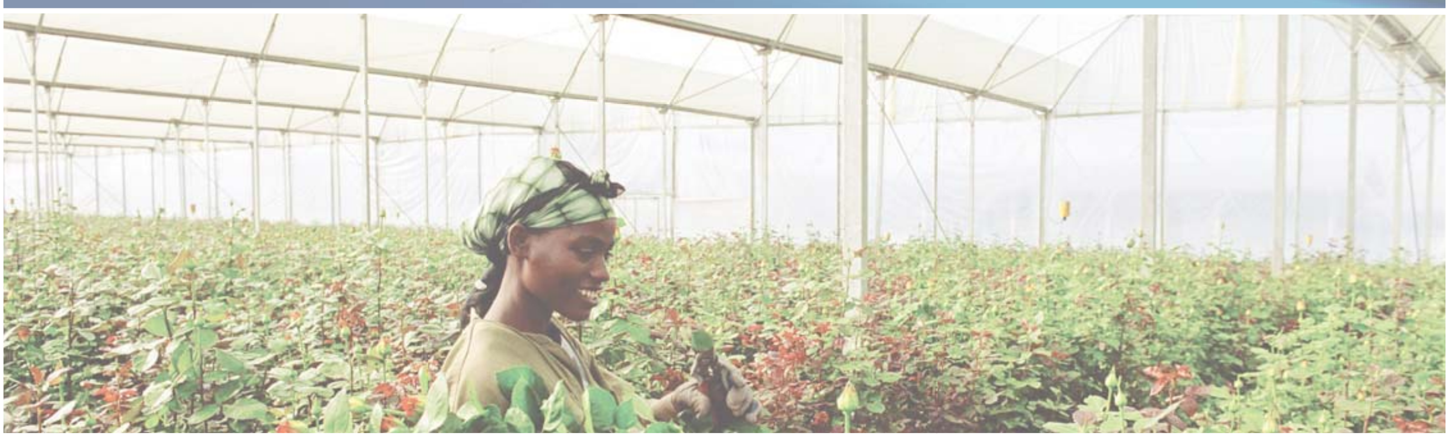
UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

TECHNOLOGY AND INNOVATION REPORT 2010

Enhancing food security in Africa through science, technology and innovation



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PREFACE

The increasing prevalence of malnutrition – there are now an unprecedented one billion hungry people in our world – provides dramatic evidence of the severely strained capacity of many developing countries to meet the minimum nutritional requirements of their people. Current estimates predict that the Earth will need to feed an additional two to three billion people over the next 40 to 50 years. This will exert enormous pressure on the productive capacity of agricultural systems across the world and will have important consequences for farmers and consumers everywhere. Tackling this challenge requires a radical rethinking of how food is produced, distributed and consumed globally.

Any changes in the world's food production and consumption patterns must go hand in hand with sustainable responses to several other equally critical challenges, such as reducing poverty, adapting to climate change and supporting rural development. Science, technology and innovation alone cannot provide all the solutions, but they must be key ingredients of the policy mix to achieve food security through sustainable, equitable agricultural systems.

UNCTAD's *Technology and Innovation Report 2010* focuses on the technological challenges that small-holder farmers in developing countries, especially sub-Saharan Africa, face in increasing agricultural productivity. It outlines the agricultural sector's challenges and the roles of technology and innovation in raising production and the income of small-holder farmers. And it describes readily available technologies that can be applied now to improve soils, manage water shortages and resist drought.

There is an urgent need to accelerate progress to meet growing demand and ensure synergy between food security goals, environmental sustainability and social equity. I look to all partners to advance this agenda through investment, research, technology transfer and stronger international cooperation. Together, we can help farmers in developing countries to produce more food for the world's growing population, reduce poverty and support global efforts to achieve the Millennium Development Goals.

BAN Ki-moon
Secretary-General
United Nations

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LIST OF ABBREVIATIONS

ABC	Brazilian Cooperation Agency (Ministry of Foreign Affairs)
AGRA	Alliance for a Green Revolution in Africa
AMCOST	African Ministerial Council on Science and Technology
ATDF	African Technology Development forum
BRIC	Brazil, Russian Federation, India and China
BSP	Bali Strategic Plan for Technology Support and Capacity Building
C4	'Cotton 4' West African cotton producers (Mali, Chad, Benin and Burkina Faso)
CAADP	Comprehensive Africa Agriculture Development Programme
CC	Climate Change
CDD	community-driven development
CEEPA	Centre for Environmental Economics and Policy for Africa
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Centre
CPLP	Community of Portuguese Speaking Countries
CSD	Commission on Sustainable Development
DAP	Draught Animal Power
DFID	Department for International Development (United Kingdom)
EMBRAPA	Brazilian Agricultural Research Corporation
EU	European Union
FAAP	Framework for African Agricultural Productivity
FAO	Food and Agriculture Organization
FDI	Foreign Direct Investment
FOCAC	Forum China Africa Cooperation
FTA	Free Trade Agreement
GDP	Gross Domestic Product
GHG	Greenhouse Gasses
GIS	Geographical Information System
GMO	Genetically Modified Organism
HRD	Human Resource Development
HYV	High Yielding Varieties
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
IAC	InterAcademy Council
IBSA	India-Brazil-South Africa Dialogue Forum
ICAR	Indian Council of Agricultural
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	Information and communication technology
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
IFOAM	International Federation of Organic Agriculture Movements
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
IPR	Intellectual Property Rights
IRRI	International Rice Research Institute
ISAAA	International Service for the Acquisition of Agri-biotech Applications
JICA	Japan International Cooperation Agency

LDCs	Least Developed Countries
MDGs	Millennium Development Goals
MVs	modern varieties
NARS	National Agricultural Research System
NEPAD	New Partnership for Africa's Development
NERICA	New Rice for Africa
NGO	Non Governmental Organization
NPACI	NEPAD Pan African Cassava Initiative
NPFS	National Programme for Food Security
ODA	Official development assistance
OECD	Organisation for Economic Cooperation and Development
OECD/DAC	Development Assistance Committee
OPEC	Organization of the Petroleum Exporting Countries
PRONAF	Brazils' National Program for the Strengthening of Family Agriculture
PVPA	Plant Variety Protection Act
R&D	Research and development
RPFS	Regional Programme for Food Security
SFAC	Small Farmers Agro Business Consortium
SIDS	Small Island Developing States
SME	Small and Medium size Enterprise
SP	Special Products
SPFS	Special Programme for Food Security
SRO	Sub-regional Research Organizations
SSA	Sub-Saharan Africa
SSC	South-South cooperation
SSM	Special Safeguard Mechanism
SVEs	Small and Vulnerable Economies
TICA	Thailand Development Cooperation Agency
TICAD	Tokyo international Cooperation for Africa Development
TWN	Third World Network
UNCCD	United Nations Convention to Combat Desertification
UNCSD	United Nations Commission for Sustainable Development
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNECA	United Nations Economic Commission for Africa
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
WB	World Bank
WDR	World Development Report
WFP	World Food Programme
WTO	World Trade Organization

EXPLANATORY NOTES

The term ‘dollars’ ($) refers to United States dollars unless otherwise stated. The term billion means 1,000 million.
Two dots (..) indicate that data are not available or not separately reported.
A hyphen (-) indicates that the amount is nil or negligible.
Due to rounding, percentages may not total 100 and figures may not add up to the total shown.

EXECUTIVE SUMMARY

Sub-Saharan Africa is the developing region most likely to miss the first Millennium Development Goal (MDG1), aiming to reduce by half extreme hunger and poverty by 2015. Per capita food production in least developed countries (among which African countries are over-represented) has declined continuously since the early 1970s, so that in 2003-2005 it was one-fifth lower than in 1970–1972. While Asia and Latin America have seen significant increases in their agricultural productivity over the last three decades, Africa's agricultural productivity has stagnated. This has created serious problems of food insecurity and has presented a major development challenge given that the agriculture sector forms the basis of many African economies and provides the largest source of employment and livelihoods for the vast majority of the continent's population. The core challenge that confronts Africa is one of promoting steady growth in agriculture in the dynamic context of economic transformation of countries. Agriculture will remain important for food security but at the same time, building productive capacities in agriculture and identifying multi-sectoral linkages between agriculture and other sectors will be important to support sustainable economic development of Africa. The onus therefore lies in the identification and support of processes and linkages that promote technological change, productivity increases and innovation.

This report focuses on the challenges of improving agricultural performance in Africa and the role of technology and innovation in raising agricultural production and incomes of all farmers, including smallholder farms. Much of the analysis is to some degree applicable to farmers in developing countries outside Africa. The report argues that the main challenge that lies ahead is one of strengthening the innovation capabilities of African agricultural systems in order to be able to successfully address poverty, improve food security and achieve broader economic growth and development.

African policy-makers can make the changes needed, provided there is sufficient political will and international support. Innovation, as opposed to science and technology, refers to the interactive process of application of knowledge in production and building further upon it. Such knowledge might be acquired through learning, research or experience, but depends on the presence of technological capabilities to be applied in the production of products across sectors, including agriculture.

Technological innovation is not all composed of radical discoveries, and much of what is relevant to African agriculture relates to the ways in which incremental improvements in processes, products, inputs, or equipments are needed to adapt existing technologies to the local environment in ways that enhance productivity and lower costs. The ability to adapt, therefore, is a significant step in technological empowerment, which over a period of time, can lead to the creation of knowledge generation capabilities amongst actors that are demand-driven rather than simply those that aim to replicate the successes of other regions of the world.

Declining agricultural productivity in many developing countries can be reversed through building what are called agricultural innovation systems that provide the enabling framework not only for the adoption of existing technologies and the development of new ones that are suited for African needs. Agricultural innovation systems denote the network of economic and non-economic actors, and the linkages amongst these actors enable technological, organizational and social learning of the kind needed to devise context-specific solutions. The dissemination of already existing technologies from outside could help this endeavour, but a major challenge relates to the ways and means in which innovation that is relevant to African agriculture could be promoted.

However, the ability of the agricultural innovation system to be able to access, use and diffuse knowledge embedded in agricultural technologies depends on the presence of an enabling framework that supports the emergence of technological capabilities by strengthening existing linkages, promoting new linkages and fostering inter-organisational learning that leads to capital accumulation and technical change. Such an enabling environment, by definition, is one that strengthens the absorptive capacity of local actors while protecting their interests through a policy framework that recognises their legal rights and privileges, linkages, socio-cultural norms and historical context. This report defines an enabling environment for technology and innovation in agriculture as one that provides the actors, skills, institutions and organizations required to promote the use, dissemination, diffusion and creation of knowledge into useful processes, products and services.

Creating an enabling environment for technology and innovation is an essential requirement to enable African countries to address the following constraints that impede their agricultural development:

- **Declining investment:** most developing countries already had investment deficits in agriculture well before the onset of the current financial crisis in mid-2008. The long decades of neglect of the agricultural sector in the Africa region are partly a consequence of the policy of strict fiscal austerity imposed on African countries, which has severely curtailed state support of agriculture. The perception that investment has merely to do with the provision of agriculture research has exacerbated the situation further. This has resulted in poor rural infrastructure, low coverage of extension services, reduced provision of subsidies for inputs and finance for farmers, and reduced investment in research and development in the agricultural sector. As a result, farmers in Africa are now poorly equipped to deal with the new challenges that they face, which include climate change, desertification, competition from cheap imports, and highly concentrated global value chains dominating the world's commodity markets. Investing in activities that promote new forms of partnerships, use of local knowledge (including traditional agricultural knowledge), practices and preferences, as well as policy-driven demand-based approaches have been missing to promote the African response to its agricultural challenges.

- **Land tenure and credit access:** access to credit is another fundamental institutional constraint that circumscribes the ability of African farmers to cope with the rising prices of land, seeds and other agricultural inputs. However, this clearly needs to be accompanied by an enabling framework that guarantees better physical and scientific infrastructure of relevance to African agriculture, and improved market access and demand forecasts. Guaranteed land tenure could be vital to accessing credit and investing in the medium and long-term productivity of the land.

- **A focus on small-holder farmers:** focussing on smallholder farmers has proven an effective means to contribute to a country's economic growth and food security. Smallholders make up over half the population in most developing countries and their farms are often efficiently run and enjoy significant growth potential. However, smallholder farms are diverse in terms of the challenges and limitations they face in the light of which adaptation of technologies and reconfiguration of supply chain roles and responsibilities will be critical to enable small-scale farmers to frame the issues of appropriate agricultural outputs and activities on their own terms. Their isolation makes them susceptible to both external and internal shocks, and also hinders resilient responses. A focus on smallholder farms is required to ensure that they are well networked into all available technical and institutional support mechanisms that is so critical for them to consolidate their activities.

- **Adapting to climate change:** climate change is a global challenge with critical development implications. The negative impacts are especially severe in marginal lands. Some 300 million farmers in Africa live and work on marginal lands at increased risk of soil degradation, droughts, floods, storms, pests and erratic rainfall. Climate change technologies and innovations for mitigation and adaptation strategies are needed to accelerate the development, deployment, adoption, diffusion and transfer of environmentally sound technologies from developed to developing countries.

- **Bioenergy:** energy is at the centre of the development challenge in many developing countries, with inadequate supply hindering capacities to expand production and improve human wellbeing. If properly managed, the high technical potential of bioenergy in regions such as sub-Saharan Africa could make a significant contribution to fighting poverty while also addressing climate change and expanding trade opportunities in sustainable energy products.

- **Structural policy reforms:** the thirty-year legacy of structural adjustment and trade liberalization has turned Africa from a net food-exporting continent to one that predominantly imports. The food insecurity situation in Africa is better framed in terms of missed opportunities as a result of serious failings of development strategies. Africa's agricultural sector implemented programmes designed to eliminate price controls, privatize state farms and state-owned enterprises, abate taxes on agricultural exports, remove subsidies on fertilizer and other inputs and encourage competition in agricultural markets. The anticipation that these measures would encourage the private sector to move in and provide these services was not matched by reality. Longstanding policy failures must be reversed. Experience from the most recent crisis also shows that countries that specifically aim to achieve food security can cushion the blows from a cyclical world market. Future trade agreements must ensure that the space to apply such policies is preserved and, indeed, strengthened.

- **Building locally relevant research and innovation priorities:** African agricultural research has not been weak, but it has lacked the right impetus to bridge ongoing research with product development initiatives. There has been a tendency to focus on applying international models of agricultural development without questioning their applicability to local circumstances. An accompanying attitude that looked down on regional research, as against international research (where the latter was considered to be far more superior), has been entrenched since colonial times. In reality, patterns of knowledge change are related to the increasing convergence in the different areas of science and technology, and indigenous capabilities of countries matter. The benefits attending to convergence include new organizational production structures and advances in communication apart from global trade. This calls for policies that help re-orient actors towards local sources of technology and learning, and address the negative perception towards local research.

It is important to realize that there are no quick fixes. This can be seen in the case of other developing countries which are now benefiting from public and private investments that were made into the development of agricultural technologies and innovation capacity since decades. Brazil, for example, has achieved its current leading position in tropical agriculture technology and increased agricultural productivity as a result of more than three decades of public and private investment in the development of technological packages tailored to its own soil and local agro-ecological conditions.

Amongst options available, international cooperation can potentially be a strong factor in helping relevant new technologies be adopted, adapted and diffused throughout host economies. In particular, a handful of South-South cooperation models have already proven their worth as mechanisms for ensuring the right technological tools are made available to African farmers. So-called triangular cooperation, where a Northern neighbour signs on as a sponsor to South-South technology sharing efforts, has also shown promise as a model for the international diffusion of technologies.

On this basis, when the new African Agriculture Revolution is eventually implemented, it is likely to be built on Africa's own indigenous technology and knowledge requirements, and the nutrition and food security needs of its people. Building capabilities for science, technology and innovation of relevance to local agriculture however, is the only path to achieve this.

THE REPORT

This T*echnology and Innovation Report 2010* looks at how the current trend towards declining agricultural productivity in many developing countries can be reversed through building what are called agricultural innovation systems, that provide the enabling framework not only for the adoption of existing technologies and the development of new ones that are suited for African needs, but also focus on improving agricultural infrastructure, services and land management practices, new marketing networks and partnerships, novel credit schemes and a coherent institutional framework to support agricultural development in the long run. The report discusses current and future developments that are likely to affect agricultural production and food supply, and explores the role of technology and innovations in the quest to achieve sustainable agriculture production on one hand and facilitate access to food for the poorest populations on the other.The first chapter outlines the critical issues in the development of agriculture in Africa. Chapter 2 emphasizes the crucial importance of building innovation capabilities in African agriculture through investments into 'agricultural innovation systems' and the importance of an enabling environment to utilize technologies and inventions. Chapter 3 discuss the key issues in the development of agriculture in Africa including the determinants of national food security, the options available to improve domestic food production and the role of agricultural trade in food security. Chapter 4 focuses on challenges and opportunities to achieve national food security. It also examines the drivers of a new Green Revolution while drawing lessons from the Asian Green Revolution to suggest the contours of the new agriculture paradigm for Africa and Chapter 5 examines the transfer and farm-level diffusion of agricultural technologies, including the international transfer of technology through South-South cooperation. Chapter 6 discusses the main types of agricultural technologies and the importance of choosing a mix of technologies suitable to the diversity of local agro-ecological conditions found in Africa. Finally, Chapter 7 sets out a number of policy recommendations addressing the range of issues covered in the preceding chapters.

