improve their quality and help sustain livestock production. Inadequate veterinary services can preclude intensive production because a major disease or pest outbreak could decimate a whole herd. Pests such as ticks are important vectors of diseases such as heartwater, liver fluke and anaplasmosis. Newcastle disease is of serious economic importance to poultry production in SSA.

## Aquaculture development in Sub-Saharan Africa

Aquaculture is a young and small sub-sector in some SSA countries and is an important contributor to the agricultural incomes. In countries like Botswana, Lesotho, Mozambique and South Africa, the ministries of agriculture have been responsible for inland or freshwater aquaculture (FAO, 1996). Zambia, Tanzania, Nigeria, Uganda and South Africa are among the leading countries in aquaculture in SSA, with actual production of above 4,000 tonnes (FAO, 1996:10).

The constraints facing aquaculture include limited availability and utilisation of water and water bodies, lack of post-harvest handling and storage facilities leading to post-harvest losses, absence of aquaculture legislation and policies, lack of finance and plans for aquaculture development, limited training and research facilities, variable quality of extension services, absence and shortage of appropriate breeds due to absence of expertise and poor management practices, and low availability of fingerlings (FAO, 1996:1).

# Chapter Three
# Progress in the implementation of FOCAC 2006 agricultural commitments

## Chinese involvement in Sub-Saharan Africa agriculture

China has pursued technical cooperation with Africa in agriculture and rural development. In this regard, China continues to promise significant involvement in agriculture in SSA through quasi-government agencies, in line with a vision to fund production of food crops in several African countries for a period of 50 years. In the last five decades, China has extended assistance *inter alia* to Africa's agricultural sector. Shelton and Paruk (2008) report that since 1960, about 200 agricultural programmes and 13 aquaculture projects have been implemented in more than 40 African states. These projects, regarded as aid at the time, have been implemented in, among others, the Democratic Republic of Congo (DRC), Uganda, Niger, Guinea and Mauritania. This included friendship farms such as in Zambia (Figures 4 and 5) and support from the agricultural institute in China's Hubei Province to establish a Chinese farm in the DRC.

Source: Author's Research, 2009

*Figure 4: Largescale cistern, China-Zambia Friendship Farm Ltd.*

To support technology transfer, the Chinese Ministry of Science and Technology has established a Department for International Cooperation to handle technical cooperation. An example of such cooperation is the cooperation with Mozambique, in which China supports the agricultural research and technology transfer centre at Umbeluzi and a Technology Park in Moamba, both in Maputo Province. In 2004, China funded 31 international seminars dedicated to developing nations, covering a variety of topics such as agriculture, energy and environmental protection.

Source: Author's Research, 2009

Figure 5: *Maize field, Zambia Johnken Estates Ltd.*

## Forum On China–Africa Cooperation

Since its launch in the year 2000, the Forum on China–Africa Cooperation (FOCAC) has become the roadmap for China's cooperation with the African continent. This roadmap has been based on five principles of cooperation for future development of both Africa and China, which include the following.

- Equity and mutual trust
- Diversity in form and content
- Emphasis on practical results
- Pursuit of common progress
- Amicable settlement of differences

Ministerial meetings were held in Beijing in 2000 followed by another in Addis Ababa in 2003. The FOCAC Addis Ababa Action Plan 2004–2006 recognises that 'agricultural development is an effective approach to ensure food security, eradicate poverty and improve people's livelihood in Africa'. The China–Africa agricultural cooperation plan 2004–2006 was structured to enhance agricultural cooperation in areas including land and water resources management, agro-infrastructure development, crop husbandry, breeding, aquaculture, food security, exchange and transfer of applied agricultural technology, skills transfer, technical assistance, manufacturing of farm machinery and value addition of farm produce.

At the FOCAC meeting held in Beijing in 2006, the Chinese government pledged to double Chinese aid to Africa in the period from 2006 to 2009. Following the conclusion of the meeting, China's current and potential role as a development partner for Africa cannot be underestimated. This was reiterated by China's President Hu Jintao's opening remarks at the FOCAC November 2006 meeting where China's support for Africa's sustainable development and the unveiling of a multi-billion dollar development package to help boost the continent's initiatives was reaffirmed. The development assistance package, which included a range of commitments, was underpinned by major projects in the infrastructure and agricultural sectors. These two sectors will form the agenda for the upcoming FOCAC summit in Egypt in November 2009.

Pledges that were made to support agriculture were made by the Chinese government at the Third FOCAC Summit in November 2006, Beijing, and included the following:

- sending 100 senior Chinese agricultural experts to Africa
- setting up ten agricultural demonstration sites in Africa
- sending 300 young volunteers to support education, agriculture, sports and health-related projects.

## Progress in the implementation of the FOCAC commitments

Immediately after the 2006 Summit, China put together a plan and specific programmes for implementing eight policy areas.

In January 2007, Chinese Foreign Minister Li Zhaoxing visited seven African countries to start implementing the Summit outcomes. Soon afterwards, Chinese President Jintao visited eight African countries namely Cameroon, Zambia, Mozambique, Namibia, Liberia, Seychelles, South Africa and Sudan. He held consultations and made agreements with African Heads of States on advancing a new type of China–Africa strategic partnership, expanding practical cooperation and promoting common development.

President Jintao's visit to Africa marked the full launching of the eight policy measures. Later, Wu Bangguo, Chairman of the Standing Committee of the National People's Congress, and Jia Qinglin, Chairman of the National Committee of the Chinese People's Political Consultative Conference, made visits to Africa and further advanced the implementation of the Summit outcomes. Further, Chinese government departments in charge of commerce, education, agriculture and health, and Chinese financial institutions sent a number of delegations to Africa to consult African officials on cooperation in their respective areas of responsibility and to conduct field studies.

African leaders and governments have supported China and offered many good and constructive suggestions to augment the implementation of the Third Summit outcomes. A number of African countries have set up special committees or coordination units headed by government leaders and composed of respective government departments. Some countries have even sent delegations to China for consultations on cooperation. So far, over 40 African countries have reached an agreement with China on the implementation of the 2006 Summit outcomes.

## Agricultural demonstration centres

The Chinese President Jintao pledged to construct ten agricultural demonstration centres in Africa by 2009. The study noted that by June 2009, 14 contracts had been signed to construct the demonstration centres across Africa. These agricultural demonstration centres were negotiated on a bilateral arrangement between China and the respective countries. The status of the centres as at June 2009 is as shown in Table 5.

Table 5: Progress in establishing the agricultural demonstration centres

| Country | Status |
|---|---|
| Benin | Contract signed in March 2008 |
| Cameroon | Contract signed in November 2008 |
| Congo | Contract signed in March 2008 |
| Ethiopia | Contract signed in April 2008 |
| Liberia | Contract signed in March 2008 |
| Mozambique | Contract signed in November 2008 |
| Rwanda | Construction commenced on 4 April 2009 |
| South Africa | Contract signed in 2008 |
| Sudan | Field visit by Chinese company in October 2007 |
| Tanzania | Field visit by Chinese experts in 2007 |
| Togo | Construction commenced on 22 October 2008 |
| Uganda | Contract signed in June 2008 |
| Zambia | Visit by Chinese experts in December 2008 |
| Zimbabwe | Contract signed in 2008 |

Source: Author's Research, 2009

The establishment of the agricultural demonstration centres is at different stages in the respective countries. Whilst the study team managed to get some information on the progress in the implementation of these demonstration centres in some countries, in others the information was very scanty. However, the following is an overview of the progress in the establishment of the demonstration centres in some of the countries.

### Mozambique

The agricultural demonstration centre will be based in Boane just some 20 kilometres south west of Maputo. During President Hu's visit to Mozambique in February 2007, he announced that Mozambique would be the first African country to receive one of the ten agricultural technology demonstration centres. Subsequently, the Chinese government pledged US$ 55 million towards its establishment. When the implementation agreement was finally reached in 2008, the Instituto de Investigação Agrária de Moçambique (IIAM) made 52 hectares of land available for the project. At the time of the research team's visit to the site in February 2009, the land was being been cleared in anticipation of the heavy machinery and equipment from China. Lianfeng Farm in Hubei Province was selected to host the centre in Mozambique. A total of ten Chinese technicians will be overseeing the construction of the demonstration centre. The project leader, Mr Shao Jiayun, had previously worked in Nigeria for three years at the International Institute for Tropical Agriculture (IITA) as an expert of the South–South Cooperation project under the Food and Agriculture Organisation (FAO). Mr Shao is one of two agricultural technicians who have already arrived in Maputo to supervise this preliminary phase of the project. Seven other expert technicians, with different specialisations, will join the team later to coordinate training programmes.

Although the centre's design was proposed by China, Mozambican stakeholders made their contributions. According to the initial design, the centre would have cost an estimated RMB 4 million (approximately US$ 580,000), but the budget was reduced significantly after some functions had been removed. The final contract was signed by both parties on 18 February 2009, detailing the final design and implementation timeline. Considering the structural changes in the Ministry of Agriculture, the project is actually being managed by Mozambique's Ministry of Science and Technology, with Minister Venâncio Massingue being personally involved. The Chinese agricultural technicians envisage that the agricultural demonstration centre will become a viable training centre for local farmers within the next three to five years so that a transformation of the sector will be possible in ten years time. The centre has access to water and electricity from the municipal supply, a pump station will be built along the Pequenos Lebombos River, just two kilometres away.

The technicians will bring planting material from China for trials in the Mozambican climate, for example maize, rice, vegetables and fruit. In future, Mr Shao anticipates that animal husbandry, crop farming and horticulture could also be very suitable for this area. The agricultural demonstration centre will bring expertise in the areas of seed development and multiplication, and farming methods that will increase yield. According to the IIAM Director General, the institute has had minimal experience in agricultural cooperation initiatives and will be studying the new agricultural demonstration centre in Boane very closely. This will be a learning experience for both the Chinese and Mozambican stakeholders.

### Uganda

A Chinese delegation of agricultural experts was dispatched in May 2007 to conduct a feasibility study for the agricultural demonstration centre. Following discussions between the two parties, aquaculture was identified as a priority and in June 2008, a second Chinese delegation comprising aquaculture experts was dispatched to conduct a second feasibility study. It was thereafter decided that the aquaculture demonstration centre would be established in Kajansi which is close to Entebbe.

The Chinese government subsequently assigned a contractor who has been working on the design. The aquaculture demonstration centre will be built by The Phoenix Group, a company from China's Sichuan Province and will take 12 months to be completed. The aquaculture demonstration centre will focus on generating knowledge for fish farmers and researchers. The centre will have a series of ponds with a variety of species and will investigate whether species like the Nile perch can be successfully bred in ponds.

### Tanzania

In Tanzania, the contract to construct the demonstration centre for rice research in Kwakawa District in Morogoro Region was signed in 2006. This centre will use Chinese technologies to improve the yields of the New Rice for Africa (NERICA) project. China is also funding rice irrigation schemes, integrated dairy and poultry production in Mbarare, Ruvu and Mbeya respectively. The agricultural demonstration centre is yet to be constructed and reasons for the delay are not clear.

### Rwanda

The foundation stone for the construction of an agricultural demonstration centre at the Rwanda Institute of Scientific and Agricultural Research (ISAR) in Kigali was laid on 4 April 2009. It will cost US$ 4.5 million and will focus on the production of rice, mushrooms, fish and natural resource management.