Supachai Panitchpakdi
Secretary-General
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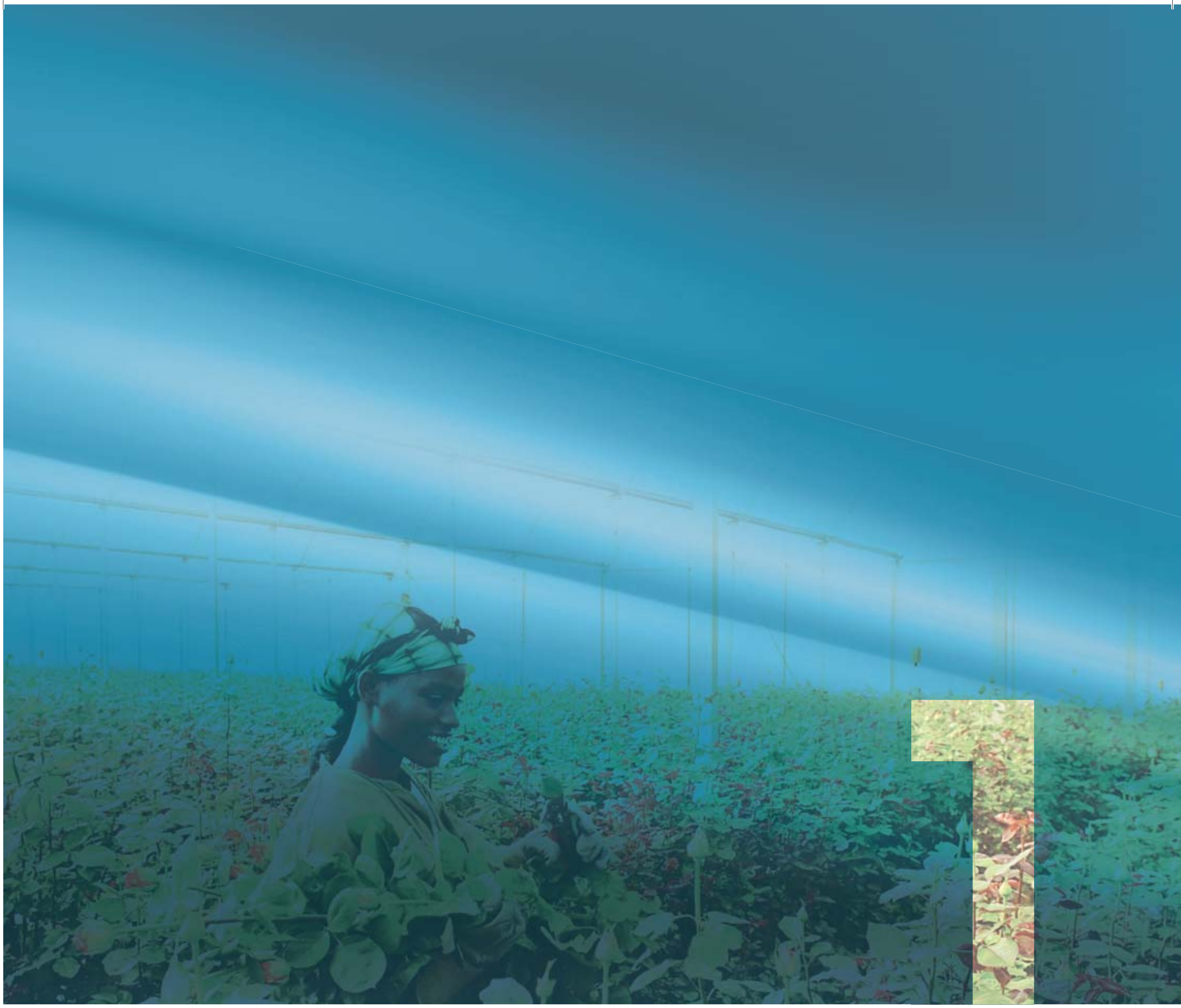


1 KEY ISSUES IN THE DEVELOPMENT OF AGRICULTURE IN AFRICA

1.1 CHALLENGES IN AFRICAN AGRICULTURE

Over the last several decades, enough food has been produced globally to feed everyone in the world. Nonetheless, the number of undernourished people in the world continues to rise, from 923 million in 2007 to over 1 billion in 2009, according to the FAO.[1] The food situation is critical in 33 countries that suffer chronic shortfalls in aggregate food production, lack of access to food or localized food insecurity.

The overwhelming majority of the world's undernourished people live in developing countries, with some 65 per cent concentrated in just seven countries: India, China, the Democratic Republic of Congo, Bangladesh, Indonesia, Pakistan, and Ethiopia. The highest proportion of undernourished people is in sub-Saharan Africa, where one in three people go chronically hungry. The causes, according to the FAO, range from low agricultural productivity, the current economic crisis, and adverse weather to the HIV/AIDS pandemic, civil strife and war.

At first sight, the fact that a billion people in the world are undernourished while some regions are producing enough food seems to call into question the effectiveness of the distribution of global food production, but figures show that the global aspect of the food crisis has been overstated. Most food is consumed and produced locally and regionally. In fact, 90 per cent of the world's rice is produced and consumed locally, as is 75 per cent of the world's wheat and maize.[2] Rather than a 'global hunger epidemic', the world faces a proliferation of localized instances of chronic food insecurity. This is the key reason to focus on structural improvements to the way food is produced at the local and regional level in areas where food shortages are common, especially in sub-Saharan Africa and parts of Asia.

The situation in Africa is particularly worrying. Farmers in Africa have lost 25 per cent of their purchasing power in the last 25 years, and farm income levels are now below $200 per person per year. Nonetheless, in some areas productivity is improving, supported by the low costs of land and labour and the rising prices of farm products.[3]

Some semblance of hope for the future of African agriculture is emerging, as evidenced by a number of recent studies. In southern Uganda, for example, farmers have turned to growing apples, displacing imports and earning as much as $0.35 per apple at the farm and an even higher price in the capital, Kampala. In Zambia, cotton production has increased ten-fold over the last ten years, bringing new income to 120,000 farmers. In Kenya, floral exports now threaten to surpass coffee as the country's leading cash earner, while tens of thousands of Kenya's small-holder farmers grow and export French beans and other vegetables to Europe's grocers. In Ethiopia, the local coffee cooperatives have been able to respond to international marketing demands while being able to create a brand image that traces the product back to its origin. Overall, exports of vegetables, fruits, and flowers from eastern and southern Africa now exceed $2 billion a year, up from virtually zero a quarter-century ago.[4] Nevertheless, the volumes involved in these cases are far from adequate, especially for African countries struggling to meet their Millennium Development Goals, particularly MDGs 1 and 7 (aiming to end poverty and hunger and achieve environmental sustainability).[5]

While demand for food continues to rise in conjunction with demand for goods and services, the amount of land available for food cultivation is decreasing due to soil degradation and competition for other uses such as housing, industrial development, roads, and commercial production of cash crops such as tobacco and coffee. Over the last 30 years, sub-Saharan cities grew at the astonishing rate of over five per cent per annum, while the growth in North Africa was three per cent. It is anticipated that over the next 25 years, the key driver behind the evolution in the African food markets will be urbanization.[6] Achieving food security in the face of these trends will require breakthrough technologies, some of which have yet to be developed.

1.2 ROLE OF TECHNOLOGY AND INNOVATION

The predominant model of transfer of technology model that served to guide public sector research in agriculture in almost all developing countries in the 1960s and 1970s was built on the faulty premise that transfer of technology relates to linear flow of information generated in the science institutions that could be easily transferred to farmers for application purposes.[7] This 'linear model for science and technology' attenuated the focus on science and research as removed from application (and commercial innovation), and at the same time, promoted the notion of technology as embodied in spare parts and equipments. As a result, there was a misplaced focus on 'science suppliers' (production of engineers and scientists) that were key to promote research and transfer of technology (understood) as equipments, blue prints and other codified sources of information in order to promote local capacity.

The National Agricultural Research Systems (NARS) framework that served as a basis to guide policy actions on how research can contribute to agricultural development for well over four decades was based on this premise: that sharing agricultural research through technology transfer, leads to technology adoption and productivity growth.[8] The Agriculture Knowledge and Information Systems (AKIS) framework that emerged as an alternative to explain the difficulties of the NARS framework to agriculture development focused predominantly on the importance of agriculture extension services. The framework seeks to integrate farmers with researchers, scientists, cooperatives and extension services in order to generate the kinds of knowledge that was crucial for their improved performance. This framework, promoted by the Food and Agriculture Organisation of the United Nations, is based on the recognition that knowledge of relevance to agricultural development has several sources and linkages.

Three changes in the context of agricultural development call attention to the need to examine how innovation that underpins greater productivity occurs in the agricultural sector:[9] (i) markets, not just production, increasingly drive agricultural development; (ii) the underlying knowledge structure for agriculture has changed remarkably, with the private sector becoming a major player; (iii) agricultural productivity and performance is increasingly related to availability of updated, technologically-advanced extension services which have undergone much advances as a result of the exponential growth in information and communications technology (ICT), especially the Internet. These factors have changed the face of agricultural development and rendered it intricately linked to global economic trade and knowledge capabilities of countries, but also focused the associated emphasis on the inability of economic growth to address the food security needs of the poor clearer than ever before. Placing agriculture in a knowledge-based innovation-driven context point attention to the notion of science, technology and innovation capacity building and what the prospects might be for Africa's own agriculture revolution.

Knowledge, as opposed to information, is the basis of technological learning, and requires the development of cognitive learning skills, linkages and institutional support structures that promote access, use, dissemination and applications based on existing knowledge. The presence of absorptive capacity locally therefore is a pre-requisite to build capabilities through an interactive process for technology and innovation in agriculture. Promoting agricultural innovation requires new actors, processes and technologies who would be the carriers of new knowledge to replace the largely fragmented agrarian knowledge system that form the basis of rural poverty. The notion that peasant producers are 'efficient but poor'[10] is true in most of Africa thereby pointing to the need to create conditions in which agriculture could be made more efficient based on productivity enhancing technologies. Technological capability that focuses on sustaining capacity in food producing areas is critical to sustain the rate of yield growth needed to achieve food security and expands on the resilience of smallholder farms to both internal and external shocks are. For example, farmers rely on research to control weeds, pests and diseases and keep ahead of the emergence of resistant strains. These technologies form an integral part of improving the efficiency of the production system. However, a range of factors beyond technology affects the development of productive capacities for agriculture in Africa. Human resources are critical both to the development and application of relevant technologies.

The presence of science infrastructure, stronger linkages between various actors both for sharing information and knowledge, improved physical infrastructure that helps secure easier access to markets, land security and protection of farmers' rights are other factors that will determine the ability of African agriculture to access relevant technologies. However, the widespread adaptation, acceptance and use of such productivity-enhancing technologies will rely on the emergence of social and organisational innovations that promote horizontal linkages amongst actors. These could take the form of new dissemination processes, efficient extension services, emergence of novel intermediary or incentive structures that promote technical change, access to new forms of credit schemes, among other changes to the institutional context in which science, technology and innovation

Box 1: Addressing challenges in agricultural technology [13]

A recent United Nations report on sustainable development highlighted the key challenges facing developing countries seeking to achieve sustainable agricultural growth:

"Agricultural technologies are vital to sustainable rural development, both to increase crop and livestock productivity and to strengthen resilience of agricultural systems. Traditional emphasis on yield maximization has been tempered in recent years by growing recognition of the need to ensure the long-run sustainability of yield improvements and to preserve vital rural ecosystems and their functions. The recent food crisis and slow progress towards the achievement of the Millennium Development Goal of eradicating hunger have highlighted the wide disparities in technologies used and productivity achieved in different agricultural systems. While input and resource-intensive agriculture is the norm in many developed and middle-income developing countries, many developing countries continue to rely on low-input, low-productivity agriculture. Even as the former group of countries need to shift towards less intensive and more environmentally sound methods, farmers in many developing countries would benefit from greater input use. Yet, in principle, they should also benefit from the latest scientific knowledge and field testing of sustainable methods able to achieve high and stable yields and resilience in the face of climate change."

Source: United Nations, (2009)

for agriculture occurs. All these factors jointly form part of the enabling innovation environment that will enhance the absorption capacity amongst local firms and farms. 'Absorptive capacity' refers to the ability of local producers to access, absorb, use and diffuse relevant knowledge into enhancing productive capacity. Finally, technological innovation must be simultaneously supported by an enabling environment that boosts the absorptive capacity of local producers by, for instance, working with farmers to develop the skills needed to implement new technological breakthroughs that enable them to produce, store and sell more food. Non-technological innovation is also important in creating an environment that enables the introduction of new products and new processes. Such processes involve scaling-up investments to identify and deploy technologies that increase productivity and facilitate farmers' access to new techniques. All these actions are technically and financially feasible, and their adoption has been estimated to require investment of $38 billion from 2009 to 2013, or $7.5 billion per year, in a well-designed package of modern agricultural inputs and provisions.[11] Upgrading the enabling environment would also call for improving and extending transport infrastructure, especially major transport corridors and rural feeder roads. Finally, it would require the lowering of trade barriers, which remain much higher in agriculture than in other sectors.[12] Box 1 sets out some of the main issues and challenges involved in developing appropriate and sustainable agricultural technologies.

It must be borne in mind that, given the array of challenges involved, it is unlikely that improvements in agricultural technologies and the sector's enabling environment would be enough to provide reliable livelihoods for the growing populations in many developing countries. Alternative or additional income generating opportunities are therefore needed to support the millions of poor families who can no longer rely solely on the land for their livelihoods. Agro-processing has the potential to provide some of these opportunities, as shown by poor countries in other parts of the world such as Bangladesh.[14]

1.2.1 Renewed drive for investment

The steep decline of investment in agricultural research, technology and infrastructure that has occurred all over the world and mainly in sub Saharan Africa over the last few decades has affected food security in two distinct ways. First, it has resulted in production falling short of the growing demand, with smaller stocks of food surpluses available around the world.[15] Second, the decline in infrastructure investment has contributed to high production and distribution costs that in turn have kept food prices high and exacerbated the lack of access to food, especially in sub-Saharan Africa. The cost of transportation and distribution will be critical in shaping strategies and policies for agriculture.

Reversing these trends will require a shift in focus: what should developing countries invest into, in order that agricultural innovation results? Besides the different agro climatic conditions between Africa and Asia, the success of the Green Revolution in much of Asia and the lack of transformation of Africa's agriculture in spite of research efforts over the last few decades is increasingly being explained in the context of changing knowledge and capabilities of countries. Agricultural development depends to a great extent on how successfully knowledge is generated and applied. Knowledge-based investments, especially focusing on science and technology provision, have played an emphatic role in devising strategies that aim at promoting sustainable and equitable agricultural development at the national level.[16] Although many of these investments have been quite successful, the context for agriculture is changing rapidly and the process of knowledge generation and use, and agricultural innovation, has transformed as well.

Public sector research has played a central role in agriculture globally in promoting the creation of knowledge of relevance to commercial application. In the developed countries, despite the general trend of reduced public sector research for agriculture, the research intensity in agriculture (defined as the percentage of total GDP generated through agriculture that is invested into public sector research) is still 2.36 per cent, as compared to 0.53 per cent for developing countries.[17]

Increased investments in science and technology should be accompanied by extension services and the identification of strategic policies and investments needed to transform agriculture and the food system and stimulate broad-based economic growth. For example, countries may opt to shift some domestic food production and processing closer to consumers in urban centres. Such a move would provide investment opportunities in smallholder agricultural businesses and the development of public-private partnerships to address the productive side by tackling supply-side constraints and deficiencies. However numerous barriers would need to be overcome, including typically poor infrastructure, very low density of productive links with small- and medium-sized enterprises (SMEs), and little capacity in domestic enterprises (processors, millers etc.) to supply value-added goods or services either to the domestic or the export markets.

1.3 KEY ISSUES

1.3.1 The global financial crisis

It is important to note that most developing countries already had investment deficits in agriculture and the supporting infrastructure well before the onset of the current financial crisis in mid-2008. With the advent of the crisis, employment has declined in many areas, lowering income and threatening many households' access to food. The financial crisis has also impacted government social services, trade, investment, aid, remittances, and exchange rates, making imports more expensive and, in many cases, food less accessible.

Even more importantly, the global financial crisis has overshadowed the food crisis, creating new difficulties in mobilizing external resources to address the increasing shortage of food in Africa. The figures for official development assistance (ODA) for agriculture have also been steadily on the decline, falling from 13 per cent of total ODA in the early 1980s to 2.9 per cent in 2005–2006, and could have further adverse impacts on building science, technology and innovation capacity as governments turn their attentions to other short-term goals.[18]

1.3.2 Land tenure and credit access

One of the main barriers hindering smallholders' access to agricultural credit in developing countries is the inability to convert property into usable assets, due to the lack of clear-cut, legally recognized and transferable land tenure rights. There are millions of dollars trapped in 'dead property' around the world due to the fact that owners do not have official title to their land. Over 80 per cent of the land occupied by the poor in developing countries is not legally recognised tenure. This restricts their ability to not only to access credit, but also to integrate land management practices that could help increase the productivity of the land due to the absence of well-defined and enforceable property rights. Thus, awarding title to land is an important way to fight poverty at its most basic level.[19]

1.3.3 The food crisis

From an African perspective, the food crisis can be seen as the result of two overlapping crises: a supply crisis (caused by low productivity) and the hike in food prices as a result of the commodity crisis as a result of speculation, as illustrated in Figure 1.[20]

The debate on the price volatility of agricultural commodities has for a long time taken place in the context of agricultural trade liberalization. However several aspects of domestic food price volatility are also rooted in the low productivity of smallholder agriculture and the difficulties farmers face in marketing their products given their scant market information and their limited capacity to contain post-harvest losses. Price volatility, in addition to the already existing constraints, has implications for the ability of agricultural producers to undertake investments. At the same time, the uncertainty that price volatility breeds makes consumers wary and less willing to spend. Price volatility is therefore an important disincentive to long-term investment in agriculture.[21]

The global food crisis should serve as a wake-up call for the international community to revitalize agricultural systems of production and innovation, and trade, in order to rectify systemic imbalances. Developing countries must use the latent potential for the growth of productive capacities thus breaking away from decades of policy bias against agriculture.