The centre is also expected to bridge the gap between the researcher and the end user, who is the farmer or agro-processor. The centre will build capacity in the extension system so that research output can be able to reach the end user. The centre will focus on training farmers and extension workers on agricultural value addition for the market. The Agriculture Minister, Christopher Bazivamo, hailed Rwanda-China relations saying that the bilateral cooperation in the agricultural sector will take them to another level. The Minister reckons that the centre is in line with the country's vision of transforming agriculture into a productive, high value, market oriented sector. Through the centre, local farmers and their cooperatives will receive training on modern farming technologies which they will be able to transfer to their communities.

### Togo

The agricultural demonstration centre was part of a US$ 2.29 million grant and US$ 1.35 million interest free loan provided by the Chinese government. Not much information was gathered on the progress of the operationalisation of the demonstration centre.

### Zimbabwe

An agro-tech demonstration centre was agreed upon and the contract worth US$ 100 million was signed in 2008 as part of the Sino-Africa Cooperation Fund given to Zimbabwe. The demonstration centre will be located at Gwebi Agricultural College 10km outside Harare. The Chinese government will provide farming materials and maize production technical experts and showcase some of the modern irrigation and farming implements.

The centre will train farmers and agricultural students to enhance and support Zimbabwe's agrarian reform programme. Zimbabwe has a good agricultural sector, it is envisaged that these projects will contribute to turnaround the country's economy and enhance the bilateral ties between China and Zimbabwe.

### Cameroon

The governments of Cameroon and China signed an agreement on 10 January 2008 where the Chinese government would construct an agricultural technology demonstration centre (ATDC). The ATDC will serve as an experimental research and technical training, and sustainable development centre. It is also intended to help the government improve food security, alleviate poverty and fight unemployment.

### Sudan

China will assist Sudan to establish an agricultural demonstration centre, following a coogeration protocol signed in October 2007. The centre, covering about 60 hectares in Al-Qadarif in eastern Sudan, is designed to boost agricultural production by breeding improved strains, setting up production demonstration and training of personnel.

### Liberia

On 28 March 2008, HE Zhou Yuxiao, the Chinese Ambassador, and HE William Bull, acting Foreign Minister of Liberia, signed a protocol between the government of the People's Republic of China and the government of the Republic of Liberia for the establishment of an agricultural demonstration centre. The contractor of this project, Yuan Longping High-tech Agriculture Co. Ltd. signed the contract worth 40 million CNY (US$ 5.9 million) for the survey, design and construction of the demonstration centre with the Hon Christopher Toe, Minister of Agriculture for Liberia.

The centre is located in the Central Agriculture Research Institute in Suakoko, Bong County and covers an area of 36.2 hectares. The centre will focus on experimental research, technical training, farmer training and sustainable development. The centre will explore how to operate in a commercial, sustainable and mutually beneficial manner. It will also enable the local farmers to master modern farming technology, as a way of helping Liberians become self sufficient in food production.

### Ethiopia

Since April 2008 China has embarked on the construction of an agricultural demonstration centre in Ethiopia to train on improved crop production and contribute to poverty reduction. The demonstration centre will also increase the agricultural cooperation between the two countries.

### Senior Chinese agricultural experts

Since 2003, more than 10,000 Chinese agricultural experts and technicians have been dispatched to African countries to train local farmers as requested by the respective African governments. However, there was no information on some 100 senior experts dispatched to Africa following the 2006 commitment.

In Angola, for example over 120,000 farmers from 60 farmer associations and cooperatives benefited from the construction of a dam and irrigation channel, and training of agricultural technicians by Chinese agricultural experts. Most recently, Angola has secured a US$ 1 billion loan to boost the country’s agricultural sector, specifically focusing on the production of cereals and processing of agricultural products.

### Young volunteers to support education, agriculture, sports and health related projects

Whilst the Chinese government has sent many young people to Africa, it was difficult for the researchers to get information on the number of volunteers. The researchers did however note the presence of many Chinese technicians working in agricultural sectors of the countries visited.

## China–Africa Development Fund

One of the eight measures announced by President Hu Jintao at the third FOCAC Summit, in November 2006, was the creation of the China-Africa Development Fund (CADFund) – an independent commercial equity fund to facilitate Chinese companies investing in Africa. The fund was created with assistance from the China Development Bank (CDB), one of China’s three policy banks and the main shareholder in the fund. Officially launched in June 2007, the fund had an initial starting capital of US$ 1 billion and is to be increased to US$ 5 billion over the next few years.

The CADFund is the first global fund specifically aimed at African development, with the purpose of accelerating the economic and trade cooperation between China and Africa. Through the provision of capital for Chinese firms to invest in Africa, the fund reflects Beijing's foreign policy and strategy regarding the African continent. The fund focuses on sectors such as agriculture, manufacturing, infrastructure (energy and power) development, extraction industries and special economic zones. It is reported that since the establishment of FOCAC, more than US$ 400 million has been dispersed to support about 20 projects on the continent in these key sectors. This has mobilised a further US$ 2 billion in direct investment from the Chinese private sector.

In August 2009, the fund opened its first representative office on the continent in Johannesburg, South Africa. It will serve the Southern Africa region and will lead in identifying investment opportunities in Botswana, Comoros, Lesotho, Madagascar, Mauritius, Mozambique, Namibia, South Africa and Zimbabwe. Four more offices in eastern, central, western and northern Africa will be established in the near future. With the fund looking to expand its resources and investment on the continent, African agriculture can tap into the financial support and funding from the CADFund and partner with Chinese state owned enterprises and private investors.

In order to meaningfully gain from technology transfer, African policymakers must ensure that Chinese funding is directed to priority areas. African leaders should investment in science and technology and set skills transfer as a conditionality for future business deals. Encouragingly, African presidents have supported the role of science and technology in alleviating Africa's current problems, and encouraging agricultural and economic development.

## The availability and utility of Chinese technology to transform African agriculture

China is a member of the FAO Special Program for Food Security which is part of the South-South Cooperation which has supported countries like Gabon, Sierra Leone, Ethiopia and Ghana through provision of technical support. In early April 2009, China made a contribution of US$ 30 million to the FAO trust fund aimed at improving African agricultural productivity in the next three years, in order for African states to better meet the Millennium Development Goals (MDGs).

China has a lot to offer African agriculture and investment in the sector can aid in African countries' economic recovery and development. Consequently, more than US$ 20 million from the CADFund has been set aside to support ten agricultural projects by March 2009. These projects include forestry, animal husbandry, aquaculture, crop production, processing, agricultural machinery and agricultural trade promotion, to improve the livelihood of African people and to 'bring in practical Chinese technology and skills' to African farmers.

Examples of such projects are cotton production and processing in Malawi, Mozambique and Zambia (in cooperation with Chinese companies such as Coloured-Cotton (Group) Company Limited and Qingdao Ruichang Cotton Company Limited), and an Ethiopian leather processing project established in collaboration with Heitian Mingliang Leather Manufacturing Company, which aims to improve livestock breeding and leather processing skills.

Respondents from Uganda felt strongly that the country will benefit immensely from capacity building in agro-processing, aquaculture (Nile perch and tilapia farming), fruit and coffee production. They also suggested that assistance could include direct investment by Chinese agro-processing businesses, provision of hand tractors, research and infrastructure development.

The CADFund will support projects aimed at 'the introduction of advanced and appropriate Chinese industrial technology' and will include supplying agricultural projects with cheap machinery such as tractors. This will be done in collaboration with companies like One Tractor Group in a number of African countries. Initiatives will facilitate agricultural technology transfer to respond to demand as more people are realising the benefits of agricultural mechanisation.

The progress of fulfilling the commitment made in 2006 is slow but it is anticipated that with proper coordination and cooperation, Africa will benefit immensely from Chinese agricultural technologies. The commitments have managed to set a foundation for the evaluation of Chinese agricultural activities and the demonstration centres will be central to the facilitation of technology transfer. Chinese experts in these centres will train African technicians and farmers in order to ensure that these technologies are adopted and utilised. Once the technologies have proven to be useful, it is envisioned that many farmers will appreciate them and start to utilise them to increase productivity. This is already evident in Zimbabwe, South Africa and Angola where there has been an increase in demand for Chinese water pumps, two wheeled tractors and irrigation equipment.

# Chapter Four
# Chinese agricultural technologies

This section is as a result of a study in China by a team of researchers under the auspices of the AATF and coordinated by the Centre for Chinese Studies (CCS) and the Ministry of Agriculture in China. There was also a lot of interaction with officials from the Chinese Academy of Agricultural Sciences, China Agricultural University and Henan Agricultural University.

## Agriculture in China

The modernisation of agriculture through appropriate technologies in the pursuit of sustainable agricultural development and rural economic growth are central to China's agricultural policies. China has a per capita arable land of 0.093ha (this is about 9% of the total land), which is much lower than the world average, yet at these levels, the land supports 1.3 billion people (22% of the world's population). By 2007, China had 121.78 million hectares of cultivated land, with another 11.82 million hectares in gardens, orchards and plantations, 261.93 million hectares of grassland and 25.54 million hectares in 'other agricultural uses'. Around one quarter of the farmland is irrigated and the rest is dryland. The country also suffers from both periodic droughts and floods. Incredibly, China has managed to feed 22% of the world's population using only 10% of the world's arable land. Agriculture contributes 11.8% to the GDP and employs 42.6% of the working population. The contributions of different agricultural enterprises to China's agricultural GDP are as follows: crops 52%, livestock 34%, fisheries 10% and forestry 4%.

### History of Chinese agriculture

Chinese agriculture has transformed over the years since 1949. This has led to massive increases in production occasioned by changes in land tenure system, innovative technology and comprehensive extension systems. The Chinese government began consciously moving the economy from a sluggish, centrally planned economy to a more market-oriented one. China has taken four major steps to achieve food security as listed below.

1. Institution of stringent economic policy reforms
2. Increased investment in agriculture
3. Emphasis on science and technology in agriculture
4. Enhancement of agricultural extension and education to farmers

During this period agricultural production rose sharply, rural industries absorbed a large part of farm labour, poverty fell dramatically, and the level and quality of food consumption improved significantly.

Hence, the current growth in Chinese agriculture has been realised largely from an integrated package which includes the following.

1. An enabling environment
2. Public investment in agriculture
3. Agricultural technological advancement
4. Expansion of agricultural extension services

The twelve key technologies that are considered useful in the improvement of productivity in China are as follows.

1. Improved varieties and hybrids, for example rice.
2. Use of fertilisers.
3. Use of irrigation technology.
4. Insect control, use of insecticides, Integrated Pest Management (IPM), insect resistant varieties (for example *Bt* cotton) and use of biotechnology for insect control.
5. Planting technologies and systems, for example rice system from one planting season to two seasons.
6. Land improvement and reclamation, for example desalinisation and improved fertiliser use.
7. Agricultural mechanisation especially appropriate size machinery.
8. Fruit and vegetable production thrust and production technologies, for example greenhouse technology and tissue culture.
9. Animal management technologies, for example grazing systems.
10. Animal feed and nutrition technology, for example forages technology and plant straw improvement.
11. Animal health technology, for example disease control and vaccines.
12. Aquaculture technologies, for example fish breeding and nutrition technologies.

Besides the technological advancement, the Chinese government provided basic services to the farmers that assisted in increasing productivity. These included the following.

1. Financial support to the farmers, credit, tax exemption and subsidies.
2. Establishment of value addition factories at village and township levels owned by collaborative communities.
3. Improvement of the marketing systems to facilitate market access to the farmers.
4. Utilisation of partially controlled market forces determined the pricing system for agricultural produce.

## Chinese agricultural technologies

China’s agricultural research and development system has become more than capable of generating new conventional technologies such as those created by biotechnology.

Meanwhile, Chinese commodity markets have become remarkably integrated across regions, between the coast and inland, and between county markets and villages, even in remote areas. Finally, although the emergence of inland markets is fairly recent, they are developing quickly, efficiently and equitably. FAO considers that productivity in China's agricultural sector could increase substantially if existing conventional technologies were implemented more widely.

The lessons from Chinese agriculture are derived from the integrated approach; from policy reforms through to intensive research backed by an effective extension service and an information dissemination system that endeavours to 'leave no farmer behind'. It is worth noting that agricultural technology research and dissemination is result-oriented and interlinked with scientific research, technology demonstration and extension, and commercialisation of technology.

## Technologies that address constraints of lack of high quality seed and plant breeding resources

### Germplasm improvement and storage technologies

The Chinese government has consistently supported the development of the seed industry as evidenced by its annual budget of 700 million RMB (US$ 102.5 million) for the development of scientific research, production, processing and storage of seed, and establishment of a comprehensive system of registration and introduction of new plant varieties. The public and private sector are motivated to breed new varieties through regulation, monitoring and provision of incentives. This deliberate creation of the necessary environment has fostered the development of top range breeding technologies and varieties that have revolutionised crop production. One of the notable results is the development of high yielding rice by Professor Yuan Longpin. The technologies utilised have helped to shorten the duration for the approval of research findings thus speeding up access of new varieties by farmers. The proprietary rights to varieties developed by public institutions, government departments and universities remain with the government of China.

### Breeding for new improved varieties: High yield and disease tolerance

Breeding activities and technologies in China have produced more than 6,000 varieties in plants and animals to date. Over 95% of the seed used in China are improved varieties. The focus of crop breeding has been on factors like drought resistance, adaptability, high yield, high plant population compatibility, fertiliser use efficiency, quality, nutritional advantages, versatility, and pest and disease tolerance. For example there are over 220 hybrid rice varieties cultivated in China. Some breeding successes that come to mind are hybrid super rice that has made it possible to achieve yields as high as 12tonnes/ha, and high protein soyabean. Hybrid rice bred in China yields 20–30% more than ordinary rice because of better genetics including a well developed root system, high photosynthesis utilisation coefficient, big panicles/spikelets and more grain, wide adaptation (resistance to drought, floods, alkali, acidity and various topographies), and more nutrient content (for example high protein 1–2% higher than normal rice, and 0.5% more fat than normal rice). Some other specific examples of the results of top notch breeding technologies are high yielding Zhengmai 9023 wheat variety and Zhengdan 958 maize variety.

Advantages are also derived from the fact that various public institutions such as CAAS are actively involved in breeding improved varieties. CAAS, for example, is credited with developing a batch of agronomically important genes and the release of 150 varieties as well as patenting 40 agricultural technologies. CAAS has also come up with more than 50 hybrids of ordinary cabbage, Chinese cabbage, broccoli and cauliflower, while BAAFS institute issued more than 70 cultivars of fruit and nuts (peach, apricot, grape, chestnut, hawthorn, walnut and jujube) since 1958 (see Table 6). There exists a comprehensive germplasm bank, which is well controlled and documented and holds about 390,000 lines. This germplasm resource is available to researchers in both public and private institutions for use in crop improvement.

### Biotechnology and recombinant gene technology

The technology of genetic modification is also referred to as recombinant gene technology, gene technology, genetic engineering or genetic manipulation. This technology provides new tools for speeding up the development of crop varieties and transferring of desirable genetic traits into a crop often from an unrelated species. This technology has brought improvement and great potential in the improvement of crop quality, yield, and pest and disease resistance and tolerance, thus creating room for reduced use of chemicals which helps in environmental protection, healthier food and reduced costs of production.

The GMO plants developed and used in China include pest resistant cotton (China's largest GMO crop), tobacco, papaya, peanut, sweet pepper, *Bt* cotton, round-up ready cotton, round-up ready soyabean, corn borer resistant corn and a vaccine carrying tomato. The development of transgenic wheat with tolerance to barley yellow dwarf virus by Chinese researchers is another example of application of GMO technology to overcome productivity constraints.

The GMO rice has not been released onto the market, but studies done by Chinese researchers showed that GM rice has low production costs could benefit poor farmers and improve the health of consumers. Generally, the use of biotechnology in China has over the years been growing consistently. In 2002, China planted 700,000 hectares of transgenic cotton, a figure that has now increased to 3.7 million hectares. This makes China the fifth largest grower of transgenic cotton after the USA, Argentina, Canada and Brazil.

Table 6: Examples of improved crop varieties developed and used in China

| Crop | Special characteristics | Institution where it was developed |
|---|---|---|
| Rice | Super rice hybrid varieties yielding 13.5tons/ha | China National Research Institute – CAAS |
| | Resistance to bacterial blight | Institute of Crop Science – CAAS |
| Maize | Multiple resistance and high yielding hybrid cultivar – Zhongdan 2<br>Hybrid 'yuyu 11' – vertical leaf, large ear, high yield, high quality, wide adaptability and resistance to multiple diseases<br>A single cross maize hybrid 'Zhengdan 958' – high and stable yield, wide adaptability and tight type plant | Institute of Crop Science – CAAS<br>Henan Provincial Academy of Sciences<br>Henan Provincial Academy of Sciences |
| Wheat | High quality variety 'Zhengman 9023' – strong gluten, early maturation, resistance to multi-diseases, high yields and wide adaptability | Henan Provincial Academy of Sciences |
| Soyabean | New variety 'yudou 18' – high yield, good quality and multiple disease resistance | Henan Provincial Academy of Sciences |
| Cotton | Short season variety 'yumiam 12' – fine fibre quality, stable yield, drought tolerant and early maturity<br>Bt cotton | Henan Provincial Academy of Sciences |
| Solanacea hybrids (tomatoes, brinjals, capsicums) | High quality, disease resistance and high yield | Institute of Vegetables and Flowers – CAAS |
| Canola: Hybrid Zhongyouza No. 2 | High and stable yields, wide adaptability | Oil Crops Research Institute – CAAS |
| Pears | Dwarfed pear root stock – Zhongai No. 1; makes the dwarfed cultivar dwarf and precocious and increases grafting compatibility<br>New cultivar (Huasu) – precocious, big, better appearance, high quality, high disease resistance and wide adaptability | The Research Institute of Pomology – CAAS |
| Apple | New cultivar – Huahong – big size, oblong, red blush, long term storage, good resistance to diseases and chilling injury.<br>New cultivar – Huafu – big size, red blush, high quality, edium cropping efficiency, high disease resistance, long term storage<br>Early maturing – Huamei – long term storage – Huaguan | The Research Institute of Pomology – CAAS<br>Zhengzhou Fruit Research Institute<br>Zhengzhou Fruit Research Institute |
| Water melon | New triploid hybrid seedless variety – Zhengkang No. 3 | Zhengzhou Fruit Research Institute |

Source: Author's Research, 2009

More than 1,000 transgenic lines of maize with higher drought, cold and virus resistance have also been developed through genetic engineering. However, despite the considerable research being done on GMOs in China, the only release is the celebrated *Bt* cotton. In China, transgenic plants resistant to insects, diseases, herbicides and stress tolerant or plants with improved quality have been approved for field release, and some are ready for commercialisation. Examples of transgenic crops are listed in Table 7.

Table 7: Examples of transgenic crops in production in China

| Crop | Variety | Traits | Examples of techniques used |
|---|---|---|---|
| Cotton | CCR146 | Insect resistant (cotton bollworm; *Helicoverpa armigera*), high quality | Used modified insecticidal crystal gene (Cry1A) from *Bacillus thuringiensis* and Trypsin inhibitor gene (CpTI) from cowpea, constructed highly efficient express plasmid and transfer genes through pollen tube pathway (technique patented in 1988) |
| | CCR148 | Big boll, high quality | |
| | CCR153 | High yield, insect resistant | |
| | 99267 | Disease resistance to Verticillium wilt | |
| Banana | T67 | Resistant to panama disease | |
| Rice | Minhui 63, Kangyou97, | With WAN21 gene, has resistance to *Xanthomonas oryzae* p.v *oryzae* (rice bacterial blight), high yield (up to 12t/ha) | |
| | | Insect resistance to various stem borers (*Chilo suppressalis*, *Tryporyza incertulas*, *Cnaphalocrocis medinalis*) | -Modification of insecticidal protein gene CpTI<br>- *Bt* |
| | | Golden rice: Improved nutrition – more vitamin A | |
| Tomato | | Lycopene molecular breeding of tomato, using genes borrowed from *L. hirsum*. | |

Source: Author's Research, 2009

Chinese scientists have also made strides in the research and application of gene marker (molecular marker), variety identification, virus definition, virus identification, gene transformation and in-vitro propagation technologies. Additionally, there is extensive utilisation of molecular marker technologies for genetic fingerprinting for the facilitation of desirable trait incorporation. For example more than 1,000 gene sequences have also been obtained from Almond (*Amygdalus communis*), using gene sequencing technology. It is expected that in less than five years, the genotypes of many crops will be known, with all genes identified, variants of important genes determined and gene-trait associations established. This will pave the way for genome-based breeding. The use of these technologies in the breeding programmes will shorten the cycle for crop improvement as they allow a shift from the long term random chance selection of conventional breeding to specific trait manipulation, which reduces the number of breeding generations.

The use of micro-propagation (tissue culture) in potato breeding helps to propagate true-to-type crops with desirable traits including resistance to pests, viral, bacterial and fungal diseases. This tissue culture technology is also used extensively in chrysanthemum and orchid propagation.

### Seed quality technology

China has made great strides in developing technologies and mechanisms that ensure the quality of planting material. Seed testing utilises scientific methods to analyse and appraise seed quality reducing the possibility of using low quality seed. Low quality seed works against efforts to achieve desired plant populations, raises complications of mixed seeds arising from non adherence to true-to-type and purity requirements. Seed quality technology and regulations are also useful in controlling the spread of insect pests, weeds and diseases, in addition to ensuring the quality and viability of seed through field testing, lab testing and trials. Purity analysis is used in China for the verification of species and cultivars.

The other essential components of seed quality technologies are seed processing and handling made possible by advanced seed processing plants. Seed processing technologies provide for the removal of trash, weeds and other contaminants by use of efficient equipment such as the Scalper, Air Screen Machine, Gravity Separators and Seed Coating Equipment. These technologies are complemented by strict monitoring governed by laws and regulations that enforce quarantine and testing before seed enters the country from external sources. Biosafety testing techniques currently applied for evaluating transgenic crops are very crucial.

## Technologies that could address constraints of drought and poor water management

### Irrigation development

The lessons from progress made by China in increasing productivity for smallholder farmers show the importance of the complementarities in farming technologies. One can have the best varieties and the best fertilisers, but when this is not complemented by enough moisture, the chances of getting maximum benefit is seriously curtailed. China has embarked on a massive irrigation infrastructure development program, systematically increasing the area under irrigation as shown in Figure 6. In the 1950s to early 1970s, irrigated area increased from 16 million hectares to 35 million hectares and further increased to 48.7 million hectares in the 1980s. By 2002 it stood at 56.6 million hectares.