Developing countries have had mixed results in dealing with the food crisis and reducing the impact of soaring food prices on consumers and producers. Innovative short-term solutions that deal with reducing the threat of food prices on food security have been tested in some countries such as Indonesia, where the government intervened in the market to stabilize prices, including managing available stock and, in certain cases, limiting exports. A different approach was adopted by the governments of Mexico and Jordan, which pursued price negotiations with agro-industries, leading to agreements not to pass increases in production costs on to the consumer.[22] These experiences are relevant to African countries simultaneously burdened with the urgent task of improving productive capacity for agriculture and ensuring greater availability of food at reasonable prices for all.

UNCTAD has suggested that in order to overcome the 'commodity trap' that African countries are faced with as a result of their increasing reliance on trade in commodities, there is a need for mechanisms that help Africa achieve a structural transformation to productivity enhancing technologies in the medium or long-term.[23] This transformation needs to be augmented by a compensatory financial mechanism for African producers to meet short-term price shocks and declining incomes, as well as a 'diversification fund' that supports the rise of new products and services in African economies.

1.3.4 Focusing on smallholder farmers

Smallholders make up over half the population in most developing countries and small farms are often efficiently run and enjoy significant growth potential. Stagnant agricultural productivity in Africa has worsened the situation of the continent's farmers who are finding it increasingly difficult to cope with the new and mounting pressures of climate change, input costs and drought. These are the kinds of issues that an African agriculture revolution must address.[25] There is evidence from countries such as Vietnam, which has gone from being a food-deficit country to the second-largest rice exporter in the world, that points out that a focus on smallholder farmers can contribute to a country's economic growth and food security.[26] A fundamental issue is that smallholder farmers are not necessarily deprived due to their size, but rather due to their isolation from the knowledge and information systems. Their isolation makes them susceptible to both external and internal shocks, and also hinders resilient responses. A focus on smallholder farms is required to ensure that they are well networked into all available technical and institutional support mechanisms that is so critical for them to consolidate their activities

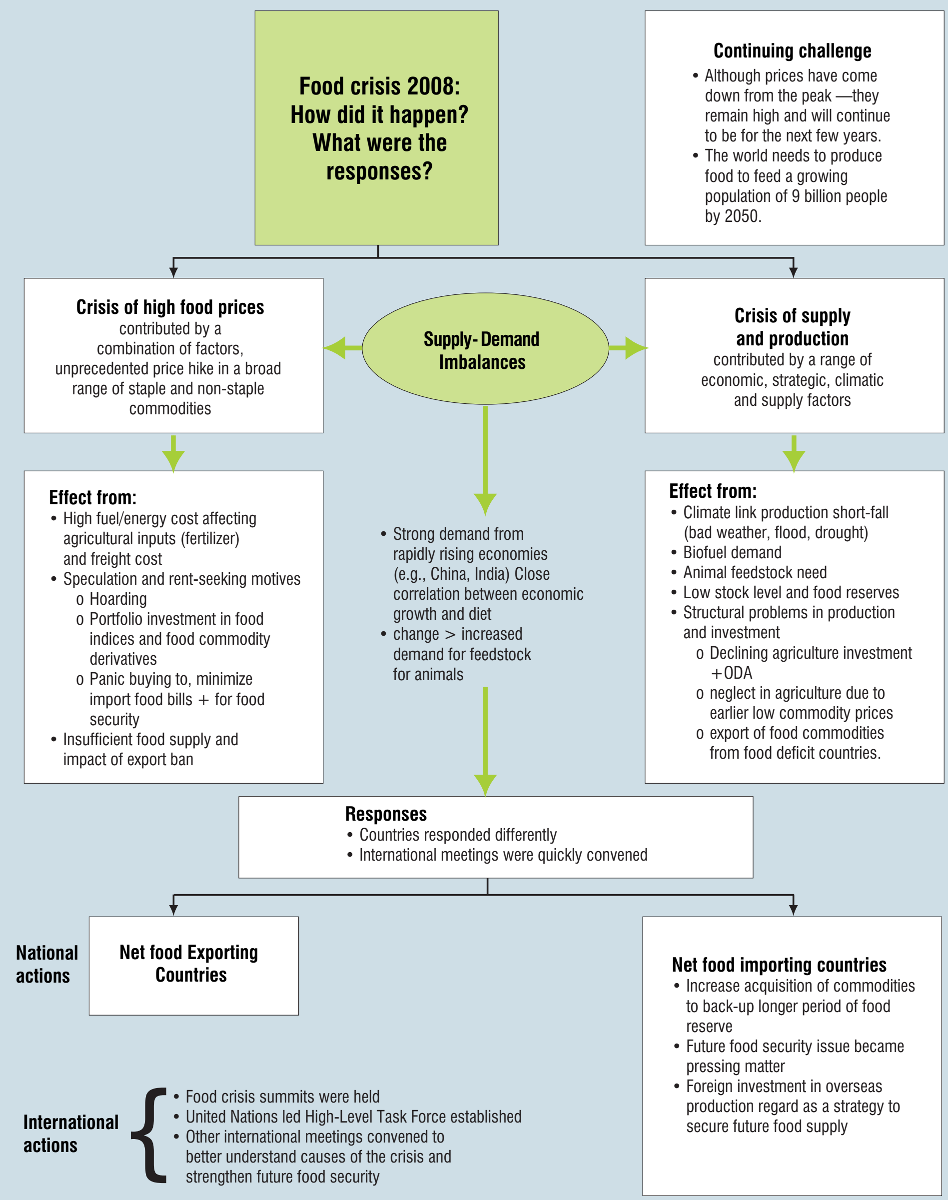
To enable a number of fundamental production related conditions for smallholder farmers to manage risks and uncertainty and become effective players in the market, it is necessary to improve:

- access to agro-inputs;
- adequate storage capacity;
- access to up-to-date market information and extension services;
- access to formal markets;
- access to clustering and cooperative forms of organisations; and
- access to credit.

Focusing strategies thus to enhance food security on smallholder farmers would imply a strategic shift towards working primarily with them in analysing the root causes of hunger and overcoming risk and vulnerability. Several recent initiatives have begun to introduce such activities in a successful way.

For example, a range of innovative procurement and programme practices is now used by the World Food Programme (WFP) to reduce the risks faced by small-scale farmers. These include forward contracting and warehouse receipt programmes that can serve as collateral for loans, and supporting value-added production and local food processing. Other options include improving tendering systems so that small-scale farmers are in a better position to compete for locally issued contracts, supporting producers' access to market information systems, and improving regulatory structures to govern quality standards and address the problem of speculation in commodity markets.

Figure 1: Causes of, and responses to, the 2008 food crisis [24]



Source: UNCTAD, (2009)

1.3.5 Adapting to man-made change

Urbanization, land degradation, population pressure and climate change are global challenges with critical development implications. Populations in developing countries are more vulnerable to, and will be more adversely affected by, climate change. The negative impacts especially in marginal lands include soil degradation and increased risk of droughts, floods, storms and pests. Three hundred million farmers in Africa live and work on marginal lands.

The Intergovernmental Panel on Climate Change has found that "*agricultural production and food security (including access to food) in many African countries and regions are likely to be severely affected by climate change and climate variability*."[27]

In low-latitude regions, where most developing countries are found, even moderate temperature increases are likely to result in declining yields for the major cereals. Growing aridity is expected to affect agricultural productivity directly in some regions, such as southern Africa and some parts of Asia and Latin America. On the other hand, in temperate regions and tropical highlands, production may increase due to warmer weather. In the East African highlands for example, higher temperatures may result in land becoming unsuitable for wheat but more suitable for other grains.[28]

A consequence of these expected changes in production potential (increasing in mid- to high-latitude areas and decreasing in low-latitude areas) will be a shift in global trade patterns. Generally, production and trade flows of high-latitude and mid-latitude products are expected to increase, with products such as cereals and livestock products being exported towards low-latitude regions. However, the exact nature of these shifts remains unclear, and more research is needed before policy-makers can properly understand the likely implications.

1.3.6 Bioenergy and sustainability in agriculture

Energy is at the centre of the development challenge in many developing countries, with inadequate energy supply hindering capacities to expand production and improve human wellbeing. In the context of global efforts to address climate change and its impacts on agriculture, many developing countries are credited with significant potential to produce agriculture-based energy sources. Several studies have shown that, if properly managed, the high technical potential of bioenergy in regions such as sub-Saharan Africa could make a significant contribution to fighting poverty while also addressing climate change and expanding trade opportunities in sustainable energy products. This would seem to make bioenergy development a particularly beneficial strategy for oil importing developing countries.

However, such a strategy would need to be carefully designed and managed as the large-scale production of biofuels poses a number of significant challenges. First, it is important to fully analyse all aspects of bioenergy technology, in particular, the crop type. A comparison of arable land requirements for a given amount of energy production shows that soybeans require almost 12 times as much arable land as sugar cane, while corn requires twice as much land as sugar cane.[29] This means that to replace 25 per cent of the transportation energy from fossil fuels with energy from liquid biofuels would require 430 million hectares for sugar cane – 17 per cent of the world's arable land[30] – and 5 billion hectares for soybean – 200 per cent of the world's arable land. The competition with food crops on land and resources (e.g. water) is clear. Biofuels therefore should be viewed as one potential source of energy to be used in combination with others.

1.3.7 Structural policy reforms

In the 1970s, many African countries like Malawi, Kenya, Zambia and Zimbabwe were net exporters of agricultural products and farmers in these countries were recipients of government support. This trend changed drastically in the 1980s when the debate on food security in Africa was marked by two major trends. One was growing concern on how to continue 'feeding the cities' (which shifted the policy emphasis to sustaining and providing the growth of cities in Africa, thereby neglecting agricultural development) and the other concerned Structural Adjustment Policies (SAPs).[31]

The food insecurity situation in Africa today points to a serious failing of development strategies at both the national and international levels. Addressing the UNCTAD Trade and Development Board in 2009, AGRA's Vice President for Policy and Partnerships Mr. Adesina asserted that the problems facing smallholder farmers in Africa today are "*a result of missed opportunities and decisions made by governments and international institutions rather than a result of stubborn facts*".[32]

Africa's agricultural sector has implemented programmes designed to eliminate price controls, privatize state farms and state-owned enterprises, abate taxes on agricultural exports, remove subsidies on fertilizer and other inputs and encourage competition in agricultural markets. The effectiveness of these programmes is disputed.[33] For their proponents, such reforms have improved market efficiency, reduced budget deficits, stimulated export production, and increased the share of the final price received by farmers. Opponents point to the destabilization of agricultural prices, the widening of the income distribution gap, and reductions in access to low-cost inputs.[34]

The agricultural sector continues to face structural and institutional constraints in most African countries, including issues of ownership, access and security of tenure of land, access to credit, the marketing system and the fluctuation of prices, as well as low farm gate prices. The longstanding policy failures leading to such problems in the agricultural sector must be reversed.

1.3.8 Liberalization, agricultural trade and global markets

African agricultural systems are still recovering from liberal reforms of the 1980s that resulted in declining investments in public agricultural research and dismantling of marketing boards and reduced the support to extension services. While global markets and the potential for integration therein will be vital, there are several factors that may not make this an easy transition for African countries. Studies on other developing countries show that the impact of opening up agriculture and removing farming subsidies is most likely to be on crop prices, and not on crop outputs.[35] This is because structural rigidities in agricultural systems tend to stunt the short and mid-term supply response. In the light of the fact that the demand for food remains constant, despite the pressures imposed on the agricultural system to cope with liberalization and removal of subsidies, a short term price increase in food grains is to be anticipated.[36]

1.4 DEVELOPING AND DISSEMINATING RELEVANT TECHNOLOGY

Transfer of technology can occur at several levels. Primarily, the transfer of tacit know-how and skills between people internationally, regionally, nationally or between organisations is recognised to be the most basic and effective form of dissemination of technology and skills. A second important source of technology is the result of the increased specialization in the trade in components and finished products which are causing a shift in production to locations that offer economies of scale as part of global value chains in all sectors, including agriculture.[37] Firms and farms that are part of such production networks benefit from the linkages with buyers and other competitors in the market, wherein not only machinery and equipments are transferred, but also marketing skills, management standards and quality protocols and production systems are shared.[38] However, these two forms of technology transfer require the steady movement or exchange of researchers from international or regional organisations to national organisation within Africa and the integration of local production to global value chains.

These channels can be strengthened through South-South cooperation policies for agricultural development and trade. South-South cooperation offers an important catalyst for addressing the issues of productivity at bilateral, regional and interregional levels among developing countries and in building food security. Such cooperation can include exchange of best practices, technologies and technicians on agricultural production. It can be undertaken within the framework of sub-regional or regional organizations of developing countries through dedicated agriculture and food sector development programmes and trade programmes. South-South cooperation offers an ideal avenue through which constructive discussions could take place between food surplus countries and food deficit countries on meeting the food needs of the latter without undermining those of the former.[39]

A third form of technology transfer is market-driven, where potential technology seekers (firms or individuals) from developing countries seek partners in the technologically advanced countries to acquire relevant technologies. The motives for the users to seek these technologies mainly stem from the expectation of benefits such as reduced costs and increased output (see the case of Zambia in chapter 2). Such market-driven technology transfer is largely dependent on the ability of the technology seeker to pay the market price of the technology (which may or may not include tacit know-how transfer). In addition to purchasing ability, a range of other factors impede the ability of the technology seeker, such as lack of bargaining power, increased search costs in finding the right partners and most importantly a lack of quid pro quo in the technology licensing/ technology sharing contracts.[40] A large number of such technology transfer efforts do not materialize since the size of the market and the ability of the technology seeker to pay for the technology does not meet the expectations of the technology holder. This is especially true in small markets or markets where the majority of the potential technology users are poor and have no ability to pay, such as the agriculture sector in Africa. Chiefly as a result of this, public-not-for-profit entities have been actively engaged in promoting the dissemination of technologies in the agricultural sector in recent times.

Scientific and technology partnerships are thus increasingly vital for African countries seeking to address issues of food security. To a certain extent, the ability to sustain large-scale in-house R&D efforts that conferred clear advantages upon larger countries and firms in the past in the agricultural sector can also be matched by the flexibility and size of the network to which smaller producers belong. Such networks and partnerships provide critical support to innovative activity at the technological frontier.[41]

1.5 THE IMPERATIVE OF DEMAND-LED APPROACHES TO AGRICULTURAL DEVELOPMENT

Despite concerted efforts by different international and national organizations to promote food security and reduce poverty by way of stimulated trade efforts and introduction of improved crop and animal breeding varieties, Africa remains food insecure and farming communities generally remain poorer than those engaged in manufacturing and services. Some exceptions do exist, as demonstrated by the experience of the horticulture industry in East and southern Africa and cassava in Zambia (see case studies in chapter 2). In these cases, partnerships and intra-firm trade have played a central role in helping African producers to offer value-added within global value chains. Value chains denote inter-connected activities offered by firms, cooperatives or individual entrepreneurs towards creating, developing and producing a particular product or services at different nodes of the production chain. Integrating small-holder farmers into global value chains can help to significantly upgrade their activities by enabling them to access product design/ delivery information and also prescribing quality standards that need to be adhered to. They provide small-holder farmers the relevant access to the services provided by a network of information, credit and service providers, suppliers, buyers and processing companies.

Contract farming provides yet another way to raise small-farm income by delivering technology and market information to small-holder farmers and incorporating them into remunerative new markets. Critics of contract farming see it as a means by which agribusiness firms take advantage of the unequal bargaining relationship to pass production risk to farmers. However, well managed contract farming has proven effective in linking the small farm sector to sources of extension advice, mechanization, seeds, fertilizer and credit, and to guaranteed and profitable markets for produce. Another model is to stimulate demand and improve productivity through targeted support such as in the case of cotton where training, credit, market development and agriculture inputs are made available.

Despite such advantages, supply-led approaches such as global value chain promote products that have a regional/global market and are not a mechanism through which the prevailing local demand for specific agricultural products can be reflected. Strong productivity and (real) income growth which is key for industrialization of countries,[42] however, derives mainly from the ability to achieve scale economies in production, specialization and technological learning on the supply side; and on the demand side, the ability to respond to demand.[43]

The real challenge that remains is one of matching supply led approaches by demand-led ones. There have been several models in recent times, including the community-driven development (CDD) approach of the World Bank, where the focus is on empowering communities to take charge of their development processes and options.[44] Other approaches seek to enhance farmers' ability to upgrade and compete such as out-grower schemes in flower and vegetable production systems. These schemes present new ways of bringing together producers and agribusiness and they establish and enforce grades, standards and regulations, improve the investment climate and provide essential public goods such as rural infrastructure. The schemes have the potential to support equitable and sustainable development as they recognize the market, socioeconomic, cultural and management aspects of rural farming and link these to public policy and good institutional settings aimed at sustainable and profitable agriculture.