To compliment the irrigation system, China has developed 85,000 reservoirs with a capacity of 520 million m$^3$ of water. The irrigation and drainage machine power has

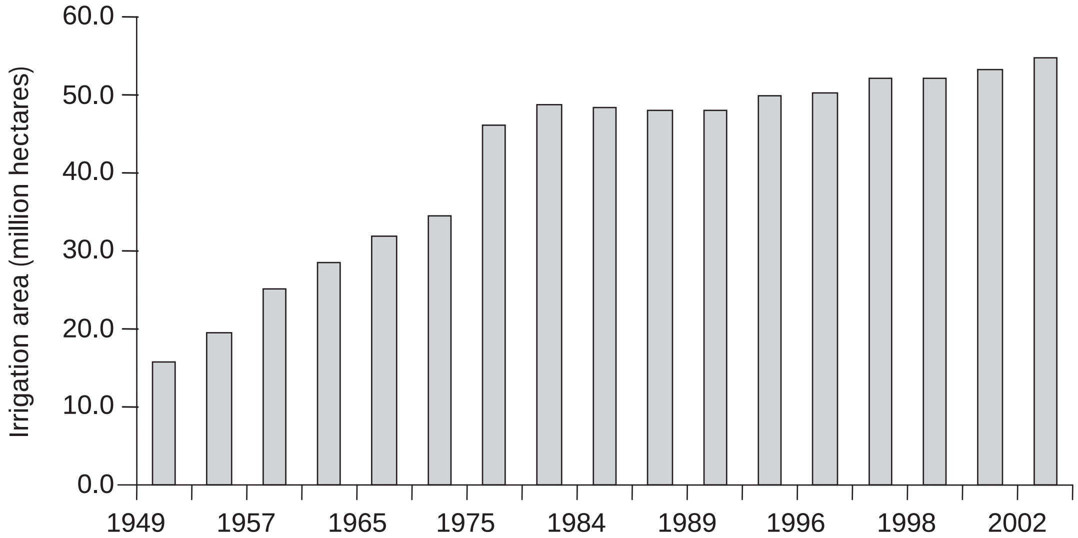


Figure 6: *Area under irrigation in China from 1949 to 2002 (Source: Author's Research, 2009)*

reached 68.24 million kilowatt. There are 500,000 fixed irrigation and drainage stations, 3.17 million wells with pumps and 5,562 irrigated areas covering over 700ha each.

While the past progress is noted, the current situation shows that much of the available water resources have been harnessed for use. Consequently, the increase in irrigated land over the last 30 years has been modest. The thrust for development irrigation technology in China is towards more efficient utilisation of water. The technologies for more efficient irrigation include drip irrigation, smallscale water storage techniques, breeding of drought resistant varieties, new cultivation techniques such as direct seeding rather than deep ploughing, and moisture conserving techniques such as mulching and plastic water retention methods, composting and recycling of plant residues, crop rotation, and more attention to fertiliser applications. The relative distribution of forms of irrigation in China is illustrated in Figure 7.

### Water use management technologies

These technologies are directed at soil improvement, efficiency in rainfall use, water conservation and preservation of soil moisture for crop use. They include farmland construction, terracing, furrow tillage, organic fertilisers, cultural practices, use of chemicals and mulching. Water harvesting is aimed at achieving efficiency in use of rainwater by harvesting and harnessing water that would otherwise be lost as runoff. China has a programme of construction of small-scale water harvesting infrastructure such as the water cellars, water retention wells, small reservoirs and ponds. These structures store water that can be mobilised by use of simple treadle pumps or mechanised pumps. The water cellar system consists of the water gathering surface, water conducting channels, sand deposit cistern, a silt blocking fence behind, water input pipe, water cellar chamber, cellar opening apron and well apron. In the northwest

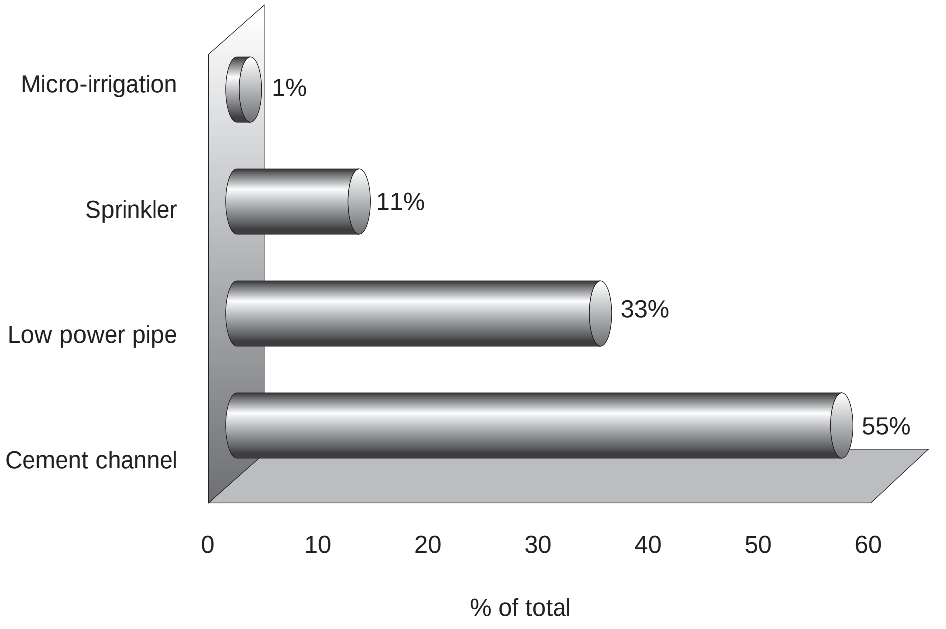


Figure 7: *Types of irrigation in China* (*Source: Author's Research, 2009)*

of China where annual rainfall is a meagre 350mm, a water cellar with a 50m$^3$ capacity has been utilised to produce a good maize crop on about 0.13ha of land.

In some cases, there is the use of bio and chemical agents for facilitating organic matter decomposition whereby chemical decomposition agents, cellulose decomposing bacteria or fermentation bacteria are applied to plant residue composts to facilitate decomposition and produce a high quality organic fertiliser. Livestock rearing is also designed to accumulate manure conveniently. Chicken manure is enhanced through use of yeast, elimination of odour, drying and the addition of supplementary materials. China has also embraced and developed use of commercial organic fertilisers.

Mulching enhances soil moisture retention by regulating evaporation, preventing soil moisture loss and evaporation producing radiation. It regulates soil temperature as it creates a relatively stable ecological environment and improves the soil's physical properties. Chinese farmers use plastic mulch, crop residue mulch and gravel mulching.

Plastic film mulch is used in China as inter-row mulch, row bed mulch, ridge mulch and crop furrow mulch. It is also used in combination with micro-ditches or micro-furrowing. The plastic film mulching is also used in a side combination technique where seeds are sown on both sides of the plastic film mulch or can be combined with dibbling. Another use is the alternating row plastic film/crop straw technique or the layered arrangement where the straw mulch forms the sub-surface while the plastic film is applied on the surface. The uptake of the plastic film mulch technique is made possible by a comprehensive extension system, combined with affordable plastic and also importantly the labour saving animal drawn and tractor drawn downscaled equipment for laying out the plastic or laying out the plastic combined with planting (Figure 8).

Source: Author's Research, 2009

Figure 8: *Multiple function equipment for planting and applying plastic film mulch*

## Dryland farming practices

In the low rainfall areas of China, there is emphasis on the utilisation of high yielding drought tolerant crop varieties. China has bred drought tolerant varieties of maize, sweet potato, soyabean, wheat, millet, sorghum, sunflower and peanuts. Utilisation of drought tolerant crop varieties is sometimes augmented by use of microbe-enhanced drought tolerance. This is the technology that involves use of bacteria that enhances tolerance to water stress by elongating the roots of seedlings.

Intercropping is also used as a fallback cultural practice in China with the aim of using limited rain water and land more efficiently. It helps to adapt the farming system to rainfall variability water and help save both crop output and income. A high yielding crop is intercropped with a drought tolerant crop, or grain crop with cash crop, or grain crop with green manure. Intercropping systems used may include wheat and pea, maize and potato, maize and peanut, potato and pea, wheat and shallots or young orchards with various crops.

Supplementary irrigation is widely practiced in China, and it aims at using harvested water more efficiently (Figure 9). The techniques used cover water planting, irrigation under plastic film mulch, injection irrigation targeting the rhizosphere, drip irrigation and dibbling irrigation. The aim of these forms of irrigation is to direct moisture where it is needed (in the root zone), without wastage. Some of these practices are discussed below.

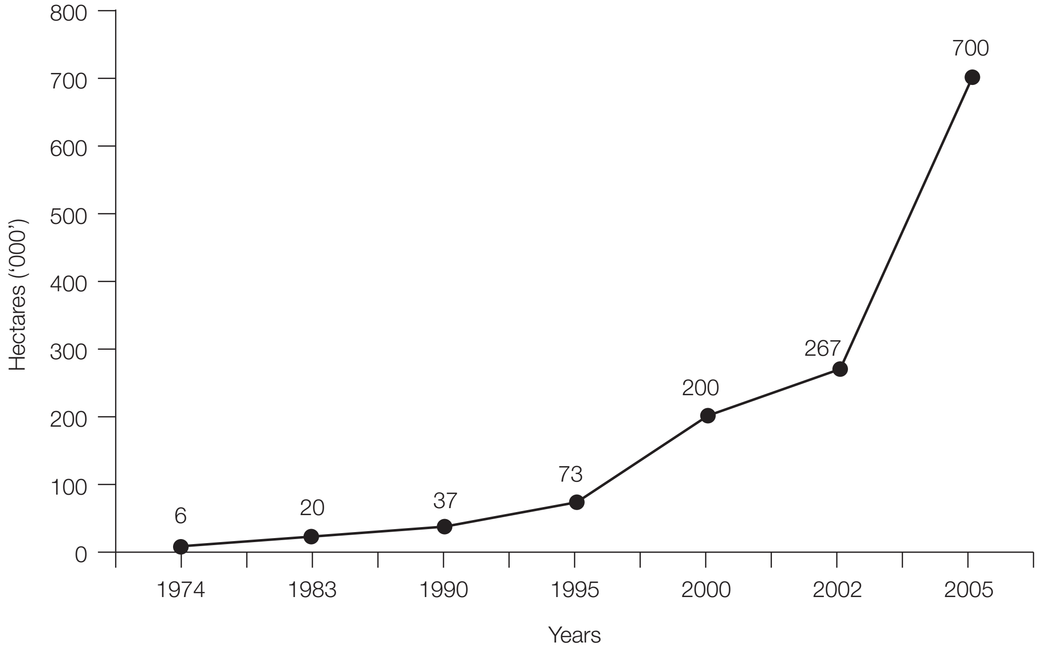


Figure 9: *Micro-irrigation development in China (1974 to 2005) (Source: Author's Research, 2009)*

In comparison with sprinkler irrigation, drip irrigation saves 15–25% of water which makes a huge difference in rain water deficient environments. Drip irrigation also uses only 20–25% of the water required for surface irrigation. The levels are even higher when drip irrigation is combined with and put under plastic mulching. Drip irrigation is essentially a small piping system in the field with an orifice per planting station and dispenses water in drops targeting the plant root zone, as shown in Figure 10. When the same piping system is placed on the sub-surface, the system is referred to as percolation irrigation. Drip irrigation is also amenable to fertigation thus achieving twin objectives of water use and fertiliser application. The efficient utilisation of water using the drip irrigation technology makes it ideal when the water utilised is from smallscale water harvesting such as the cellar system or pool and pond water reservoirs with a capacity of 1,000m$^3$ to 15,000m$^3$. Drip irrigation technology can save up to 40% of water and increase yield by 20–50%.