This report suggests the innovation systems approach as a potential means to view agricultural systems. Although there are several common sets of actors in value chains and innovation systems, value chains emerge and respond to market needs (global, largely) whereas innovation systems tend to be local demand driven.

1.6 RETHINKING AFRICAN AGRICULTURE FROM AN INNOVATION PERSPECTIVE

Comparative advantage in agricultural resources by itself is a static condition that can no longer form the basis for competitiveness. Such initial local advantages need to be supported through technological improvements that render production competitive. The notion that divides sectors into "hi-tech" and "low-tech" based strictly on R&D-intensity is misleading viewed against the progressive intensification of knowledge across all sectors. This suggests clearly the need to move beyond the linear conceptualization of technological progress as doing R&D to a more systemic notion that includes other actors to factor in these realities.

An innovation system is a network of actors, both market and non-market oriented, collaboration and linkages amongst whom is the basis for learning and commercialization of products cater to local demand. Such "systems of innovation" involves purposive actions of governments in the deliberate creation of organizations and incentive mechanisms to foster the creation, transfer, adoption, adaptation, and diffusion of knowledge. These non-market avenues are necessary (contrary to the pure market view) because the market alone is a poor filter for technical change, which is the locus of production and innovation. All the other non-market coordination mechanisms are particularly important, but they are notably weak and suffer from poor systemic coordination in developing countries. Prominent among these are what this report classifies as the enabling environment for innovation, and includes the structures of research and development (R&D), finance support, metrology, standards and quality centres, and, at the base of it all, the system of education, which is responsible for new knowledge from basic research and the training of scientists and engineers.

Declining agricultural productivity in many developing countries can be reversed through building what are called agricultural innovation systems that provide the enabling framework not only for the adoption of existing technologies and the development of new ones that are suited for African needs. Agricultural innovation systems denote the network of economic and non-economic actors, and the linkages amongst these actors enable technological, organizational and social learning of the kind needed to devise context-specific solutions. The linkages are both vertical (supply chains, organisational support, firm structures) and horizontal (extension services, market access infrastructure). The dissemination of already existing technologies from outside could help this endeavour, but a major challenge relates to the ways and means in which innovation that is relevant to African agriculture could be promoted.

However, the ability of the agricultural innovation system to be able to access, use and diffuse knowledge embedded in such technologies depends on the presence of an enabling framework that supports the emergence of technological capabilities by strengthening existing linkages, promoting new linkages and fostering inter-organisational learning that leads to capital accumulation and technical change. Such an enabling environment, by definition, is one that strengthens the absorptive capacity of local actors while protecting their interests through a policy framework that recognises their legal rights and privileges, linkages, socio-cultural norms and historical context. This report defines an enabling environment for technology and innovation in agriculture as one that provides the actors, skills, institutions and organizations required to promote the use, dissemination, diffusion and creation of knowledge into useful processes, products and services.

The objective of innovation policies is primarily to encourage linkages between the different actors of the innovation system. This requires an integrative and holistic approach to policy formulation and demands close interaction between the different ministries whose policies have an impact on innovation and performance of the economy as a whole (national innovation system) or specific sectors (ICT, agriculture, health, electronics, etc). In addition to the misconception that innovation is just for the more advanced countries and the limited understanding of what innovation means in a developing context, the huge scope for formulating an innovation policy ideally designed for developing countries undoubtedly constitutes a major challenge in Africa.

Viewing agriculture through an innovation lens is becoming more prevalent in policy circles in recent times. For example, the Framework for African Agricultural Productivity (FAAP), developed by the Forum for Agricultural Research in Africa (FARA) and its partners, also advocates putting farmers at the centre of agricultural innovation systems by empowering them to be active players in improving agricultural productivity, not just in terms of increasing their yields, but also in decision-making on how programmes and policies are shaped. The existing national agricultural research systems in sub-Saharan Africa require more efforts towards training, education and revamping the extension services. FARA recognizes that the role of extension systems must shift from prescribing to facilitating. Moving towards more participatory agricultural extension will allow greater responsiveness to farmers' needs and facilitate learning on how they can increase their own productivity, raise their incomes, collaborate effectively with one another (and with partners in agri-business and agricultural research), and become actively involved with major stakeholders in determining the process and directions of innovation, including technology generation and adoption.[45]

We argue in this report that developing strong capabilities in science, technology and innovation are key elements that are needed for agricultural firms and farms just as it applies for manufacturing and industrial firms. The capacity to innovate - defined as the ability to introduce products, processes or organizational methods in design, production, marketing and distribution *that are new to the local context although not to the rest of the world* - is becoming increasingly important as global competition increases in markets for manufactured goods, services and even primary produce. This is especially so for production geared towards export markets, but may apply even to production geared towards domestic consumption in developing countries given widespread import liberalization and the gradual lowering of tariff rates. The need for improved innovation capabilities will likely rise further in light of variations in climactic conditions as well as continued intense competition, the proliferation of standards in food production and processing and fast changing consumer preferences in food markets, even in developing countries. Improved STI capabilities will also continue to be needed if higher value addition in agriculture and food systems through local processing of agricultural produce into food products that command higher prices and provide higher incomes - which many developing countries are striving to achieve - are to be realized.

1.7 AGRICULTURE AND ECONOMIC TRANSFORMATION OF AFRICA

Three key issues confront African agriculture today. First, there is a need to enhance productive capacities that could in turn increase yield and reduce the environmental and other impacts of agricultural expansion. Second, there is a drastic and immediate need to raise the living standards of people working in agriculture. Over two thirds of the African continent is presently dependent on agriculture for livelihood and characterized by extremely limited access to health, nutrition and decent environmental standards. Over 70 per cent of child labour worldwide is found in agriculture. This calls for immediate and urgent action to improve the living standards of the people engaged in agriculture.[46] Finally, there is a need to lessen the demographic burden on agriculture in Africa by creating an institutional basis for diversification of economic activities into other sectors. This will not only be important for agriculture but also for the overall sustainable development for African countries.

The vicious cycle of poverty equally forecloses the imperative of investment in what is most urgent, the need to commit resources to building innovation capacity: investing in scientific and engineering manpower, building laboratory and industrial facilities to focus on urgent local food and disease problems. In other words, we need to address urgently the challenges of institutions, infrastructure and human resources that lead to exclusion and deprivation and secondly to break the cycle of lack of access to credit in poor African countries.

A well-focused long-term growth strategy for Africa is one that employs the twin strategy of investing in dynamically growing sectors, while at the same time, enhancing the productive capacity of the agricultural sector, where most of its labour is presently employed.[47] Agricultural systems, which employ the largest, poorest and most uneducated labour force, need to be firmly linked with the dynamically growing sectors of the economy. As UNCTAD (2006) has identified, the most effective approach clearly will be one that promotes simultaneous investments in agriculture, industry and services, and promotes exports that primarily focus on the local value-added.

A systems of innovation perspective for African agriculture shows us the intricate and complex linkages between agriculture, nutrition, health and other dynamic sectors of the economy. For this reason, income, per capita yield of crops output and capacity improvements that promote crops that the majority of small-holder farmers produce will be key to solving the poverty problem.

1.8 SIGNS OF SUCCESS

Despite the challenges faced, there are several success stories of African agriculture that serve as benchmarks going forward.[48] These include:

- Several new technologies-based developments, such as biological control of the cassava mealy bug and tissue culture applications of banana, pineapple and other agricultural products
- Agriculture based production systems – such as pineapple cultivation in Ghana and the cut-flower cut flower sectors in Kenya, Ethiopia and the United Republic of Tanzania– have been successfully developed,
- African agricultural producers have made their presence felt in several important global value chains such as coffee suppliers from Ethiopia and Mozambique,

BUILDING INNOVATION CAPABILITIES IN AFRICAN AGRICULTURE

2.1 INTRODUCTION

This chapter attempts to apply innovation systems framework to African agriculture as a potentially useful tool for identifying weaknesses in the agricultural production and innovation system of a country. Such a 'gap analysis' is a necessary step in developing policy actions to support agricultural development, both for the short term and the long term. The components of an agricultural innovation system (as illustrated in Figure 14) include the actors, institutions, organizations and policies that together support innovation in agriculture, along with the infrastructure and financing mechanisms that enable it. The characteristics of these innovation systems may vary significantly between (and even within) countries, which make country-specific analysis necessary, but there remain some common issues that affect many African countries to a greater or lesser extent.

A number of features differentiate an innovation system from both the traditional production oriented, equilibrium-based models of the economic system and from the narrower focus on science and technology systems that were an earlier effort at dealing with the role of technological change in economic development. An innovation system is conceptualized as a network of firms and other economic agents who, together with the institutions and policies that influence their innovative behaviour and performance, bring new products, new processes and new forms of organization into economic use[49] The focus is on interaction between these actors and the institutional and policy context that influences their innovative behaviour and performance.

The scope of potentially important economic actors in an innovation system also differs from the set of suppliers and clients arrayed along the classic value chains and incorporated into input-output models or from the set of organizations-- universities, public sector research bodies, science councils-- that are the traditional focus of science and technology studies. There is no assumption, moreover, that an innovation process is linear or that knowledge outputs feed directly or automatically into products for sale in the market. Instead, the knowledge and information flows that are at the core of an innovation system are multidirectional in nature and open opportunities for the development of feedback loops that can enhance competence building, learning and adaptation.

The innovation system approach factors in the demand-side of innovations, thus centring attention on local demand for particular products/ processes, such as those for particular crops, medicines or essential goods that form part of development concerns. Demand flows are amongst the signals that shape the focus of research, the decision as to which technologies from among the range of the possible will be developed and the speed of diffusion of these technologies. Demand is not solely articulated through the market, but may take place through a variety of non-market mediated collaborative relationships between individual users and producers of products and services. In still broader terms demand can be intermediated by policies. Enhancing knowledge and information flows is yet another way to stimulate innovation and facilitate adaptive policymaking.

In applying the sectoral innovation system framework to agriculture, this chapter shows how policy makers could build a supportive enabling environment for agriculture, especially for smallholder farmers. Appropriate policy actions to enable such an environment will be important to promote the development of the agricultural sector to respond to both internal and external stimuli.

2.2 INNOVATION SYSTEMS AS A POLICY TOOL

Across sectors and time, different configurations of critical actors will emerge from among the multitude of organizations -- industry associations, R&D and productivity centres, universities, vocational training institutes, information gathering and analysis services, engineering services, banking and other financial mechanisms, standard setting bodies -- whose relationship to the innovation process within a sector or system-wide level might prove critical. Yet today, we have little information about the range of actors that currently exist in the local/national or sector context, their competences, habits and practices of learning and interacting or the propensity to innovate. How different social norms, practices and other institutions affect the processes of learning and innovation in a given national or regional context is also poorly understood. Policies are rarely monitored or evaluated thus limiting our ability to assess the way in which current policies affect the parameters within which the decisions of local actors with regard to learning, linkages and investments take place.[50]

Whether tacit or explicit, policies play a role in setting the parameters within which actors make decisions about learning, investment and innovation for all sectors in an economy. The innovation systems approach recognizes that policy dynamics supportive of an innovation process are not the outcome of a single policy but a set of policies that collectively shape the behaviour of actors. The need for an overall innovation strategy, for priority setting and for policy coordination is thus critical in strengthening innovation systems whether at the national, local or sector levels. From a policy perspective, the innovation system approach has a number of important strengths. Policy dynamics, moreover, are generated by the interaction of policies with the behavioural norms and attitudes of actors that they seek to condition. Learning and unlearning on the part of all actors including policymakers are thus essential to the evolution of an innovation system in response to new challenges.

Monitoring the policy dynamics generated by the interaction between policies and actors in the system and opening channels for dialogue, for example, would be of importance in fine-tuning policies for maximum impact and responsiveness to changing technological and competitive conditions. Policies thus have an important role to play in reinforcing older norms and rules or in stimulating and supporting change. Its dynamic strengths are also evident in the stimulus it provides for a re-conceptualization of sectors as potential 'innovation systems'. The framework derives from the experiences of other countries, mostly industrialized and more recently some developing countries, in severeral traditional and modern sectors, including agriculture.

Most importantly, the framework recognises that the capacity to innovate will involve a system of diverse organisations or actors, notably the private sector but also others outside of the State, whose actions are shaped by a variety of institutional, policy, market and technological signals. The framework is therefore particularly suited to exploring sectors where the private sector and other non-governmental actors are playing leading roles and where firms, sectors and countries have to cope with shocks and deal with competitive pressures.

2.2.1 Characterizing an agricultural innovation system

An agricultural innovation system (AIS) can be fundamentally characterized as the set of actors, the collaborative linkages between whom are critical for the development of products/ processes or services that are new to the local context where they are introduced. These linkages are primarily fostered through policies and institutions (that refer to the rules of the game, as set by laws and regulations or simply cultural and social attitudes) that promote access, diffusion, use, adaptation and creation of new forms of knowledge in agricultural production through learning mechanisms of various sorts. R&D and science conducted within centres of excellence and premier institutions within the country and outside, is one such form of knowledge, but not the only one.

From the standpoint of this definition, one is forced to ask the obvious question: do agricultural innovation systems exist at all in African countries where private sector is largely absent, governmental R&D spending is marginal and technological capacity is not well advanced? If we were to assume so, what are the points of departure of African agricultural systems of innovation?

Three major factors stand out while analysing agricultural innovation in Africa. First, the private sector is conspicuous largely by its absence, rather than for its proven ability for product development as is the case in the industrialized countries. The systems of innovation at the sectoral level are quite often so stymied by the absence of private enterprise that most research results from the public sector do not find their way to the market.[51] The point to take home here is two fold: the knowledge base is more dispersed than what we know from our experiences of studying agricultural innovation systems from industrialized and other developing countries, and the organisations that play the critical role in applying existing knowledge or generating new knowledge through learning activities are in the public sector.

Second, the market for agricultural products is severely fragmented in African countries and this stunts advance that require demand and supply side coordination. In other words, local demand never gets codified into local research or innovation agendas due to information asymmetries within user-producer networks[52] as a result of which directed and targeted investment into R&D capacity (even in the public sector) does not materialize. Markets in African countries not only have relatively small size (thrive on personal exchanges of kinship relations, personal loyalty and social connections) but also fit in many respects with types of markets that are characterized by low profitability, limited economies of scale and low intensity learning that slows long run technological capability building. These shortcomings of markets needs to be addressed by policy, because in addition to articulating demand, markets are important for transfer of technologies in agriculture, especially those related to biotechnology and other advanced technological applications through arms-length transactions.[53]

Finally and perhaps most importantly, technological advances in agriculture of relevance to Africa has not progressed in an adequately coordinated manner and is largely at its infancy. Historical constraints that have prevented a large set of countries from enjoying the benefits of a well-coordinated education and public research system either as a result of their colonial heritage or structural policy reforms persist and these remain a major impediment to the emergence of an indigenous African agriculture revolution.

2.2.2 Mapping key actors and linkages

Actors or agents operating in the sectoral system include individuals such as farmers, enterprise owners, and engineers/ scientists; and organizations including enterprises universities and firms, R&D departments, financial institutions such as development banks, and intermediary organisations such as seed banks and providers of extension services, such as marketing boards, cooperatives among others. There are important attributes of the actors that mediate the innovation process including ownership structures (whether firms are owned by multinationals or local entrepreneurs), size and extent of local enterprise, quality of local research institutes, available human skills, among others.

Since innovation processes are heterogeneous, factors and policies that may trigger off optimal interactions between various systemic counterparts vary from one country to another. The schematics in Figure 2 captures some of the triggers to collaboration incentives which feed into the system from multiple sources namely, international and national policies, finance institutions, physical infrastructure and extension services and local market orientation of research and products. A range of externally imposed factors, such as the multilateral trade regime and intellectual property rights, play a large role in determining the ways and means in which innovative capacity is built, sustained and deepened over time in developing countries.

A wide variety of governmental agencies, such as those that provide finance and help mitigate risk amongst firms, those that specify and enforce agriculture-related laws and rules, those that enable parties to contract and conclude agreements, all play a key role. Finally agencies that represent collective demand, such as farmers associations and collectives are a critical set of actors.