Notable technological advances in micro-irrigation include the development of the automatic counter flushing Gravel Filter AFS-X series that has improved water filtration, and the portable sub-surface drip irrigation. This system is reliable and cost effective, requiring a relatively low capital outlay of 2,250 RMB Yuan (US$ 330) per hectare.


Figure 10: *Drip under plastic mulch irrigation*

Surface irrigation refers to irrigation systems that include flood irrigation, furrow irrigation, basin irrigation, border strip irrigation and surge flow surface irrigation. Surge flow surface irrigation can be used to increase efficiency of furrow irrigation. It involves intermittent application of water to furrows, rills or borders in a series of on and off periods in a cyclic application through a gated pipe system. This system is very cost effective and ensures uniformity of application and water use efficiency.

Spraying irrigation is used in field crops such as maize, soyabean, wheat, vegetables, fruits and tobacco. It includes sprinkler irrigation, centre pivot and side roll irrigation. In comparison to surface irrigation it saves 30–50% of the water used. The system consists of water reservoirs, pumps (electric, diesel or gasoline) with the water delivery piping and dispensers such as sprinklers.

### Water delivery systems

Farmers in China also use a knapsack based water injection method and manual dibbling that deploys water in the crop plant rhizosphere. The soft pipeline irrigation is also utilised by farmers in low cost irrigation systems.

China has developed low cost appropriate technologies such as water pumps and equipment which are operated by hand or powered by electricity, diesel or gasoline to irrigate the fields (Figure 11). There are other fascinating inventions like the water planting and sowing machines.

Source: Author's Research, 2009

Figure 11: *Manual pumping of water from a cellar*

## Chemical use

There are two chemical products which can be used to conserve soil moisture. These are soil absorbent polymers (SAPs) and fulvic acid. SAPs are organic polymers with hydrophilic groups in their structure and can absorb water that is several thousand times their weight. Eighty-five percent (85%) of the absorbed water can be used by plants. SAPs are used to coat seeds and the roots of seedlings/transplants. SAPs can be applied directly to the soil or used to transport seedlings over long distances. They help seedlings to survive after transplanting and help to delay transplanting even after seedlings have been removed from the seedbed. They decrease evaporation, avail water to the crop, improve water use efficiency and ultimately increase yields. Fulvic acid is a transpiration resistance conditioner and is used to regulate transpiration. It helps to reduce soil moisture loss and to increase water use efficiency.

## Conservation agriculture

Farmers in China practice conservation agriculture as a way to conserve and use moisture efficiently. It also protects soil from wind and water erosion while increasing soil fertility. Conservation agriculture is an integrated approach to soil, water and agricultural resource management which seeks to achieve economically, ecologically and socially sustainable agricultural production. Conservation agriculture has three principles as below.

1. Maintenance of a permanent vegetative soil cover or mulch to protect the soil surface.
2. Minimal disturbance of the soil by planting through the mulch covers without seedbed preparation.
3. Diversified crop rotations for annual crops or plant associations for perennial crops.

In conservation agricultural techniques, inputs include cover crops, use of knife rollers or herbicides to crush or kill weeds and no-till planters.

## Technologies that could address constraints of low labour productivity or mechanisation

### Farm machinery technologies

China has focused its efforts to shift from human labour and animal draught power to mechanised farming. By the end of 2003, the mechanically ploughed area had reached 60.943 million hectares (46.8%), the mechanically sowed area had reached 40.714 million hectares (26.7%), and the mechanically harvested area reached 27.36 million hectares (19%). Evidence of increased mechanisation is abundant. In 1994, there were only around 60,000 combine harvesters in use but by 2003, they had increased to 360,000. Mechanised wheat harvesting also increased from 47% in 1995 to 82% in 2004.

There are other innovations like the small tractor and the versatile '3 in 1' piece of equipment. The '3 in 1' (power tiller) is a small diesel powered machine that can be used to draw equipment such as ploughs, harrows and trailers, and can be used to pump water. There are several small farm equipment that can be used in Africa as listed in Text Box 1.

Text Box 1: Forms of advanced machinery used in China

- Combined machine for laying out plastic film and sowing
- Combined machine for irrigation, fertiliser application, sowing and laying out plastic mulch film
- Mobile water saving irrigation equipment
- Mobile water saving irrigation which combines effective irrigation with fertiliser application, sowing and plant protection agents application
- Dibbling machines for planting wheat (human powered and tractor drawn)
- Zero tillage seed drill
- Zero tillage and fertiliser application drill
- Deep tillage plough
- Zero tillage and covering drill
- Mounted spraying machine
- Tractor mounted irrigation machine
- Water application and sowing machine
- Self propelled linear and centre pivot overhead irrigation systems

*Source: Author's Research, 2009*

### Other improved agronomic technologies

These include the use of dry nursery, seedling throwing and thinning. Dry nursery technology is used on 40% of the rice produced in China and increases yield by 8–15%. Seedling throwing saves labour while increasing its efficiency by 5–8 times. It reduces the cost of production when complemented with the scientific application of fertiliser and the use of chemical growth regulators. Other available technologies include the use of plastic film mulching in wheat, use of crop rotation and greenhouses to grow vegetables, improved sugarcane and tea cultivation methods, and the development and use of hybrid rape seed. Another fascinating technology is the multi-cropping system for rice; increasing from one crop per year to two, then to three crops every two years. Other advances have been made in the use of cultural practices such as pruning and production of dwarf fruit rootstock, improved seedling propagation techniques and use of plant growth regulators.

## Technologies that could address constraints of low soil fertility and lack of fertilisers

### Soil fertilisation technologies

One of the major drivers of agricultural production in China is the increased use of inorganic fertiliser, from 0.6kg in 1952 to 213kg in 1993.

The setting up of comprehensive soil testing, attention to micro-nutrients and tailor making fertilisers to release nutrients in quantities that meet specific crop requirements is an important step in the management of soil fertility in China. The fertiliser technology development has focused on application technique, use of equipment, timing and placement. The increase in fertiliser usage has been a factor in increased crop production in China, but it must be complemented by improved seeds, better irrigation and soil management techniques, and correct application rates, timing and placement.

The introduction of control release fertiliser (CRF) and fertigation technology has ensured efficient use of fertilisers. CRF controls the rate of nutrient release to meet crop nutrient demand, leading to increased yields and reduced environmental pollution. Currently in China, even smallscale farmers are using this technology with very encouraging results. Fertiliser use is supported by research to improve the efficiency nutrient uptake and use, with emphasis on plant morphology, plant physiology and genetics.

### Organic fertiliser and organic matter incorporation

Chinese agriculture has benefited from the use of organic fertiliser, compost techniques, and use of crop residue and mechanised incorporation of crop residues in the soil. There has been tremendous progress in the use of nitrogen fixing technologies such as nitrogen-fixing bacteria for soyabean, rice and corn. Investigation is being carried out on inoculation of legumes and non-legumes such as rice, wheat, sorghum and maize with endophytic bacteria such as *Azospirillus*, *Acetobacter* and *Enterobacter spp*, which can fix nitrogen. Another important technology is the use of bacteria that enhance phosphorus uptake and availability.

## Technologies that could address constraints of biotic stresses

### Pest and disease control and forecasting technologies

China has had to grapple with about 150 diseases and pests of which 30 have been serious (locusts and wheat rust are singled out as being most important). Pest control and prevention technologies in China are multi-faceted. The starting point is the use of conventional breeding and genetic engineering (for example transgenic insect resistant cotton), to select for tolerance and resistance to crop insect pests and diseases.

Researchers have also made progress on sustainable management of the major plant diseases, insect pests and weeds. Most important has been the development of pesticide application methods and equipment that are accurate and place chemical pesticides where they are required effectively and efficiently. In addition, complementary methods such as application pesticides through seed coating technology that provides for effective pest and disease control have been perfected. Researchers have also come up with models and technologies for pest and disease forecasting and monitoring, for example the forecasting system for the oriental armyworm and epidemiology of wheat stripe rust. The government and farmers are supplied with information from the monitoring of plant pests and diseases so that they are prepared for outbreaks.

### Use of integrated pest management technologies

Integrated pest management (IPM) is widely used in China and it involves the use of pest control strategies such as cultural methods, disease and pest-resistant crop varieties, reduced use of pesticides and use of natural enemies for pest and disease control. Researchers, extension agents and farmers who advocate and practice IPM follow a four point approach as follows.

1. Setting an acceptable threshold for a particular pest that establishes when it becomes an economic threat.
2. Monitoring and identifying insects, weeds and other organisms that may require control.
3. Using prevention as the first line of defence, for example cultivation, crop rotation or the use of pest-free rootstocks and resistant varieties.
4. A proper evaluation of alternative control measures for controlling the problem at minimal economic and environmental costs once control is necessary.

### Biological control technologies

Biocontrol technology involves the release of an insect pest's specific natural enemy to control its population in a crop. For instance, the use of ladybirds, such as *Trichogramma* and *Encarsia Formosa*, for biocontrol has become relevant with pesticide use reduction strategies in organic farming and integrated pest management. Biopesticides that make use of the toxins that some organisms (such as fungi) produce are used as substitutes for chemical insecticides. One other example involves the use of bacteria to control locusts. The Chinese government has given financial support for intensive research in biopesticides and to date over 41 biopesticides have been successfully developed and registered.

## Technologies that could address constraints of agro-meteorology and climate change

### Agro-meteorology, early warning systems technology and climate change

China has advanced satellite based weather forecasting and early warning system which is very accurate. It provides vital information to the farmers to help establish farming programmes, adjust the programmes or implement appropriate agronomic practices.

Related to agro-climatic issues are advances in technologies and equipment used for disaster avoidance, reduction and mitigation as well as coping with and ameliorating the effects of climate change. Advances have also been made in the development of seeding material and efficiency among other weather manipulation competencies. Such competency was used during the Beijing Olympics in 2008, where weather manipulation technology was used to prevent rain during the official opening ceremony. Other examples of early warning systems that may be applicable to Africa is the development of a Grassland Fire Danger Index (GFDI) like the one used in Northern China to warn of and prepare for wild fires.

The GFDI was developed using remote sensing images and weather station data. Seven basic indicators which include relative humidity, temperature, wind velocity, precipitation, degree of grassland curing, fuel weight and grassland continuity were selected to calculate the GFDI. GFDI is classified into low, moderate, high, very high and extreme levels.

## Technologies that could address constraints of lack of affordable energy to support agriculture

Alternative energy sources have been deliberately developed in China to improve the quality of the rural smallholder farmers as well as lessen pressure of energy demands on the natural environment. Some of the energy sources are discussed in this section.

### Biogas

Biogas is used by approximately 22 million households in China and by 2006 more than 5,200 large and mid-sized biogas projects were based around livestock and poultry farms. Biogas is vital as it forms part of an integrated farming system where farm waste is used for energy production while the waste after biogas production is used as manure.

### Solar energy

Solar energy is another alternative energy form used in China by approximately 30 million smallholder farmer households. There are over 28.5 million square metres of solar energy water heaters in China. While solar power generation is still being investigated by experts globally, the Chinese low cost approach may offer more opportunities to African farmers. Critical advancement in this technology in China is the development of affordable high efficiency photovoltaic cells and high volume durable energy storage technologies.

## Technologies that could address constraints of post-harvest losses of agricultural produce

### Post-harvest handling, food processing technology and local value addition

The Chinese government has pursued a vertically integrated local agricultural system promoting local value addition of agricultural produce to improve farmers' income. The development of village enterprises has stimulated agricultural production, transformed traditional farming methods and promoted the development of the rural and national economy. Currently, farmers earn 20% more with local agro-processing and activities of the agricultural cooperative societies. Township enterprises have become a major force in the rural economy and an important part of the Chinese national economy. By 2001, there were 21.15 million township enterprises, having increased significantly since 1978 when China embarked on national reforms.

Research and development of agro-processing technologies have been extended and exploited throughout the township enterprises. China has also made technological advances in fruit and vegetable storage, processing and preservation. The fact that some public institutions such as CAAS have an institute of Agro-Food Science and Technology dedicated to research on these issues shows the seriousness with which China takes agro-processing and value addition.

## Lessons to address constraints of inefficient agricultural systems

### Extension and information systems

Extension systems are commissioned using the approach where farmers are assisted to adopt new technologies through programmes with appropriate agro-technical components such as the bumper harvest plan, plant protection programmes, fertilisers and soil improvement technologies. Other approaches include the seed technology programmes using improved varieties, seed coating, and use of demonstration, participatory extension approaches, technology plus product packages and group training approaches. In addition other channels such as the mass media are used to disseminate extension messages; training of trainers, refresher training and farmer field school approach. Currently, there are 30 million young farmers undergoing training in agriculture and agricultural technologies.

The extension workers are complemented by an information system which is accessible to farmers. Radio and television programmes also disseminate extension messages to enhance good agricultural practices. Since the 1990s, there has been tremendous progress in the development of agricultural information systems in China. Agro-information networks have been developed. For instance, there is a national web-based agro-portal that hosts China's agricultural information and integrates it with over 20 other specialised networks.

## Lessons in addressing constraints of markets and infrastructure

### Markets and infrastructure

Low profitability and unstable prices are a major disincentive to agricultural production as is evident in SSA. In order to stabilise grain prices, the Chinese government has strengthened the regulation of grain production and circulation through market liberalisation, provision of stabilisation loans and establishment of grain reserves.

The total cereals output has been consistent for five consecutive years (2004 to 2008), meaning that China has had and will continue to have guaranteed harvests. Similarly, farmers' income has grown consistently by 5% in recent years. Farmers are encouraged to form cooperative societies to collectively address constraints in production, marketing and processing. There are other government policies that have been put in place to benefit farmers, for instance reduction of taxation on agro-products. Until the late 1990s, farmers paid various taxes and fees, but these have all been progressively discontinued at the start of 2006. Furthermore, Chinese farmers receive subsidies on improved seed, special fertiliser formulation and new technologies. These policies not only encourage adoption of new technologies but translate to increased yields.

## Other technologies available in China

### Computer based agriculture and precision agriculture

Chinese agriculture uses agricultural intelligent systems, remote sensing and global positioning systems. Precision agriculture, where the right amount of fertiliser, chemical or water is applied in the required quantities where and when it is required is also used. An example of this technology is the Variable Rate Fertiliser Applicator which derives its functioning from geological statistics spatial analysis and related software and hardware. Institutions such as the National Engineering Research Centre for Information Technology in Agriculture (NERCITA) focus their research and development on automated nutrition systems, nutrition precision management, effective water and fertiliser utilisation, and precision irrigation. This is in addition to the development of an agricultural expert system and portable digital information technology system such as the intelligent control system in greenhouses (greenhouse baby). Other important technology developments include production of greenhouse sensors, portable agricultural digital information and intelligent systems that incorporate site soil testing, and tailor made fertiliser applications, and agricultural information products such as interactive educational agricultural videos.

### Edible fungi research selection and efficient cultivation technology

There is research on edible fungi focusing on selection of new varieties, appropriate substrate, micro-environment and factors of production. BAAFS for example is working on ten new strains of edible fungi such as *Pleurotus nebrodensis*. Commercial production and post-harvest handling uses a variety of methods developed from the world class research facilities and expertise.

#### Greenhouse technology

Greenhouse technology (Figure 12) has made multi-cropping possible as greenhouses create an environment that allows for production during periods that would otherwise be off-season due to very low temperature. Advances in greenhouse technology include special heating systems, precision nutrition, automation and use of intelligent systems. The ‘Greenhouse Baby’ (Figure 13) is another technology that has been designed to monitor greenhouse micro-climate.

Source: Author's Research, 2009

Figure 12: *Typical smallholder farmer greenhouse in China*

Source: Author's Research, 2009

Figure 13: *Greenhouses for horticulture*

## Animal breeding technology

China has an advanced breeding system which has, over the years focused on productivity, quality and disease tolerance. Successes have been made in the breeding of the Z type Beijing duck and the yellow broiler which have excellent carcass quality and high feed conversion ratios. Genetic engineering is also being utilised to develop transgenic animals.

## Animal feed and nutrition technologies

China has made advances in animal feeding and nutrition through forage breeding and selection. One example is the development of a new clover blossom variety Zhonglan No 1 with good resistance to diseases, frost and drought, and is high yielding. The Institute of Animal Science is involved in research for animal feed and nutrition improvement, genetic resources and breeding, and disease control. Other areas of research include micro-ecological preparation of feed additives to enhance the feed conversion ratio of chicken and piglets, while cutting edge technology is being used to develop the expression technique of phytase as enabled by recombinant *P. pastoralis*. The Feed Research Institute of CAAS has developed a milk replacer for calves which meets their nutritional needs at relatively low cost.

## Animal health technologies

The animal health research in China has made strides in pest control and disease control such as the development of the simple on-farm testing strip for disease identification, for example the rapid test strip for detecting chicken infectious bursal viral disease. China has developed herbal medicine to manage endometritis in sheep. This drug is not prone to resistance and is not residual in the meat as would antibiotics. The technology has produced vaccines at lower cost and a highly effective broad spectrum anti-coccidial drug called Diclazuril. Chinese researchers have also achieved efficient production and use of existing vaccines; achieved success in the control of brucellosis, leptospirosis, bovine virus diarrhoea, and other respiratory and intestinal diseases in young, pre-weaned animals. This has significantly reduced mortality in livestock and improved their long term productivity.

The potential exists and is pursued to support a variety of approaches to vaccine development for animals from attenuated bacteria to DNA vaccines. Some vaccines such as the serial vaccines against foot and mouth disease would be very useful if adapted and adopted in Africa. In China, farmers enjoy the benefits of technology advances through the biotechnology produced recombinant vaccines for infectious laryngothracheitis and bovine ephemeral fever among others.

## Fish farming technologies

In aquaculture, technologies for breeding have been developed and they include artificial fertilisation, use of incubators, technique of polyploid cultivation and gynogenesis, technique of gynogenic diploid cultivation, breeding using hormones to improve productivity, and research on the transgenic breeding of fish. In fish medicine, techniques for diagnosing diseases such as the technique for isolating trout *Vibrio anquillarum* and the pathogens causing Streptococcicosis and diplostomiasis, prevention of and cure for some parasitic diseases such as gyrodactylosis, and common bacterial and viral diseases of fish.

# Chapter Five
# Identification of relevant technologies for Sub-Saharan Africa

The Chinese agricultural sector has a huge number of technologies that can be used to address the technology gaps in Africa. Agricultural technology is only useful if it can be applied to different ecosystems. While there are many agricultural technologies in China, many of them would not be easily transferable to Africa for various reasons. In order to select relevant technologies, screening of the available technologies is imperative in order to determine their relevance in specific and related environments. It will be necessary to establish their conformity and their adaptability to the socio-economic conditions of the smallholder African farmer, inter-relationship between technologies, the environment, economy, culture, politics, beliefs and attitudes.

## Criteria for identifying relevant technology

In order to identify the relevant technology, there is need to develop criteria that will be useful in evaluating the technologies to ensure that there is conformity in terms of technical feasibility, economic viability and compatibility with different agricultural systems. This criterion is suggested in Text Box 2.

Text Box 2: Criteria for evaluating technology

1. Is the technology technically feasible, relevant and applicable to addressing agricultural constraints in Sub-Saharan Africa?
   (a) Does it address a problem that is specific to these regions?
   (b) Would it have a direct effect on agricultural productivity in these regions?
2. What are the levels of farming systems compatibility and perceptions of potential beneficiaries?
3. What is the magnitude of the expected benefit?
   (a) Will many farmers and the rural poor benefit from the technology?
   (b) Will it address a widespread or severe problem?
   (c) How complete a solution would it provide?
   (d) Would it empower the farmer?
   (e) Is it likely to have a direct effect on farmer income?
4. How long would it take for the technology to become available?
5. Could the technology be easily disseminated and adapted? Is it scalable?
6. Does the technology address an issue that cannot be approached in any other way?
7. Is the technology a gateway to other innovations in agriculture?
8. Will it leverage the development of other technologies to help farmers in SSA?

*Source: The National Academies – Technologies to Benefit Farmers in SSA and South Asia*

## Identified relevant technologies

Based on the evaluation criteria outlined in Text Box 2, the study team identified a number of technologies that can be transferred to Africa to increase productivity. It is important to highlight that some of the technologies are already in use but the scale is limited and fragmented. Success in the transfer of these technologies will depend largely on government policy on agriculture, market reforms, availability of funds, capacity building of research institutions, a viable and effective extension system, incentives for enterprise creation in agriculture, advocacy for changes in land policies, agricultural financing specifically in the creation of village enterprises, increase in budget support to the agricultural sector to enable farmers access agricultural inputs, processing and packaging materials and equipment.

The conclusion, based on the findings using the evaluation criteria, suggests that there are a number of Chinese technologies that can increase agricultural productivity when transferred to Africa. The research team identified five major areas of intervention that could have the greatest impact in technology transfer. These are technologies that help to:

1. improve genetic characteristics of crops and animals (Figure 14)
2. reduce biotic constraints ( diseases, weeds and pests, Figure 15)
3. those that provide affordable, renewable energy to farmers (Figure 16)
4. manage natural resource base of agriculture (Figure 17)
5. those that provide mechanisation (Figure 18).