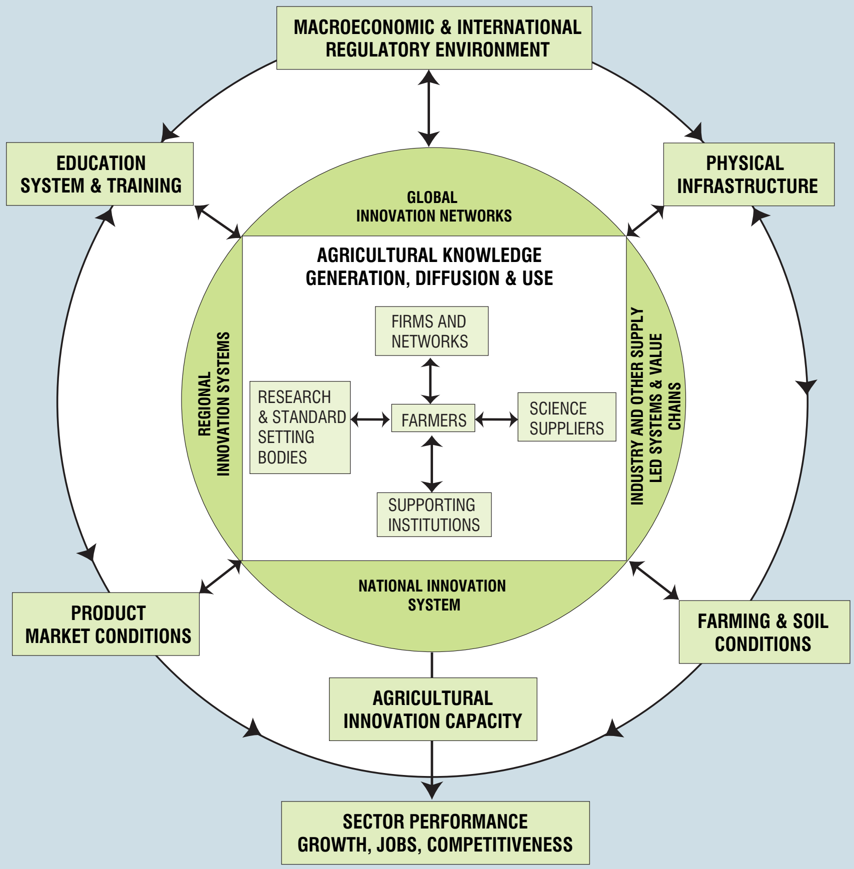
The widely dispersed knowledge base as well as the complex processes involved in bringing products from the firm to the farm makes a range of knowledge interactions critical to competence building within the AIS:

- Knowledge interaction between university departments, centres of excellence and public research institutes conducting research of relevance to agriculture;
- Knowledge interaction between traditional knowledge holders (farmers communities) and other more research-based and product development actors;
- Knowledge interaction between local and foreign firms and universities;
- Knowledge interactions between local and foreign firms and domestic research institutes;
- Knowledge interactions between local and foreign firms engaged in product, service or process innovations;
- Knowledge interactions between farmers, consumers, seed banks and other intermediary organisations that help gauge local demand and issues imminent to the agricultural system;
- Knowledge interactions between farmers and providers of extension services, such as marketing boards
- Knowledge Interactions between various governmental agencies responsible to promote these competencies locally.

2.3 INNOVATION AS AN INTERACTIVE PROCESS

The absence of linkages between the key actors not only prevents the ability of the agricultural system to use available knowledge to innovate and respond to local demand, but it also stymies its ability to be

Figure 2: Actors and linkages in an agriculture innovation system



Source: Adapted from OECD, (1999)

resilient in the face of external shocks, such as that posed by the global food crisis. In the context of an agriculture system of innovation for countries, linkages are rendered even more significant due to two reasons. First, the main users and creators of new applications (the farmers) are largely unskilled and uneducated. Second, a majority of the smallholder farms have functioned in isolation from the African knowledge and information systems that until now was the predominant model for promoting agricultural development in countries. It is their isolation, more than any other factor that makes them susceptible to external and internal shocks, and also impedes their ability to recover and respond. Linkages that enable them to be well networked into the innovation system are critical to enable them to consolidate their activities. This report identifies the following forms of linkages to be of importance to policy.

2.3.1 Linkages between scientists and practitioners, including farmers

Linkages between two potential networks or communities, namely the scientists and the practitioners (including farmers), engaged in the process of agricultural innovation are critical for the development of productive capacities over time. The first is the research-intensive public science, organized largely around those creating new knowledge through intensive R&D activities and creative design that initiate entire processes of innovation. Although it is difficult to draw the lines conclusively, basic research (and some applied) tends to be the domain of universities and highly advanced public laboratories while firms tend to focus more on applied and developmental research. This was largely led by the public sector organisations even in the industrial countries, up until recent times, because private firms tend to have little incentive to engage in socially relevant basic research. In recent times, trends that promote the commercialization of university/ public sector research through policy incentives such as intellectual property rights have blurred the boundaries between basic and applied research, as well as tended to promote the privatization of some basic research. The second is a set of actors driven largely by commercial motive of translating inventive or design work into products processes and services; they are made up of engineers, scientists and technicians and practitioners, such as farmers. Both these communities may overlap at times, and they are found in networks created to advance technological innovation. The knowledge base of both these networks comprising farmers, producers and organisations grows on the basis of routine learning-by-doing where the individual capabilities of actors are largely tacit.

Public research of relevance to agriculture has suffered from two concomitant pressures: on the one hand, research expenditure for agriculture research has been on the decline and on the other, there has been very little attention given to applied research and product development that builds on on-going research in the local research institutes and universities. Some of this can be attributed to a widespread attitude of local actors (including policy makers) that relegates local research to be of lesser quality and relevance than international research and technological advances. Together these factors have resulted in the lack of collaborative linkages between African scientists, local technology developers and farm-level activities which needs to be addressed urgently.

2.3.2 Horizontal linkages between farmers and extension services

Promoting innovation capabilities among African farmers will depend on strengthening the linkages between farm-level users and the extension services that link them to the markets and other user-producer networks. Trade liberalization and fiscal austerity as a result of structural adjustment programmes have led to reduced public investment in extension services and large-scale abandonment of marketing boards that served to coordinate farmer production in a wide variety of ways.[54] These exacerbate the already huge challenges faced by farmers such as the inadequacies in infrastructure and financing mechanisms and weak linkages between research and on-farm activities.

More recently, evidence suggests that agricultural reform programmes have shifted to addressing issues such as inadequate rural infrastructure and crop storage capacity, the affordability of inputs, the quality of agricultural research, the accessibility of credit, the effectiveness of extension services and the availability of basic social services such as health and education.[55] While this is a step in the right direction, further strengthening of horizontal linkages is required to address the non-technological constraints to agricultural production and innovation as outlined in Table 1.

Table 1. Important non-technological constraints to agricultural development[56]

Constraints	Possible solutions
Lack of agronomic research and information systems	New models of public-private collaboration in technology development and dissemination are needed that will be pro-active in seeking out, adapting and disseminating new technology from international research centres and private sources
Lack of market-support services	In cases where improved technologies have been developed, the ability of farmers to use them has often been impeded by high distribution costs, caused by poor infrastructure, high transaction costs, and policies that thwart private investment in the system.
Tax reforms and high energy, input, and infrastructure costs	Fiscal benefits favourable to agriculture, VAT policies, import duty remissions, simplified tax on gross revenue, export tax, tariff structures.
The structure and set of regulations in place to manage agriculture activities and resources	Good governance, decentralization, and farmer empowerment are key to agricultural transformation and global integration in this regard; It is important to address natural resource depletion (fisheries, forests, water supplies); Combat disease, prevent pests; Manage land and water rights.

2.3.3 Linkages between the farming and non-farming systems

The prevailing understanding of economic development and how it occurs leads us to believe that development results from technological progress that enables surplus labour and resources to be reallocated to manufacturing and to services (in the order mentioned here).[57] The evidence on economic development as seen in a broad range of countries largely substantiates this view, although there is recent evidence from other developing countries, such as India that there could be a direct progression from agriculture to services, with little focus on manufacturing. Regardless of this, developing productive capacity for agriculture in African countries will be a pre-requisite for both agricultural and non-agricultural development. The linkages between farming and non-farming activities are therefore important for a variety of reasons. A range of non-farming activities generates income for rural households either through work for wages or self-employment.[58] These activities are predominantly closely linked to the farming and the food chain and have potential for employment, income or growth. Such activities include food and fish processing, labouring and foreign remittances. Some African countries, for example, Senegal, have relied on non-farming activities to make up for 50 per cent of rural income since 1960s.[59]

Linking farming with non-farming systems is also important because although the agricultural innovation system has its own knowledge base and learning processes, it is connected indirectly with policies, activities and processes outside its own sector boundaries. Some institutions (e.g. basic service and utility organizations such as security, customs, water and electricity boards, and research conducted in universities and research institutes) connect with all sectors. Cross sector linkages between agriculture and other sectors result from collaborations between R&D performers and users with different levels of knowledge (technical information, field experience, scientific research results, among others).[60] Agricultural innovation is also dependent on advances in other sectors, such as biotechnology, which may have the potential for agricultural application. It is therefore important that policy recognises and promotes such inter-linkages.

2.4 LINKAGES BETWEEN FARMERS, GLOBAL NETWORKS AND VALUE CHAINS

Demand –led approaches, such as global value chains, can be a very useful mode of transfer of technology and production information (including quality protocols) in specific products that may have global markets. The past decade has witnessed a steady integration of several agricultural products from African countries into established global value chains, including Ethiopian and Mozambique's Coffee, cut flowers from Kenya, Ethiopia and the United Republic of Tanzania among others. Integrating small-holder farmers into global value chains can help to significantly upgrade their activities by enabling them to access product design/ delivery information and also prescribing quality standards that need to be adhered to. They provide small-holder farmers the relevant access to the services provided by a network of information, credit and service providers, suppliers, buyers and processing companies.

The examples below show how the immense potential of African production that has remained largely unrealized is being transformed through the initiatives of grower groups and the private sector enabling farmers to sell directly to wholesalers by linking African food producers who normally operate in relative isolation to international value chains.

2.4.1 Banana value chain: the case of East Africa

There are several widely varying cultivars of banana, which are either grown as a staple crop (plantains and East African highland bananas) or traded as a commodity on global markets (dessert bananas, predominantly of one cultivar: Cavendish). The NGO TechnoServe and the fair trade company AgroFair both looked at how to transform the banana sector and change the fortunes of banana farmers by reforming the market chain. TechnoServe, for example, used a 'value chain analysis' approach examining each step in the life of a banana crop, and identified one important sticking point – farmers could not afford to buy fertilizer or other inputs and banks would not lend to banana growers. All this made farmers sceptical about the possibility of turning bananas into a cash crop, especially as many had lost money to traders and brokers in the past.

AgroFair, for its part, looked at the value chain of export bananas. The export Cavendish banana industry is typically considered high-cost and price-sensitive. On the cost side, the banana industry exhibits economies of scale and is highly capital-intensive in both production and transportation. Since small-holder farmers cannot reap any scale benefits, they often have to bear a high cost price due to low yield and efficiency. On the price side, global banana markets play a balancing role in that they fill on a spot basis the difference between supply and demand. However, since small-holder farmers often lack the means to access these markets, their position becomes insecure if prices are low and/or fluctuating and therefore not covering the real costs. AgroFair has turned the chain 'upside-down', by pooling the small volumes of small producers into a stable, marketable offer. The model places the small banana farmers at the centre of the value chain and allows them to co-own the AgroFair company. The producers have an influence over the company's commercial policy, are paid dividends and receive technical and organizational support. This type of value chain ensures that small banana farmers receive a fair price and enjoy a long-term, stable relationship with other players in the value chain. This kind of model has shown that small producers can be good partners in the export banana chain.

2.4.2 Cassava value chain: the case of Zambia

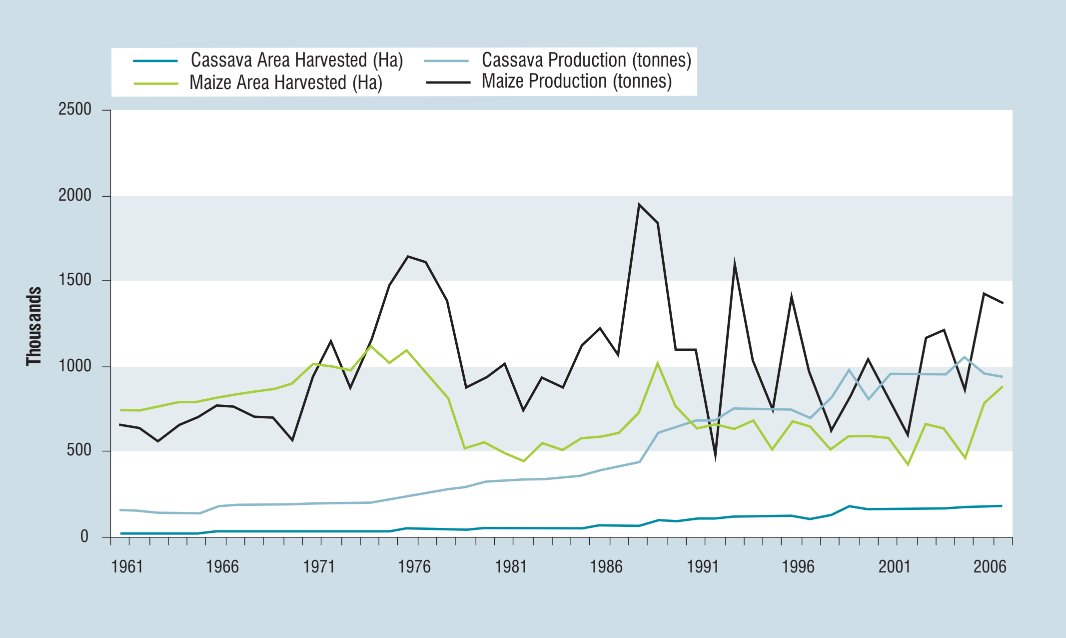
Cassava, the staple food crop in northern Zambia, saw rapid production growth over the past fifteen years (see Figure 3), at times overtaking maize, Zambia's other staple food.

In Zambia, a two-pronged approach to the commercial promotion of agricultural supply chains was undertaken to accelerate the production of cassava. This involved a multi-stakeholder taskforce that identified and addressed bottlenecks, and a team of innovators who developed markets. The bottlenecks revealed by the taskforce's analysis included, for example, the absence of trading standards, poorly coordinated market information, the need to transport produce over long distances, small volumes and consequently high marketing margins. The taskforce also identified five distinct supply channels linking cassava producers with various final markets, ranging from subsistence consumption to the commercial sale of industrial starches and related products.

Prior efforts to increase cassava production had focused largely on a supply-led strategy of promoting food production among subsistence households. Instead, the taskforce adopted a demand-led strategy, focusing on market development in both trade and upstream processing industries, all of which stand to benefit from access to low-cost, cassava-based carbohydrates. The taskforce anticipates that expanding commercial markets for cassava will motivate farmers to increase cassava production as a cash crop. The hope is that as production grows, household food security will improve too.[63]

The Zambian experience illustrates the advantages of an approach that combines value chain analysis with a stakeholder taskforce that ensure that the team's understanding of opportunities and constraints gets translated into actions that will facilitate commercial growth. It should be noted that the increase in cassava production can also be attributed in part to the development and introduction of new cassava varieties by IITA in northern Zambia. These improved cassava varieties are tolerant to disease and pests, have early maturity and produce yields up to three times as large as those of most local varieties.

Figure 3. Maize and cassava production in Zambia, 1961–2008[62]



2.4.3 Other examples

Other innovative models for promoting agricultural innovations include the case of the Ethiopian cut flower industry and the Kenyan horticultural industry. The latter example is primarily a private sector story, with entrepreneurs and farmers innovating and taking chances. The interactions and roles played by these partners are critical for the success of the industry. The Kenyan horticulture industry benefited from three main success factors:

- *External catalysts.* This critical role was played by foreign investors and partners in launching and expanding the industry. Domestic partners were equally critical to the industry's success. Donors played a relatively minor role.
- *Learning and experimentation.* The industry's success is a testimony to the private sector's capacity to adapt to changing circumstances.
- *Political commitment.* The government of Kenya played an effective facilitating role. Its concern for smallholder development helped promote their participation in the industry.[64]

2.5 CREATING AN ENABLING ENVIRONMENT FOR AGRICULTURAL INNOVATION

The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) 2008 report makes the point that *"Agriculture is far more than just the production of food."* This argument is supported in the report by a number of case studies that illustrate that, although macro-economic policy reforms have had positive effects on agriculture in some parts of Africa, the overall impact of the reforms has been slower and less dramatic than could have been expected. The main reason for the reforms' restricted impact is that the constraints to achieving sustainable agricultural productivity and increasing yields lie both on and off the farm. Hence, in many cases, transportation, trade, and macroeconomic policies have stronger effects on farmer and trader incentives than do agricultural sector policies, a point that underscores the need for better policy coordination across ministries. Strategies should therefore focus on transforming the weak points along the food system as a whole, and avoid too narrow a focus on farming. This calls for policy coherence. Some examples of best practice in this regard are already available. For instance, in the late 1990s, the Ghanaian Ministry of Agriculture was authorized to coordinate the budget requests of five other ministries whose activities had a strong impact on agriculture.[65]

2.5.1 What is an enabling environment?

An enabling environment is a broad concept that has been interpreted in numerous ways. A broad definition could comprise all factors external to firms, including the policy, legal, and regulatory framework; governance and institutions; physical security, the social and cultural context of business, macroeconomic policies, access of firms to financial and business services, and the availability of physical and social infrastructure services.[66] This report defines an enabling environment for innovation as one that provides the resources required for building a complex multidimensional and dynamic range of knowledge, skills, actors, institutions and policies within specific political-policy structures to transform knowledge into useful processes, products and services for agriculture. More specifically, it comprises policies and infrastructure (scientific, human resources and physical infrastructure) that leads to building capabilities for agricultural innovation and production.

The core aspects of an enabling environment include:

- the broader framework for innovation, including legal and regulatory framework for farmers (with land tenure, rule of law and access to justice); the policy framework for technology development, transfer and utilization, including competition policy; and credit infrastructure;
- the institutional and organizational framework concerned with the design, implementation or compliance of policies and programmes for the regulation, promotion and representation of farmers; and
- the provision of physical infrastructure, including roads, ports, water, electricity, irrigation facilities, and internet infrastructure
- dedicated policies for agricultural capabilities that foster collaborative linkages and networking abilities; foster greater information and knowledge flow; and lastly enhance coordination of policies and actors.
- policy incentives that help the agriculture system of innovation to cope with external shocks and constraints, including those posed by obligations under the international trade regime and intellectual property rights on traditional agriculture.