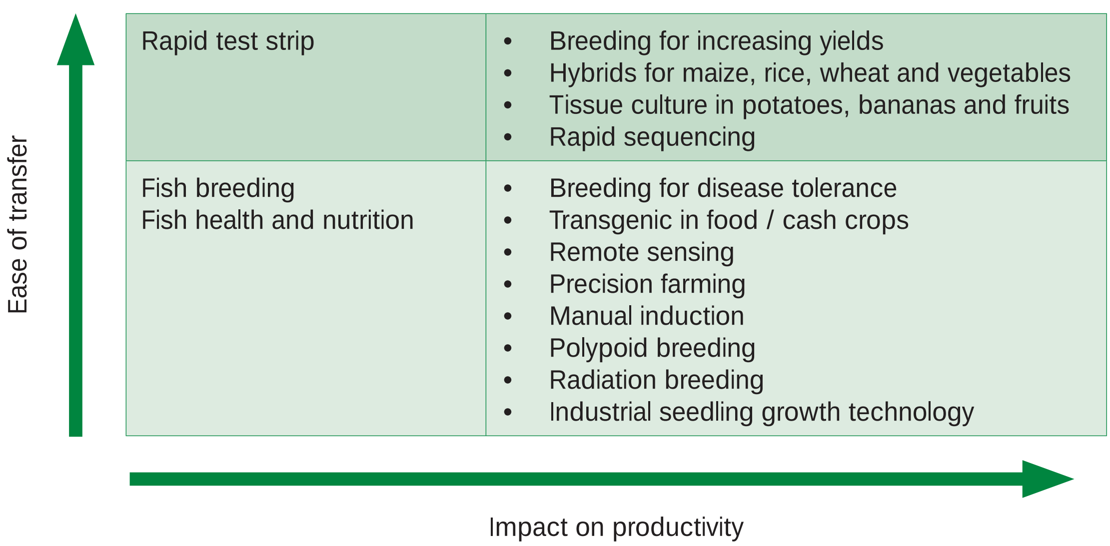


Figure 14: *Technologies that improve genetic characteristics of crops and livestock breeding, laboratory and post-harvest technologies (Source: Author's Research, 2009)*

Whilst most parts of SSA would benefit from the above technologies, west Africa will benefit immensely from technologies for breeding cereals since their seed industry is at its infancy. Uganda, Tanzania, Rwanda and Kenya will benefit from tissue culture banana as banana consumption is high. Ethiopia and Kenya will both benefit from livestock breeding technologies.

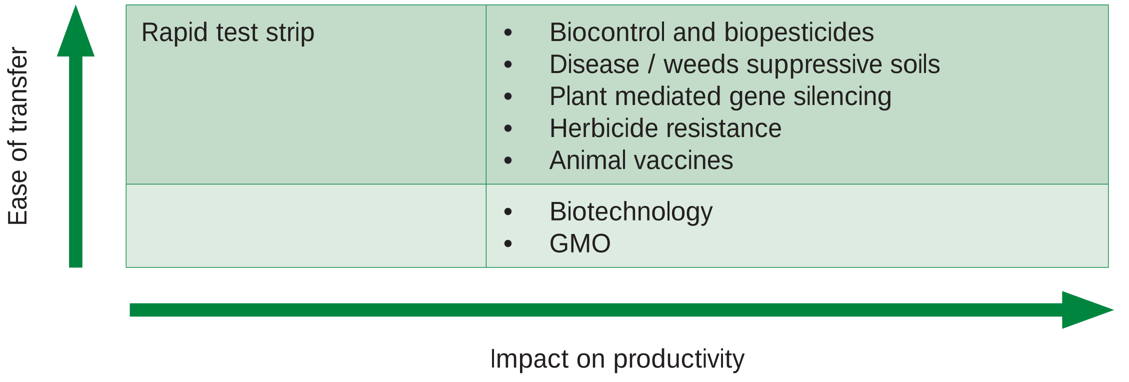


Figure 15: *Technologies that reduce biotic constraints (Source: Author's Research, 2009)*

Most of SSA is affected by pests, diseases and weeds. These technologies will have the greatest impact as the ability to control biotic constraints will ensure that the smallholder farmers can get some harvest. Biocontrol and biopesticides should be encouraged in conformity with biosafety measures, which most countries are implementing.

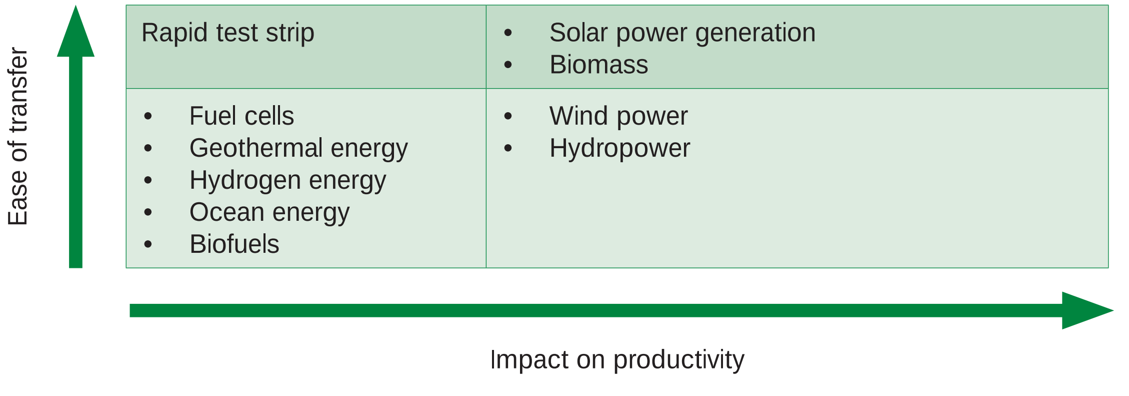


Figure 16: *Technologies that provide affordable, renewable energy to farmers. (Source: Author's Research, 2009)*

Water, soil and climate are crucial to increasing agricultural productivity. Across SSA, these components are very weak and need technologies that can quickly address them. The above Chinese technologies are easy to transfer, and can be easily adapted to conditions in Africa.

Ease of transfer ↑

| | |
|---|---|
| Use of pools, ponds | • Integrated water management techniques<br>• Water harvesting cellars<br>• Terracing and other forms of land construction<br>• Furrowing, water catchments or reservoirs<br>• Irrigation (drip, bubbler, flood, strip irrigation on the plastic film, U-shape cement channel)<br>• Soil management techniques<br>• Slow release fertilisers, organic fertilisers, mulching with organic matter, applying manure, zero tillage, contour farming, conservation tillage, terracing<br>• Integrated soil fertility management (ISFM)<br>• Climatic and weather prediction *<br>• Databases, equipment to predict weather<br>• Agro-meteorology<br>• Early warning systems technology<br>• Land data assimilation<br>• Moderate resolution imaging spectroradiometer |
| • Nutrition precision management<br>• Automated nutrition systems<br>• Water saving precision irrigation<br>• Preservation of soil moisture<br>• Nanotechnology-based applications for the soil<br>• Remote sensing of plant physiological status | • Fertigation<br>• Soil absorbent polymers (SAPs)<br>• Fulvic acid)<br>• Desalination |

Impact on productivity →

* *Needs government intervention*

Figure 17: *Technologies to manage natural resource base of agriculture (Source: Author's Research, 2009)*

Ease of transfer ↑

| | |
|---|---|
| | • Zero tillage drill<br>• Hand tiller<br>• Water pumps and generators<br>• Deep tillage<br>• Small tractors and trucks |
| • Combined machine for sowing<br>• Mounted spraying machines | • Mounted spraying machine<br>• Tractor mounted irrigation machine<br>• Fertigation machine<br>• Self propelled pivot irrigation system |

Impact on productivity →

Figure 18: *Mechanisation and transport (Source: Author's Research, 2009)*

# Chapter Six

# Strategies for access and transfer of Chinese agricultural technologies

While the focus of this study was the sustainable access and transfer of Chinese agricultural technologies to the smallholder African farmer, it is acknowledged that the right market conditions, policies and institutional arrangements must exist to support their adoption.

The transfer technology could be done through partnerships along the product value chain, collaboration in basic research and adaptive research and development, exchange of experience in skills transfer and adoption. There is need to continuously gather information on technological breakthroughs both locally and internationally in order to generate ideas that can be developed into projects to address constraints to productivity in SSA.

## Strategies for technology access and effective utilisation in Sub-Saharan Africa

Technology transfer should adopt a systematic approach. Based on the findings in China there is need for setting priorities, guiding principles, outcomes and activities that will enhance access and adoption of Chinese agricultural technologies. The following section highlights ways to enhance technology transfer.

It is envisioned that these strategies will lead to the transformation of the agricultural sector in Africa. It will also help Africa to stop over-reliance on donors and aid which has led to dependency and perpetuated poor leadership.

### Forum On China-Africa Cooperation

The Forum On China-Africa Cooperation (FOCAC) could be used as a platform for the dissemination of Chinese agricultural technologies to Africa. African heads of state could negotiate with China using this forum to ensure prioritisation of the transfer of agricultural technologies.

The African Union (AU) could advise heads of states on the opportunities presented by FOCAC and on its part, AU should spearhead a unified position on the agricultural strategy for Africa. AU organs like the New Economic Partnership for African Development (NEPAD) could develop viable agricultural projects across SSA and raise funds to access and avail Chinese agricultural technologies to smallholder farmers.

Regional bodies like EAC, SADC and ECOWAS could monitor agricultural technology transfer and ensure that they influence and advise the SSA governments on how best to tap into these initiatives for mutual benefit.

### China-Africa Development Fund

The second strategy is to leverage on the China-Africa Development Fund (CADFund), which is the first global fund specifically for African development and aims at accelerating the economic and trade cooperation between China and Africa. By promoting investment and providing capital for Chinese firms to invest in Africa, the fund reflects Beijing's foreign policy and strategy for the African continent. The fund focuses on the development of agriculture, manufacturing, infrastructure (especially power infrastructure), extractive industries and special economic zones.

With the fund looking to expand its resources and investment on the continent, there is an opportunity for African agriculture and agricultural technology transfer initiatives to tap CADFund for support. There is an opportunity to establish partnerships with Chinese state-owned enterprises and direct investment by private investor businesses. The CADFund can be used to further develop agriculture through:

- developing agro-dealers in rural areas across Africa
- establishing national agricultural input credit guarantee facilities
- setting up 'smart' subsidies for the poor and vulnerable
- organising regional fertiliser procurement and distribution centres
- removing trade barriers and promoting local manufacture
- setting up an African fertiliser development financing mechanism.

Another opportunity is to leverage on the goodwill, experience and expertise of the Alliance for a Green Revolution in Africa (AGRA), which already has significant involvement in technology transfer in areas such as soil fertility management, improved germplasm and seed delivery systems. AGRA has significant capacity on the ground to enable technology transfer and adoption in a much shorter time compared to what China alone could accomplish through FOCAC as evidenced by the slow implementation of the 2006 commitment. To this end, a strong collaboration would be established between AGRA and China to ensure that Chinese technologies are availed to AGRA for dissemination.

### Public-Private Partnerships

Another strategy to disseminate Chinese agricultural technologies is through the Public-Private Partnerships (PPPs) between government institutions, farmers, universities, the private sector and local development organisations. Activities under such partnerships would include training of extension personnel and capacity building for farmers.

Emphasis should be placed on building human capital and overcoming language and cultural barriers to facilitate the transfer of business knowledge and technology. Interaction between Chinese and African businessmen in the agricultural sector should be a first step. However, African businessmen need to develop the capacity to become leading entrepreneurs. Business schools and public administration institutes need to be supported to build the capacity of African entrepreneurs. Figure 19 is a schematic example of a contract growing arrangement.

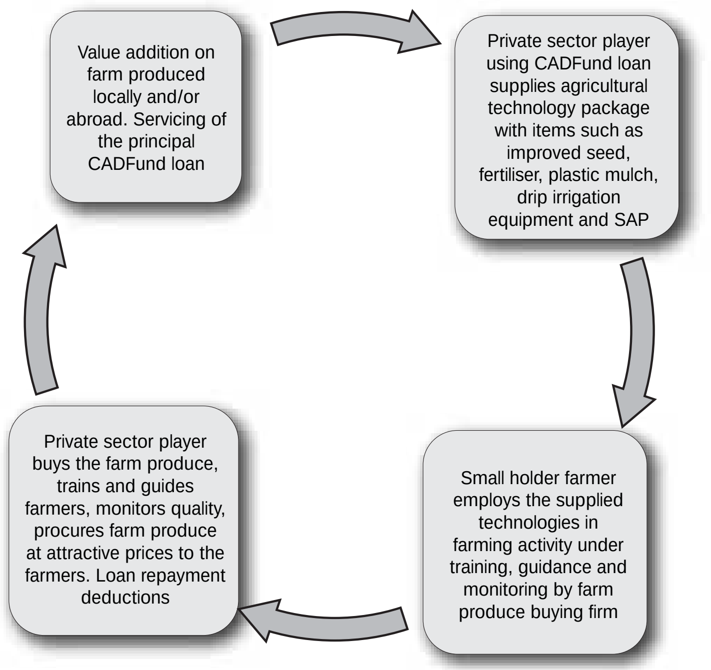


Figure 19: *Contract growing arrangement illustration (Source: Author's Research, 2009)*

## Collaborative research and extension

The key players and partners include NARS, extension systems, universities, and public, private or international research institutions. The starting point here could be adding value to enhance the impact of ongoing agricultural research and make necessary adjustments to the dissemination of Chinese agricultural technologies to smallholder farmers in SSA. This can be achieved through participatory identification or influencing the content, mode, outcome of research and extension programmes, and monitoring and evaluation. Specifically there could be integration of Chinese technologies and institutional innovations to add value to ongoing agricultural research and extension.

Technology testing and development will play a vital role in the adoption of Chinese agricultural technologies and evaluating their impact and identification of new constraints. Exchange programmes and collaborative research with Chinese public and private research institutions, universities and international research institutions can be set up. During the study tour, CAAS, CAU and Henan Agricultural University indicated their willingness to collaborate with the research institutions in Africa.

### Policy intervention

Interventions and projects should involve development of value chains that integrate Chinese technologies for improved production. The key policy thrust for Africa should be sustainable agricultural productivity and commercialisation of smallholder agriculture. Policy should be directed to creating an environment that incubates solid partnerships with Chinese technology providers.

Policy should focus on developing supportive pricing mechanisms which are critical for efficient market development. Other policy interventions include relevant tax and duty regimes, focus on regulations that support or hinder farmer productivity and Chinese technology access and transfer. Policy should also cover modalities of bilateral relations between the Chinese government and the African governments, and forums such as FOCAC.

### African Agricultural Technology Foundation

The African Agricultural Technology Foundation (AATF) can play the role of negotiating for the appropriate technology royalties for the benefit of smallholder farmers in Africa. AATF can also facilitate scaling up the technology transfer strategies. The transfer of Chinese agricultural technologies to smallholder farmers in SSA can only be considered to have useful impact if there is considerable success in scaling up, an approach that AATF is very competent at.

### Infrastructure development

It is clear from the Chinese experience that the availability of good infrastructure is critical to the adoption and access to information, farm inputs, markets and irrigation technology. Efforts by governments can be augmented by infrastructure construction bilateral agreements with China. This will create a platform for successful technology transfer from China to smallholder farmers in SSA. Such arrangements could be facilitated through FOCAC.

### Capacity building

Capacity building is integral as it strengthens the ability of farmers to take up the useful technologies. Capacity development should include all relevant actors along different value chains, that is research and extension, credit service, information sources, farmer groups, agro-processors and market agents.

SSA should focus on how China's engagement in Africa fits into globalisation. In particular, SSA has an opportunity to diversify its development by balancing assistance from the west with that from China. However, to implement a successful strategy, SSA needs to have a good understanding of which sectors and how aid from different quarters can be beneficial. For instance China's experience as a more disciplined society has the potential to curb corruption in Africa, while the United States' commitment to human rights and transparency can contain abuse of power. Africa should learn from the successes and failures of other states' relations with China and their policies on agricultural development, while developing their own experience. SSA should undertake a review to establish what agricultural policies have been beneficial for Africa's long-term development and what areas need improvement.

### Creation of an enabling environment

There is need to create an enabling environment for sustainable adoption of technologies through development strategies that create an environment for effective integration of technological, and institutional arrangements and policy.

The strategy for creating an enabling environment for increasing production is guided by the appreciation that in addition to science there needs to be significant contributions from policy, politics, social sciences, economics, regulation and market development. Thus creating the right environment for different farming systems involves harnessing different sources of knowledge, expertise, information and effective integration of views from different disciplines and stakeholders.

### Creation of efficient markets

This strategy looks at linkages across the value chain by analysing them to determine whether there is effective demand and suppliers are responding adequately, and whether the two sides can interact under appropriate institutional arrangements. This will include strengthening of market infrastructure (availability of inputs, availability of transport, transport efficiency, and availability of product distribution channels), improving the quality of and access to market information, and improving pricing policies related to agricultural inputs and products, and fostering partnerships across the value chain. Smallholder farmers must be empowered to respond to market demands effectively and efficiently.

## Challenges facing technology transfer in Sub-Saharan Africa

A major challenge to the agricultural sector is to develop and transfer technologies to suit all farming groups; peasant subsistence farmers, smallscale farmers, mediumscale farmers and largescale farmers. Overall the only way to productivity is through utilisation of modern technology such as high yielding seed varieties, fertilisers, mechanisation and efficient water management.

The second challenge is the development of a technology transfer system that is efficient. There is need for a system (whether public or private) that provides and distributes the technologies in time and at an affordable price. This will require research and development structures which can best serve the farmers to increase their productivity. With the government's role in the provision of services to the agricultural sector being reduced in most African countries, this becomes a major challenge and priority for agricultural policy researchers.

The third challenge is to ensure that produce is safely stored, transported, processed and marketed with minimal losses. The output recovery system will need storage structures, post-harvest processing technology, efficient transportation systems, marketing systems and the right pricing mechanisms. With the collapse of public marketing organisations in most African countries, alternative systems owned by the private sector or cooperatives will need to be developed.

The fourth challenge is sustaining the agricultural resource base, that is in meeting the above three challenges, there must be minimum environmental degradation, minimum soil erosion, maintaining of productivity of the land, biodiversity and development of alternative sources of energy.

## Immediate action plan for effective technology transfer

There is need to influence policy makers locally, nationally, regionally and globally to develop policies and programmes that support the adoption of relevant Chinese agricultural technologies in SSA. There is need to lobby public sector, including ministries and National Agricultural Research Systems to become more responsive to the need to adopt Chinese agricultural technologies. They need to develop ways to navigate the multiple and probably conflicting priorities, agenda and different institutional culture for the benefit of the smallholder farmers.

Research and extension institutions in African and international universities, African NARES, CGIAR centres and other international research organisations need to take a more holistic approach to agricultural research and development and be more inclusive and responsive to the needs of African smallholder farmers and consumers.

There is need for both the establishment, refurbishment or realignment of social and information networks to ensure effective scaling up and out of information, adoption of Chinese agricultural technologies and the lessons thereof and capacity enhancement so that information about both Chinese agricultural technologies and the benefits to users are presented clearly and appropriately so that it is accessible to smallholder farmers.

Farmers should be trained in the application of Chinese agricultural technologies in a manner that empowers them to forge new partnerships. This will result in the strengthening of seed supply systems and linkages between farmers, input suppliers and entrepreneurs to ensure that input and output delivery mechanisms constrain to the adoption of Chinese agricultural technologies.

# Chapter Seven
# Conclusion and recommendations

The findings indicate that smallholder farming systems in SSA face constraints that are numerous, complex and interlinked. The main constraints noted in crop production include poor access to improved varieties, low fertiliser use, and pests and diseases. Lack of high-yielding breeds, poor quality of feed and diseases hamper livestock production. In general, smallholder farmers attempt to operate highly diversified enterprises (crop and livestock) in order to spread their risks.

There have been a lot of activities following the 2006 FOCAC commitment and a number of African countries have made some progress in implementing the agricultural projects. However, many of the projects are at their initial stages, therefore their impact cannot be ascertained as yet. The lessons from the countries that are progressing well indicate that there is need for greater involvement of both parties and African governments should accept projects that are within their priorities and should be in a position to change those that do not fit to ensure that there are real benefits.

The findings from the study indicated that China has a number of well tested agricultural technologies that are relevant and useful to smallholder farmers in SSA. There is great need for a coherent and systematic plan to access and transfer Chinese agricultural technologies using platforms like FOCAC, AU, NEPAD and CADFund. Of importance is that Africa should identify its needs and negotiate with China from an informed and empowered position. Since agriculture is the economic backbone of many countries in SSA, it should be given first priority.

The study identified key Chinese agricultural technologies that may be used to overcome productivity constraints in SSA. Among them are improved crop varieties, including low fertiliser super hybrid rice, with yields as high as 13.5tonnes/ha suitable for the rice growing regions of Tanzania; multiple disease resistant high-yielding wheat that may be suitable for Ethiopia; multiple disease resistant high yielding maize that may be suitable for Kenya and Tanzania; slow/controlled-release fertilisers; dryland and water management through supplemental irrigation and other strategies; land management practices and policies; re-organisation of a moribund agricultural extension system; strategies for reducing post-harvest losses; mechanisation using appropriate technology to increase labour productivity; and integrated aquaculture farming that focuses on integrated production of fish, livestock and crops.

Information reviewed indicates that experiences with technology transfer in the SSA region are met with mixed results. It has been shown that for technological transfer to succeed it must address the needs of the farmer, must be in a complete package, and have a ready market with competitive prices. Farmers must also realise immediate and tangible results. It is proposed that these technologies could be disseminated through FOCAC, CADFund, PPPs, South–South Cooperation and bilateral agreements.

The progress made by Chinese agriculture provides important lessons for Africa.

1. Although Africa is already in possession of most of the technologies that China has successfully used to ensure food security, these technologies have not been properly supported and put into effective use. As a result, most of them are still lying on the shelves in laboratories and research stations.

2. A supportive public infrastructure like subsidies, appropriate institutional framework, marketing and land tenure is necessary to facilitate and sustain technology adoption. While progress is being made in many SSA countries, public support for agriculture is lacking in many African countries partly due to budgetary constraints and partly because African farmers do not take farming as a business.

3. Increased agricultural productivity requires a strong research extension-farmer linkage. Decentralisation of research is crucial to addressing unique spatial constraints, be they agronomic, edaphic, socio-economic or agro-ecological. China has a decentralised multi-tier research system where provincial research institutes develop technologies that address the unique characteristics of the region. This is complemented by a strong extension service and a proactive clientele. African countries could consider adopting this Chinese extension model.

4. Appropriate policy and legal framework are necessary to promote agriculture at all levels of the value chain. For instance, China has policies and laws regulating land, fertiliser and pest management as well as for germplasm conservation. Although such policies and laws could be there in most African countries, they are hardly implemented.

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