Such an enabling environment would urgently need to address the role of the state to produce optimum levels of public goods, including agricultural research; the externalities of technology use that call for regulatory frameworks, such as biosafety; and the market weaknesses in developing countries that lead to high transaction costs related to information search, and structuring and enforcing contracts. These failures call for greater public investment in research, regulation and institutional capacity development to foster growth.[67]

The capacity for regulatory functions and enforcements of systems of innovation differ, even among advanced countries, but these differences are more pronounced still between African countries and some have limited regulatory and institutional capacity for dealing with imported technologies or creating their own. Moreover, innovation processes are heterogeneous, factors and policies that may trigger off optimal interactions between various systemic counterparts may vary from one country to another. Some models of the enabling framework may work well in particular countries, while some variations may be required to promote agriculture innovation in others. Despite these observations, the core aspects identified here are critical components of enabling structural transformation of African agriculture. Policies designed on the core aspects identified here set the rules of the game not only for the transfer and dissemination of technology, but also influence the development and performance of markets, greater investment and reduce the costs of conducting business in a resource-constrained environment. Consciously creating the enabling environment through a set of mutually coordinated policies is therefore critical to enhancing the capacity of the AIS to produce and use new knowledge, which is fundamental to addressing agricultural and rural development challenges.

Many attempts to introduce new technologies have failed because they do not adequately address the enabling environment within which the technology is to be absorbed, applied and used. For example, while the deployment of agricultural technologies may increase farm yields, these gains can be offset by failures in the distribution network leading to high rates of spoilage.

2.5.2 Strengthening the enabling environment through appropriate policies

A number of policies are needed to strengthen the enabling environment for agricultural innovation in the African context. Viewing sectors or countries through an innovation policy lens lends acknowledgement to a long-overdue fact: that without considering all the key aspects of capacity. Including education and skills building, knowledge-led development will remain a myth. Ex-ante decisions on various aspects of innovation capacity, such as a country's schooling system, its preferences for secondary and tertiary education (whether there should be greater emphasis on natural sciences or other disciplines, whether there should be centres of excellence for tertiary education), investment into public sector research – all impact upon the generation of human skills and availability of knowledge infrastructure to build technological capabilities.[68] These are precisely the factors that have circumscribed the potential of African agricultural systems to innovate and respond to both internal and external opportunities. An innovation systems approach to agricultural policy not only helps to identify these long-term policy lapses, but also helps to suggest short and mid-term policy fixes to address the issue of capabilities required for agriculture. These short and mid-term policy fixes are identified here. In addition to what is listed here, longer term macroeconomic harmonization, rural development and pro-poor policies, policies for education and human resource development, as well as commodity development and enterprise policies will play a role in creating a proper enabling environment.

2.5.3 Policies for physical infrastructure and extension services

Technological innovations do not proceed in isolation, they are accompanied by social, institutional and organisational innovations that facilitate technical change in the first place, and promote the adoption and use of technologies in particular socio-cultural contexts. The presence of physical infrastructure - good roads, ports and airports, internet and communication technologies, water, electricity, irrigation - is a

Table 2. Enabling environment for agricultural innovation[69]

Policy	Function	Intended Result
Constitution, property laws and contract laws	Provides the basic guarantees for land tenure, property ownership and legal certainty	Promote well-planned and structured land management, credit access and basic guarantees of rule of law
National science, technology and innovation policy	Provides the basic framework for innovation in the country Provides coordination mechanisms between various systemic components	Promote technology-led development in all sectors of the economy
Dedicated agricultural development policies	These build further on the national innovation framework and provide additional measures specifically required to promote the growth of the sector	Productive capacity development in agriculture
Industrial property Act	Grants IPRs, specifically Patents and trade marks	Promotes investment and protection of innovation
Biosafety regulations	Ensures human, animal and environmental safety	For the safe transfer, handling and use of GM organisms
Food, drugs and chemical substances regulation	Protects against the adulteration of food and drugs	Sets standards for food, chemicals and drugs
Standards regulation	Sets standards for quality, purity and labelling	Standards setting, verification and implementation of codes of practice (CoP)
Regulations on biotechnology, biodiversity and genetic resources	Ensures balance between the provisions of the TRIPS Agreement and Convention on Biological Diversity for biotechnology and sustainable development	Prior informed consent, protection of traditional knowledge and biodiversity protection
Environmental Management and Coordination	Ensures environmental safety and land management	Provides for environmental impact assessment (EIA)

fundamental pre-requisite for transforming farming operations into more competitive modes.[70]

Policies need to focus on improving the physical infrastructure based on a comprehensive approach that integrates post-harvest storage and processing considerations to reduce losses and add value to agricultural products. This includes the distribution and marketing infrastructure that links farmers to markets. Physical infrastructure must support the capacity of African countries to rehabilitate and develop rural and agricultural infrastructure through investments in: (a) marketing processing and storage facilities; (c) irrigation facilities; and (d) relevant modes of transportation. Investment in essential infrastructure and services for rural communities can provide considerable potential for rural job creation in farming, agro-processing and rural industry.

Policies that focus on extension services should strengthen agricultural institutions as appropriate under national conditions to build efficient, effective and novel forms of agricultural marketing venues. Policies can also focus on identifying and promoting the use of simple technologies that can increase farm outputs and link farmers with agricultural research institutions and markets. For example, buyer-seller networks for agricultural produce can be organised through mobile phone networks, and such schemes have been introduced in some countries such as Bangladesh. Other extension services, such as farmers' organizations, cooperatives, enterprise associations, drought observatories and weather stations, need to be strengthened through greater funding and manpower allotments, or public private partnerships. Most importantly, organisations must be equipped with the capacities to address the economic, social and environmental impacts on agriculture and the affected communities through participatory approaches that involve civil society, local communities, indigenous people and other major stakeholders, including in particular women who are often marginalized in decision-making and policy formulation. For example, the evaluation of post-harvest technologies is best undertaken with the participation of stakeholders and the introduction and operation of a fair and practical grading system that must be supported by training and extension to improve handling, storage and packing, sorting and grading practices.

2.5.4 Policies that promote the complementary roles of private and public investment

Agricultural development in the technologically advanced countries has been promoted mainly through government-based R&D, which figures as the most important policy instrument for the sector, followed by other regulatory measures that allow for commercialization of research results, technology transfer and the creation of intermediary organizations and extension services. As of 2008, the United States government still funds 57 per cent of all basic research and approximately half of all applied research conducted in the country. The business sector invested mostly in applied research and 90 per cent of all product development activities.[71]

The specialization of actors as well as complementarities involved is further demonstrated through some examples. The United States spent an estimated $54 billions on basic research, $ 66.4 billion on applied research and $187.3 billion on development in 2006. In proportional terms, these are 18.7 per cent, 21.3 per cent and 60.0 per cent respectively of total R&D spending. Out of these, private firms in the United States spend three times more on applied than on basic research. Industrial research is in fact dominated by developmental research, which accounts for 90.2 per cent of development work carried out in the country in 2004; universities and related actors spend less than 2 per cent on development research (NSF, 2006). Over 60 per cent of all labour available in Africa is engaged in agriculture and this call for reinforced public investments into research and extension services to enhance innovation capacity.

2.5.4.1 Financing smallholder farmers

Financing for productive activities is often a central constraint for farmers and firms alike. The problem is generally especially intense for informal sector enterprises and small-holder farmers. Indeed, the single most commonly reported obstacle to investment and entrepreneurship in the non-farm rural economy is inadequate access to capital.[72] This is an important handicap, particularly in light of inadequate public sector investment in agriculture in these countries, which means that the issue of inadequate financing and unmet financing gaps undermines both private sector and public sector action to improve agricultural performance. Financial systems in most low-income African countries remain at an early stage of development, and financing of productive activity, and innovative activity in particular, is a major challenge. Microfinance initiatives have proven to be a successful institutional innovation in financial services for micro-entrepreneurs, including small-holder farmers, in some developing countries. There is a need to scale up such initiatives for smallholder farmers where they have already proved successful. There is also a need to both replicate such schemes in other countries where they could work well, and develop other institutional innovations of this kind in situations where microfinance might not be well suited. The need for such financial service innovations for agriculture is becoming increasingly widely acknowledged.[73] Policy support is required also to promote other potential sources of credit for smallholder farmers, including suppliers credit, agricultural development banks, outgrower programmes.

2.5.4.2 New financial instruments and barriers to private investment

In the light of the financial crisis and its impact on African countries, there seems to be a need to consider segmenting banking systems in order to protect some extremely vulnerable parts of the economy from external shocks. One suggestion that has been made in this regard is that of creating specialized banks for such sectors as agriculture and SMEs, which may not appear very attractive to private banks since their sole focus is on profitability.[74] This and other new financial instruments that cater specifically to farmers need to be devised.

Senior African scholars, policy-makers, and private sector representatives suggest the way forward to building an enabling environment for increased and sustainable investment in African agricultural development should include the following three dimensions: (a) governments should provide core public goods to stimulate investment in agriculture; (b) public sector interventions should be a catalyst for innovations that can be sustained by the private sector; and (c) improved data systems are needed to monitor investment in agriculture and the effectiveness of public expenditures.[75] Here targeted policy interventions should focus on the following:

- addressing the links between livelihoods and issues of poverty and vulnerability to understand the complexities of livelihood strategies that influence the choices of specific farming and food systems;
- monitoring markets and consumer trends, and promoting technology and innovation choices that will be relevant to alleviate hunger, address local needs and enhance productivity; and,
- creating new organisations to help farmers cope with the emerging environmental and biological challenges.

Most research that focuses on barriers to private investment fails to focus on investment in agriculture. This is problematic because constraints to rural investment can be quite different from those affecting urban enterprises.[76] Private investments in agriculture depend on the ability of the state to provide basic marketing and infrastructure services. The governments therefore need to take the lead in eliminating structural barriers to agricultural production and innovation. In Mozambique, for example, the three most important constraints to private investment in agriculture include: (a) lack of secure and transferable land tenure and land-use rights; (b) the pervasive problem of infrastructure (roads, bridges, electricity, marketing and storage, ports, irrigation); and (c) problems in financing, particularly difficulties in lending to agriculture and the need for sustainable and innovative solutions such as supply chain financing, warehouse receipts, microfinance techniques, mobile phone banking, point-of-service terminals, credit cooperatives etc. Another study by the National Centre for Agricultural Economics and Policy Research (NCAP) in India found that private investment in agriculture is affected by: (a) public investments; (b) institutional credit provided for medium and long term purposes i.e. loans for creation of asset; and (c) terms of trade (TOT) for agriculture. A separate study, also in India, indicates a strong link between private and public investments in agricultural marketing infrastructure.[77] The analysis found that, when private investment is made in agricultural production, public investment for the promotion of agricultural marketing infrastructure soon follows.

While private investment is a complement that needs to be attracted through appropriate policy measures, focusing solely on private investments will not be a sufficient condition to create productive capacities in agriculture. Private investments are normally motivated by expected returns relative to perceived risks. These risks and returns are determined by market conditions both global and local, and more often than not, global. It is therefore important to identify appropriate roles for, and relationships among, the public and private sectors, other elements of civil society, (such as farmer and trader associations) national and local governments, regional organizations, donors, and private voluntary and NGOs. Private investment into agriculture can also be promoted through public-private partnerships with the international private sector and national agricultural organisations. Agriculture should also be made a sectoral priority in other policies that seek to attract international private sector, such as policies for foreign direct investment, with a special focus and additional incentives for firms to engage in tacit know-how transfer to local actors.

2.5.5 Policies that promote linkages between local farmers and other actors in the AIS

Incentive systems tend to develop from more fundamental institutional roots such as labour laws and even national constitution. Terms of employment and work environments, both tangible (research and teaching facilities) and intangible (possibilities for institutional collaboration, quality of networks and colleagues) play a pivotal role in retaining skilled professionals. States have been involved in promoting academic-industry exchange by encouraging channels of learning, such as: joint publications, mobility of scientists and engineers, cooperative R&D, facility sharing, research training (e.g. capacity development at PhD level, international and local exchange of staff), and academic entrepreneurship.[61] A range of targeted policy interventions are necessary to ensure that farmers are well inter-connected with other practitioners and science-suppliers in the agricultural innovation system.

2.5.5.1 Improve existing markets and services

Developing and improving existing markets and trade services is important for the livelihoods, economic sustainability and, ultimately, the food security of rural communities. The objective should be to develop sustainable agricultural value chains and improve farmers' and agro-industry enterprises' access to, and participation in, markets. This development could be supported by: (a) actively increasing market efficiencies and access, especially to the markets for high value-added agricultural exports, including processed agricultural exports; (b) putting in place marketing information systems; and (c) designing and implementing trade facilitation programmes. The aim should be to create plans to increase both the quantity and quality of production of smallholder farmers, as well as smallholder value-added in local markets, including by increasing the contribution of local communities' products. The ultimate aim is to substantially increase the income of farmers, in particular smallholder and family farmers.

2.5.5.2 Create new organisations for collaborative learning

Three specific forms of policy interventions are critical to promote collaborations between farmers and other actors in the AIS:

- those that those that support the commercialisation of publicly funded agricultural research: such policy support mechanisms are often extremely essential in both promoting mobility of scientific labour between public sector science and industry and also ensuring that public funded research is more outcome-oriented. Policies that promote this include technology link foundations.
- those that reduce the risk of innovative activities through finance: support mechanisms here include government-support soft-loans, R&D subsidies, public risk capital funds, public support for private enterprise through grants, subsidies, private equity, Policies that could promote these (from a review of literature) include: seed-financing programmes, business angels networks, enterprise subsidy programmes, common placement funds for innovation and research tax credit programmes.
- Those that provide other forms of business and marketing support, including technology incubation facilities, and competence centres that provide expertise such as legal affairs and marketing.

These need to be enabled through the creation of new organisations, or revision of roles and competencies of existing organisations responsible for supporting agricultural development within African countries. The impact and the effectiveness of policy interventions should be monitored and assessed using a set of domestic policy indicators for policy review, monitoring and evaluation.

2.5.5.3 Linking R&D to Firms and Farms

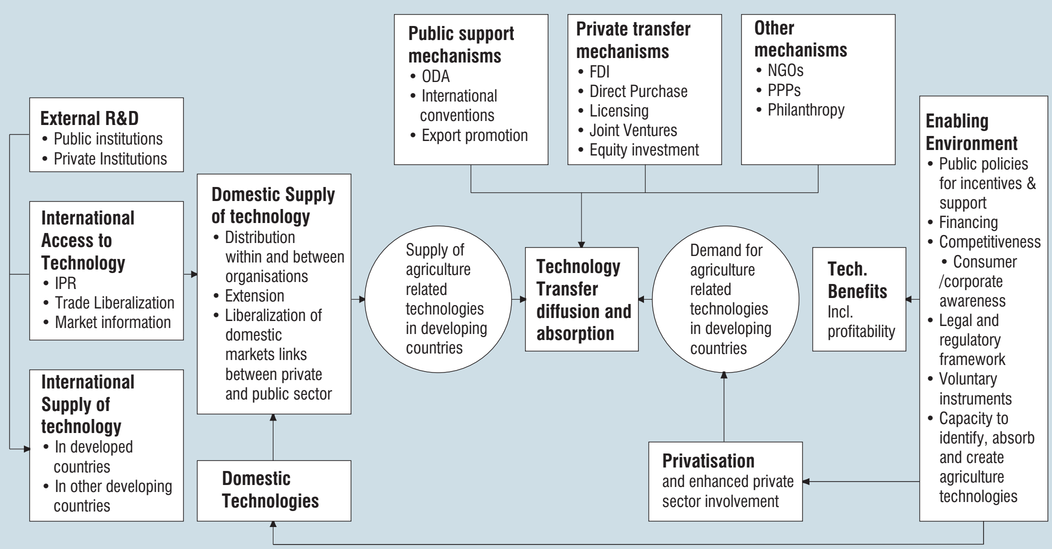
The transfer of agricultural technologies is an outcome of demand and supply to meet the needs of the farming community (see Figure 4). Many of the necessary measures such as financing mechanisms, capacity building, and regulatory environment all relate to the development of enabling environment and thus contribute to the transfer of technologies. Resources spent on promoting research and development activities need to be linked to local demand for specific products, processes and services in agriculture. Experiences in other countries show that incentives to achieve this include restructuring academic systems (for researchers and academics) to reward applied research and collaborations with agricultural communities and firms, create special R&D grants that are only for the development of specific local varieties of food grains, among others.

Transfer of technology should be promoted through a variety of mechanisms, including licensing, foreign direct investment, joint ventures, public-private partnerships (PPPs). Modes of technology transfer that focus on tacit know-how transfer and human capacity building need to be fostered. The rate of technology transfer is affected not only by access to such technologies, but also by the ability of actors to absorb. Both types of factors can be influenced by policy.[79] Special education and training programmes designed for farmers need to be promoted in order to augment their capacity to use and apply new technologies.

2.5.5.4 Facilitating access to inputs through smart subsidies and credit

In 2006, African Union Member States resolved to increase Africa's average level of both inorganic and organic fertilizer use from 8 kg per hectare currently to at least 50 kg per hectare by 2015. Achieving this goal will require specific actions to improve farmers' access to good quality fertilizers both directly and indirectly.[78] For this purpose, the Summit identified a number of supply- and demand-side constraints that must be addressed (see table 3) and called on Member States to: (a) eliminate taxes and tariffs on fertilizers and fertilizer raw materials by mid-2007; (b) develop quality-control standards for fertilizers; (c) develop and scale-up both private and community-based fertilizer use/access; (d) grant targeted subsidies to help the poorest farmers, especially women farmers and/or farmers lacking land title in order to increase fertilizer use among these groups; (e) devise fiscal incentives that encourage farmers and suppliers to invest in productivity-enhancing procedures; and (f) establish national and regional financing facilities to help suppliers of agricultural inputs receive credit, develop business plans, and make sustainable investments.

Figure 4. Supply of and demand for technology[80]



Source: Puustjärvi, E. et al, (2006)

Having studied the fertilizer subsidy systems in Kenya and Malawi, the Kenya Institute for Public Policy Research and Analysis, Tegemeo Institute of Agricultural Policy and Development and the Future Agricultures Consortium presented recommendations on the key question of how subsidies can be made effective and efficient (i.e. 'smart'). They concluded that:

- Small-holder farmers, not large farmers, are the ones who need subsidies to buy fertilizer and other inputs. Vouchers are therefore suitable instruments to direct subsidies to the small-holder farmers who need them most.
- At the same time, subsidies should help the development of networks of input dealers, rather than undercutting them. Rather than having fertilizer distributed directly by state agencies, fertilizer should be channelled through existing dealers.
- Judicious intervention in maize markets to ensure that prices remunerate farmers while providing consumers with affordable food is an important complement to subsidies.
- Fertilizer subsidies attract political interest. Monitoring the costs and results of subsidies, and publicising the results of monitoring, is one way to encourage politicians to consider the effectiveness of subsidies.

Determined to improve the country's food productivity, the government of Kenya has begun offering a form of subsidy to its farmers under the National Accelerated Agricultural Inputs Programme. One of the overall objectives according to the government is to remove the concept of subsistence farming altogether and transform farming into a commercial enterprise. The targeted or smart subsidy scheme that was initiated in 2008 is initially targeted to 45 districts with a view to reaching 2.5 million households with affordable farm inputs within three to five years. The programme allows beneficiaries to receive vouchers to buy farm inputs – seeds, fertilizers and chemicals—from selected dealers. The government redeems the vouchers using commercial banks. The targeted beneficiaries are poor and vulnerable groups with less than an acre of land and those who rely on relief foods.

Malawi, the United Republic of Tanzania, Nigeria, Ghana, Mali, Mozambique, Rwanda, Burkina Faso and Senegal are now offering smart subsidies.

2.5.5.5 Building partnerships between small- and large-scale farmers

Farmer groups, cooperatives and other partnerships are important institutions for filling the gaps left by both government and the private sector. They provide guarantees with regards to investments, supply of agricultural inputs (seeds and fertilizers) and credits, and are a suitable platform for education and training. Cooperatives also provide opportunities for marketing agricultural products, particularly in the case of smallholders who, in most cases, are not able to meet quantitative and qualitative thresholds and therefore rely on communal storage and marketing instruments. In Brazil, cooperatives have been instrumental in linking small-holder farmers into the agri-food chain. Box 5 summarizes some of the achievements of an African initiative on partnerships. Such partnerships enable and enhance agricultural entrepreneurship and thus strengthen rural development.

Box 2: Accomplishments of partnerships: the AGRA experience

The Alliance for a Green Revolution in Africa (AGRA) has developed groundbreaking partnerships between African and global institutions to address key issues such as seeds, soils, market access and policies, and a cross-cutting programme on innovative financing programme that is delivering $17 million in loan guarantee funds to leverage $160 million in affordable loans from commercial banks for smallholder farmers, agro-dealers and small- and medium-sized agricultural enterprises. This has resulted in strengthened national networks of agro-dealers in 11 countries. In parts of western Kenya served by the programme, maize productivity has increased by 115 per cent, and the distance farmers must travel to buy precious farm inputs like good seeds has been cut from 17km to 4km. In the area of seed development, funding of farmer participatory crop-breeding has led to the release of 68 locally adapted varieties of crops such as cassava, bean, sorghum, and maize. Many of these varieties incorporate traits from varieties developed by the Consultative Group on International Agricultural Research (CGIAR) and Africa's national research organizations, along with farmers' own traditional varieties. Twenty four small- and medium-sized seed companies and cooperatives have experienced a near doubling of their seed production in two years.

Table 3. Supply/demand constraints to fertilizer use in Africa[81]

SUPPLY-SIDE CONSTRAINTS	DEMAND-SIDE CONSTRAINTS
Risks associated with certain policy environment: ● Repeated and unpredictable government interventions creating an uncertain environment for the private fertilizer sector. ● A stable policy environment reduces risks, which is an essential condition if private sector agribusiness is to assume fertilizer marketing functions and develop domestic fertilizer demand	**Profitability of Use:** ● Profitability of fertilizer use as reflected in high input/output ratios affects farmers' demand for fertilizer. Profitable use of fertilizer is a function of technical and economic factors. ● Use of fertilizer should be accompanied by improved seed varieties and suitable soils. Fertilizer use also needs to be accompanied by knowledge of how to fertilizers, which fertilizers are appropriate for which crops/soil type/climate, etc. ● In addition, the cost of getting fertilizer to the farm-gate affects profitability.
Institutional Risks: ● Continuous procedural changes to laws and regulations of direct consequence for fertilizer marketing constitutes a major impediment for market entry when risk aversion on the part of rural decision makers translates into high fertilizer prices (traders) and hence ensures low demand (farmers).	**Commodity markets:** ● Demand for fertilizer is conditioned by farmers' access to output markets. ● Markets may be uncompetitive or even exploitative, or farmers may have to travel exceptionally long distances to access them.
Insufficient Human Capital: ● The fertilizer sector is characterized by insufficient and under-qualified human capital such as a limited number of fertilizer importers and wholesalers; ● poor spread of input dealer networks in rural areas; ● low business and technical capacity of dealers; ● farmers must travel long distances to purchase fertilizer; ● small number of producer and trader associations; ● lack of marketing skills and qualified input dealers; ● weak linkages between input dealers, importers, and wholesalers; and lack of proper knowledge about fertilizer capabilities and their profitable use.	**Commodity Prices:** ● The ratio of output price to fertilizer price conditions fertilizer use. Fertilizer use is concentrated on the most profitable crops. Commodity prices are a function of the strength of demand for a crop commodity, government price policies, transport infrastructure, storage facilities, market information, and seasonal variability in demand and supply.
Limited Access to Credit: ● Lack of access to finance constrains the ability of fertilizer importers, wholesalers, and dealers to raise sufficient funds at the opportune time to purchase fertilizer and/or for business development. In addition, high interest rates and exhaustive collateral requirements are unattractive for fertilizer importers and input dealers.	**Perception of Yield Responsiveness to Fertilizer:** ● Farmers' perception about the potential impact of fertilizers on yield also affects demand. Their understanding is influenced by the quantity and quality of information available on fertilizer and by their access to that information.
Lack of market information: ● Information on fertilizer prices, imports and exports, and availability by market and product in Africa is inadequate. ● Availability of such information reduces transaction costs via increased transparency in market transactions.	**Fertilizer Price:** ● African farmers pay the highest price for fertilizers in the world. For example, the ratio of farm-gate price to cost, insurance, and freight ranges from 1.42 for the United States to 2.04 and 2.56 for Nigeria and Angola respectively. ● Domestic marketing costs in many African countries account for more than 50% of the farm-gate price of fertilizer.
Infrastructure: ● Internal transport costs are high in African countries. ● Infrastructure development is critical for fertilizer distribution and for connecting farmers to markets, as each ton of fertilizer used could lead to transportation of 15 tons of grain.	● Prices and availability of substitutes and complements, capacity to invest, and the prices of different fertilizer nutrients, water, seeds, organic matter, and even farm labour can all impact the use of fertilizer.

2.6 THE ROLE OF INTELLECTUAL PROPERTY RIGHTS IN SMALL-SCALE FARMING

Intellectual Property (IP) touches on a wide range of issues from increased costs for agricultural inputs (cultivars, fertilizers, pesticides, production protocols, etc.) to outputs (improved seeds, harvesting, storage, etc.). It is important that African countries assess and prioritize the IP issues (trademarks, patents, geographical indicators, plant breeder's protection, and traditional knowledge) according to their short-, medium- and long-term implications on their modes of agricultural productivity. This necessitates an understanding of international norms, flexibilities and/or exceptions applicable to farmers in developing countries.

The impact of strong intellectual property rights (IPR) on developing countries' access to foreign technologies and on domestic technological development remain controversial questions, especially for LDCs where the conditions for successful absorption and adaptation may be weaker than in other countries due to weaker science, technology and innovation (STI) capabilities and greater deficiencies in infrastructure, financing and other areas that have an effect on the scope for technological development. The empirical evidence on the impacts of IPRs on agriculture in developing countries is scant and ambiguous.[82] Some analysts fear that strong protection of intellectual property rights is likely to hinder rather than to facilitate technology transfer and indigenous learning activities in developing countries.[83] The scope for protection of traditional agricultural knowledge under the Agreement on Trade Related Aspects of Intellectual Property rights (TRIPS Agreement) has emerged as a key issue for developing countries, both within and outside of Africa. The Agreement provides a choice between patents and a sui generis system (a system of its own) for plant variety protection. Several African countries have adopted the Union of Plant Varieties (UPOV) 1978 and 1991 conventions as their sui generis regimes, regardless of their impact on their local contexts. Literature on the point has been particularly vocal on the fact that the UPOV 1991 convention especially does not contain provisions to cater to the needs of farmers in developing countries, and expressly prevents them from saving seeds to sow back in subsequent seasons. At the same time, several other African countries have devised their own sui generis regimes that cater to their particular contexts. Policy choices on these issues will determine the space available for agricultural innovation and needs to be evaluated carefully.

The Convention on Biological Diversity (CBD) and the International Treaty on Plant Genetic Resources for Food and Agriculture (PGRFA) regulate the transfer of biological or genetic resources. PGRFA established the Multilateral System of Access and Benefit sharing covering crops that supply 80 per cent of all human consumption to be made available through Standard Material Transfer Agreements (MTAs). These MTAs regulate the transfer of biological or genetic resources between two parties. The terms and conditions of transfer have not yet been fully negotiated but it seems likely that the transfer of materials from industry to public or private institutions may include more restrictive conditions than if the transfer was between two academic institutions.[84] Policy, therefore also is needed to address research exemptions and other flexibilities allowed by the TRIPS Agreement that will be important to promote agricultural research and development.

In general, MTAs establish the rights of the material providers and recipients, the obligations of the recipient to inform the provider of any patent claims and/or innovations leading to a patent. Often, the ownership remains with the provider, including the rights to transfer to other parties.[85] Depending on the nature, mandate and orientation of the biological material provider, the MTA may encourage the dissemination and exchange of the materials. Similarly, the nature of the materials and their value (if the material is subject to a patent or to be commercialized) may influence the inclusion of restrictive conditions in MTA.

The CGIAR genebanks hold in trust the genetic material of a vast number of food and agriculture crops, and this genetic material is freely available (see Box 3). Without doubt, the single most readily applicable source of practical technologies for smallholder farmers lies in the many best practice methodologies developed by international and national centres of agricultural expertise. The FAO and CGIAR, in particular, offer an immense variety of information useful for improving smallholder productivity.

Box 3: CGIAR genebanks: plant genetic resources for food[86]

The CGIAR seed collections are a unique resource, available to all researchers. The eleven International Agricultural Research Centres (IARCs) of the CGIAR signed agreements with the Governing Body of the International Treaty on Plant Genetic Resources for Food and Agriculture (PGRFA) on 16 October 2006 to place the ex situ collections of PGRFA held by those centres (some 650,000 accessions of the world's most important crops) within the purview of the Treaty. Under these agreements, the centres recognize the authority of the Governing Body of the Treaty to provide policy guidance relating to their ex situ collections (i.e. collections of seeds stored in genebanks).

As from 1 January 2007, the centres have been using the Standard Material Transfer Agreement (SMTA) adopted by the Governing Body of the Treaty for transfers of PGRFA of crops and forages. From 1 February 2008, the Centres have been transferring all plant genetic resources for food and agriculture they hold in trust - using the SMTA.

Seed contributions have helped lay the foundations of recovery by jumpstarting agricultural growth in countries emerging from conflict such as Afghanistan, Angola, Mozambique, and Somalia. They have also helped countries recover from natural disasters such as Hurricane Mitch which struck Honduras and Nicaragua. A recent study showed that of the more than one million seed samples distributed over the past 10 years, the vast majority (80 per cent or more) went to universities and national agricultural research systems where scientists are developing new crop varieties that give higher yields, have improved nutritional value, use less water, need lower amounts of fertilizers, and have natural resistance to pests, diseases and climatic vagaries such as droughts and floods.

2.6.1 Open innovation and other alternate approaches

Open, collaborative approaches to innovation can promote productivity and the competitiveness of farmers, and a number of developing countries are already engaged in open innovation systems. Developing countries will benefit more from open innovation by bridging the digital divide, which can help facilitate collaborative research, information-sharing and global partnerships.

For innovation to be relevant to developing countries' economies, it must be seen as a means of introducing useful products and adding new value. R&D or technology must therefore be accompanied by the tapping into knowledge of other institutions such as universities, research centres and firms including competitors. This open approach to innovation must be supported by science, technology and innovation policies. This involves addressing issues pertaining to intellectual property rights, increasing the intensity of R&D and actively attracting leading researchers. Among the wider policy issues are local infrastructure, investment incentives, favourable regulatory frameworks and helpful administrative processes and building capacity to negotiate agreements in order to become effective innovators.

Open source or non-proprietary models are evolving to harness the full potential of a combined academic–philanthropic–business approach. For example, collaboration between the University of Berkeley and the Bill & Melinda Gates Foundation provides grants for the development of nutritionally enhanced sorghum seeds to be made available for royalty-free distribution in areas of need.[87] Many other royalty-free development programmes are being conducted by various universities and research institutes around the world, including the HarvestPlus initiative coordinated by CGIAR for improving the micronutrient content of rice, wheat, maize, cassava, sweet potato and beans.

The advent of GMOs has led to a much wider licensing model due to the nature of farming, which requires growers to sign a 'Seed Partner Agreement' with leading agricultural biotechnology companies, prohibiting them from replanting seed. Under this model it is possible for the inventing company to have many hundreds of seed partner licensees around the world. In this case too, socially responsible licensing is also starting to become more common within the agricultural biotech sector. One such example is the African Agricultural Technology Foundation (AATF) which is facilitating drought-tolerant maize varieties known as WEMA (Water Efficient Maize for Africa) specifically intended for small-scale farmers. AATF will work with the International Maize and Wheat Improvement Center (CIMMYT), the private agricultural company Monsanto and the national agricultural research systems in the participating countries.

Another important source of technology solutions is to be found in the academic literature covering every aspect of agricultural improvement. A number of journal articles have never been the subject of copyright protection and are therefore free to use. Although most leading journals are based on a subscription membership, researchers in developing countries can obtain free access to most of the leading publications through the AGORA system set up by FAO. However, the sheer volume of technical publications is daunting and many hours may be needed to identify just a few practical recommendations applicable to a given topic.

2.8 SUMMARY

Regardless of the theoretical viewpoints on the kind of approach best-suited to promoting agricultural development, the fundamental issue for a policy maker is how such an approach can be used to devise an agriculture development strategy. The innovation systems framework can be useful to help identify areas of weakness that could ideally be addressed through national policy action. A key issue is how to promote capabilities among African farmers and develop more effective innovation systems for agriculture at the national and sub-national levels.

This chapter has recommended an agricultural innovation systems approach as a policy instrument for African agriculture. Agriculture development strategies that incorporate the main components of the AIS approach can be transformed into a workable concept at the country level. The AIS approach depends on identifying the key actors and linkages that together strengthen knowledge flows and enable interactive learning that is important to build capabilities for agriculture. The linkages between these actors derive from two major sources: the policies and institutions (including the constitution, laws, rules, regulations and by-laws) are a very important to guide individual behaviour. Laws, rules and regulations offer specific incentives to individuals or groups to collaborate and engage in mutual learning. A second form of linkages derives from socio-political-historical attitudes and practices (that could stem from cultural norms) that dictate how or why individuals interact and what benefits they perceive from such interactions. The chapter has identified short-term and mid-term policy actions that are meant to guide policy makers to enact the AIS approach within their national contexts.

The characteristics of these systems may vary significantly between (and even within) countries, which makes country-specific analysis necessary, but there remain some common issues that affect many African countries to a greater or lesser extent.

Common challenges include poor linkages between farmers and others in food value chains and the research and education systems, weak bridging institutions between the two (extension services, for example), inadequacies in infrastructure and financing mechanisms, and policy frameworks that do not provide adequate support for smallholder famers or may even create disincentives to technological development or innovation. Policy-makers need to ensure that national agricultural research systems involve farmers fully as partners, and gear research to solving the pressing production problems that they face. There is also a need for institutional innovations and different ways of organizing smallholders, linking them better to knowledge flows and to potential markets for their produce, and policy options to enable these have also been identified in the chapter. The specific policies needed at the national level will depend on existing capabilities and human and financial resources, the political, social and institutional contexts and agro-ecological conditions.

Adequate policy space is necessary to implement appropriate policies. Promoting the sharing of experiences and relevant knowledge flows internationally and at the national level provide a starting point. Designing effective public policies, however, requires adequately prepared policy-makers and may entail some degree of experimentation to find what works best in a specific situation.

There are other gains that flow from agriculture to non-agriculture based systems that will be important in the African context, and can accrue from building agriculture innovation systems. These include the flow of rural human capital as a result of increased rural spending on education (accruing from agricultural surpluses), the release of rural labour for industrial employment and enhanced foreign exchange earnings and increase in domestic savings, all of which are needed to enable the structural transformation of African economies.[88]

3

AGRICULTURE AND NATIONAL FOOD SECURITY

3.1 THE DETERMINANTS OF NATIONAL FOOD SECURITY

Before discussing agricultural technologies and innovations, it is necessary to understand the context within which they are used. The goal for those seeking to develop and deploy these technologies and innovations in farm management is to unlock the productivity growth potential and achieve sustainable food security.

In many African countries, food security remains of great concern. The prices of staple foods remain high – above their long-term averages – and over 300 million Africans continue to face chronic hunger. Ensuring food security in the region will require action to improve productivity and rural livelihoods, and to address international market imbalances and the structural challenges inherent in African agriculture.[89]

This chapter argues that efforts to improve food security involve much more than just producing more food. It shows this by discussing the concept of food security and outlining important factors that determine it. The overall aim in tackling problems of food security is to deploy a mix of policies that increase the availability of food, ensure that consumers have improved access to food and address any upcoming challenges and opportunities to achieving food security.

Food security stands crucially on two pillars: food availability and access to food.[90]

1. *Availability of food* is determined by domestic production, import capacity, existence of food stocks and the food distribution systems.
2. *Access to food* depends on households' levels of poverty and purchasing power, the state of the transport and market infrastructure, food distribution system and, of course, prices.

Food availability can be deemed adequate when sufficient quantities of appropriate, necessary types of food are consistently available (or are within reasonable proximity) to an individual. Food access can be considered sufficient when an individual has adequate income or other resources to purchase or barter to obtain levels of appropriate foods needed to maintain consumption of an adequate nutrition level. The constraints to availability and access are diverse. For example constraints to availability include inappropriate agricultural knowledge, technologies, and practices, inappropriate economic policies including pricing, marketing, tax and tariff policies, lack of foreign exchange, inadequate agricultural inputs, a non-existent or ineffective private sector, population growth rates that offset increased production or imports, marketing and transportation systems which inhibit the cost-effective movement of food from source to need, inability to predict, assess and cope with emergency situations which interrupt food supplies, natural resource, climatic, and (especially in Africa) disease constraints and conflicting political priorities. Constraints to an individual's ability to access food can include economic growth that is inadequate or insufficiently broad-based (leading to a lack of job opportunities or lack of incentives to become a productive participant in the economy), negative impacts of national economic policies, inadequate training and/or job skills, lack of credit or other means to exchange assets or income streams, food losses associated with ineffective and inefficient harvesting, storage, processing and handling, and political decisions favouring one group over another.

Food security is an evolving concept (see Table 4). Since the world food crisis of 1974, the idea of economic access has gained ever-increasing prominence in the definition of food security, to the point that today, any approach to improving food security must go beyond farming practices to include rural development and the expansion of economic opportunities through income generation infrastructure and marketing.[91] This broader approach points to the need to focus on both technology-based research and innovation in policy processes.

To have a positive impact on food security, the application of modern agricultural technologies must simultaneously contribute to food availability and to enhancing the poor's access to food. Since food availability is a necessary but not a sufficient condition for attaining food security, relevant policy recommendations on food and livelihood security must be based on an understanding of the following types of issues: status of aggregate food supply, real food prices and real incomes, formal safety nets intended to protect the poor, how people respond to drops in real income, the response of national and local governments to changes at the household level, and networks and models of collaboration among national and municipal governments, local organizations and local communities in response to food security concerns.[93]

Table 4. The evolving definition of food security[91]

Period	Changing perceptions of food security
1974	In the 1974 food crisis, food security was defined by the World Food Conference as *"Availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices."* The definition reflects the global concerns in 1974 on the volume and stability of food supplies
1983	The FAO defined food security as *"Ensuring that all people at all times have both physical and economic access to the basic food that they need."* This new concept includes securing access by vulnerable people to available supplies, calling attention to the balance between the demand and supply sides of the food security equation.
1996	In the FAO World Food Summit, the definition changed to *"Food security, at the individual, household, national, regional and global levels (is achieved) when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life."*
2001	In the FAO's 'The State of Food Insecurity', the food security definition was expanded again to include the notion of social access to food: *"A situation that exists when all people at all times have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life."*
Future	It may become necessary to integrate additional factors such as climate change into the concept of food security.

In addition to addressing these broader development issues, technologies and innovations to improve the availability of food will need to improve the sources of food supply, including the following options:

- increasing domestic production;
- maintaining appropriate levels of food stocks;
- understanding the impacts of climate change and man-made change on soils in order to design effective adaptation strategies;
- ensuring the availability of suitable agriculture land;
- exploiting the best choice for biofuels production;
- feeding livestock;
- managing cropping intensity;
- investing in irrigation; and
- ensuring a constructive role for agricultural trade.

Before briefly assessing these determinants of food supply, it is important to develop a keener understanding of how Africa procures its food.

3.2 SOURCES OF FOOD SUPPLY

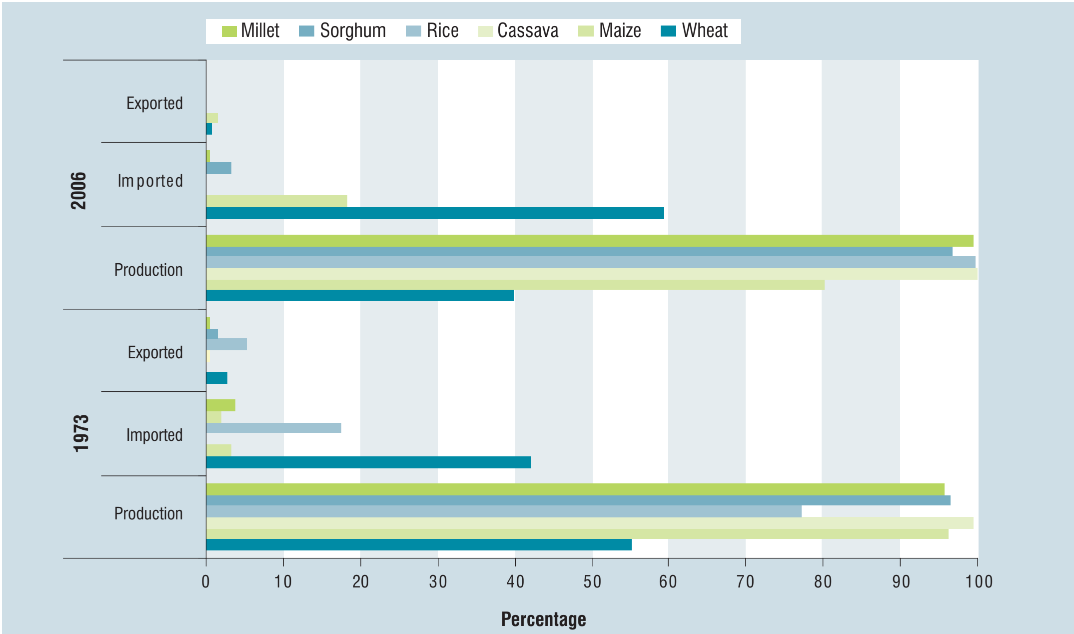
World cereal production fell by 3.6 per cent in 2005 and 6.9 per cent in 2006, with an increase of 4.7 per cent in 2007.[94] In South Asia, the one per cent increase in rice and wheat production during 2003-2008 could not keep pace with the 2.3 per cent growth in consumption over the same period.[95] While cereals do make up a significant part of the diet in Africa, roots and tubers are also important staples. Cassava, potato, yam and sweet potato, as well as starchy fruit (plantain) are among the major food crops in Africa. Indeed, cassava is gradually being transformed from a famine-reserve commodity and rural food staple to a cash crop for urban consumption.[96] Increased growth in food demand for all roots and tubers is expected in sub-Saharan Africa.

The following is a brief assessment of the status of each source of food availability (domestic production, food stocks and imports), from a food security perspective.

3.2.1 Africa's food sources

Food staples such as maize, cassava, sorghum, millet, wheat, rice, plantain and yams make up 80 per cent of the daily calories consumed in Africa. While the bulk of Africa's food is consumed and produced locally (e.g. rice 90 per cent, wheat and maize 75 per cent), some foods are more likely to be consumed locally than others. Figure 5 compares Africa's sources of food in 1973 to those in 2006 and shows that while cassava, sorghum and millet consumption has largely been satisfied by local production, wheat imports rose from 41 per cent to 58 per cent of African consumption in that period, maize imports increased from 3 per cent to 19 per cent and rice imports went up from 20 per cent to 39 per cent of total usage. In fact, most of the rise in wheat and rice consumption in Africa was met by increased imports.[97] In Cameroon for example, since the 1970s external rice purchases and the development of rice production have been influenced by changes in prices and customs regulations. The rice market grew from 15,000 tons to 60,000 tons between 1975 and 1980. Since then the progression in imports can be explained by the economic crisis coupled with growing urbanization – two factors which have had a significant impact on eating habits and farming in the country. The drop in national rice production has been accompanied by an increase in imports, and in 2007 Cameroon imported 429,864 tons of rice.[98]

Figure 5. Africa's main staple foods and their sources[101]



Yet the role of the 'world market' in providing Africa's food may be overstated.[99] Smallholder farmers produce most of the continent's food, with minimal resources and government support (and typically low yields). Despite this institutional neglect, ecological farming systems have been sprouting up across Africa for decades – systems based on farmers' knowledge, which not only raise yields but also reduce costs by using less water and fewer chemicals.[100] These are important reasons to focus on the plight of small-holder farmers as part of a strategy to structurally improve domestic food production, especially in sub-Saharan Africa and in parts of Asia.

3.2.2 Food stocks and imports

Globally, cereal stocks are dangerously low, with the ratio of stocks to utilization only 18.7 per cent in 2007–08, the lowest in three decades.[102] Grain merchants usually maintain strategic reserves from previous harvests to release into country-wide grain markets when a new 'lean period' approaches, to send prices down. However a combination of drastically decreased yields (with the 2007 harvest up to 50 per cent smaller than in previous years), locust invasions and unusually brief rains has resulted in low stocks and high prices that are cutting into the reserves.[103] In Nigeria for example, the 2008 grain harvest was double that of 2007, yet the country's grain stocks are running low, causing cereal prices to rise. This can be explained in part by the fact that the 2007 yield lasted just three months and farmers therefore did not have any surplus grains to sell. It is a similar picture across much of West Africa – despite above – average cereal production during the 2007/08 agricultural season, localized production deficits are leading to early increases in food insecurity.

If food stocks continue to decline, West Africa and other sub-Saharan African countries will need to turn to imports to make up this shortfall. The net cereal imports of developing countries jumped from 39 million tons a year in the mid 1970s to 103 million tons in 1997–99 and it is feared this figure will be as high as 265 million tons by 2030, as their own food production will be able to meet just 86 per cent of their needs. The food surplus countries of Australia, North America, Argentina, Uruguay, and the EU are expected to be the major exporters filling the gap.

Furthermore, the price of imported food has been on the rise, drawing down net food importers' foreign exchange reserves. For instance, the price of Thai export grade rice was $362 per ton in December 2007 but almost tripled to $1000 per ton in April 2008.[104] Price hikes such as this resulted in developing countries spending $343 billion on food imports in 2008, up a record 35 per cent from 2007.[105] Not unexpectedly, developing countries suffered income losses as a result.

Given the massive depletion of food stocks and the heavy fiscal burden of costly food imports that has been exacerbated by the recent food crisis, developing countries will have to intensify their own efforts to boost domestic food production in order to safeguard their food security. National food production can be increased in four main ways: (a) expanding arable land; (b) achieving higher levels of cropping intensity (the frequency with which cropland is cultivated); (c) increasing yields; and (d) agricultural reforms.

In regions where further expansions in arable land are not expected, increasing the frequency with which existing cropland is cultivated – particularly through an expansion in irrigation – could be vital for increasing national food availability. It is the degree of utilization that determines the effective amount of land resource available. The 885 million hectares of currently available arable land in developing countries is as good as 1770 million hectares, for instance, if it is used twice a year (that is, with a cropping intensity index of 200). The current cropping intensity index of 127 on irrigated land is projected to increase steadily to 138 in 2015 and then remain at a similar level until 2030.[106]

Only one-fifth of developing countries' arable land was under irrigation in 1997–1999 and there has been no major increase since then. However, because of higher yields and more frequent crops, this irrigated land accounted for two-fifths of all crop production and close to three-fifths of cereal production in the 1997–1999 time period. There are, nonetheless, wide regional variations in the share of irrigated land, with a meagre two per cent of arable land in sub-Saharan Africa irrigated in 1997–99, compared to 40 per cent in South Asia.[107]

Solutions to water management include options to invest in irrigation and other water infrastructure, to invest primarily in water conservation and better water management with existing infrastructure, or some combination of the two. For example, Senegal has seen its state of food security deteriorate as its population has risen rapidly since independence.

Even when regular droughts interrupted its food production, including rainfed rice, too little focus was put on irrigated rice production. Instead agricultural policies have long focused on the production of cash crops such as groundnuts. In a recent turnaround, the government has intensified its programmes to raise food production with a focus on rice production along the River Senegal. According to the latest production rates the 2009 rice harvest in the River Senegal valley alone totalled 350,000 tons paddy rice, equalling some 220,000 tons white rice. This is a sharp increase from the 100,000 tons harvested in 2008. The increased production is attributed to infrastructure and irrigation programmes. The government estimates that rice production will increase to 1.25 million tons of paddy rice by 2012 which would be the first year of self-sufficiency in rice in Senegal's modern history. There are numerous other examples of increased rice production across Africa. For example in Guinea a new type of rice (known as New Rice for Africa, or Nerica) has quickly superseded other varieties. And since the launch of Uganda's Upland Rice Project in 2004, the National Agricultural Research Organization reports an almost nine-fold increase in the number of rice farmers from 4,000 in 2004 to over 35,000 in 2007. At the same time Uganda's rice imports dropped from 60,000 tons in 2005 to 35,000 in 2007, saving roughly $30 million in the process.

3.3 NEW DETERMINANTS OF FOOD SECURITY

Currently, the determinants that are at the core of achieving food security are issues related to access to credit, infrastructure, access to markets and land ownership. These are critical processes that need to be put in place before contemplating a Green, Rainbow or any other revolution in agriculture. In addition there are new factors that will have an increasing impact on food security. These include the choices that are being made on the production of biofuels, the feeding of animals, the availability and efficient use of irrigation water, the manner in which arable land is utilized and the technologies to increase productivity and generate income.

3.3.1 Soil degradation and climate change

Climate change and desertification put the food security of one billion poor people at risk.[108] Persistent problems in the drylands of Asia and sub-Saharan Africa such as land degradation, biodiversity loss, and water and fossil fuel shortages, will be exacerbated by climate change and desertification. Facing these climate uncertainties head-on is the only way to enhance the resilience of dryland communities.[109] The drylands climate adaptation work that has so far been undertaken by ICRISAT and others has increased farmers' productivity by as much as four-fold and profits by three-fold, through the use of climate variability analysis and management options including the use of water-efficient crops. For example, pigeonpea hybrids developed at ICRISAT have shown a 30 to 150 per cent yield advantage and increased drought resistance by producing between 30 and 40 per cent more root mass. Unless the livelihoods and resource base of other vulnerable rural communities can be made similarly resilient, coping with climate change and desertification may be next to impossible for poor dryland farming communities. Only such science-based interventions will make farmers who depend on drylands less vulnerable in the future.[110]

3.3.2 Biofuels and food security

Given the limits reached in arable land utilization in some regions and the expected impacts of climate change on soil quality and land availability, improvements in food availability may be better served by using existing arable land for food crops for human consumption rather than diverting such land to the production of biofuels and animal feed.

In 2007–08, 100 million tons of grain was diverted to the production of biofuels (maize/corn utilized for ethanol and oilseeds for biodiesel production).[111] Four-fifths of the total diverted was produced in the United States. This boom in corn ethanol production has pushed corn prices to more than $15 per bushel, up from just $2 per bushel in 2006.[112] The spike in grain prices is partly due to policy choices on biofuels. The United States government passed the Energy Independence and Security Act in December 2007, which raised the mandated volume of renewable fuels (mostly corn-based ethanol) for 2008 from 5.4 billion to 9 billion gallons, a huge increase over a short time. Since then, the price of corn rose by about 50 per cent.

A bushel of corn yields 2.8 gallons of ethanol and in order to meet the congressional mandates, more than a quarter of United States corn crop must be diverted to ethanol production. This has effectively removed a quarter of United States corn production from the world cereal marketplace. The United States is, by far, the largest source of this commodity and the corn price increases have spilled over to wheat and other crops that can substitute for corn.[113]

IFPRI estimates that 30 per cent of the increase in the prices of major grains is due to biofuels. Unpublished figures from the World Bank indicate that biofuels have forced global food prices upwards by 75 per cent, sharply contradicting the contention of the United States government that biofuels contribute less than 3 per cent to food price hikes.[114]

Using existing biofuel technologies, the conversion of a quarter of the world's major cereal and sugar crops (wheat, rice, maize, sorghum, sugarcane, cassava and sugar beet) into ethanol could replace a meagre 14 per cent of the world's petrol consumption. Hypothetically speaking, if the planet's total available food supplies are converted into ethanol, the volume of fuel generated would not meet even 60 per cent of the current level of global petrol consumption (1,100 billion litres in 2003).[115]

In the Philippines, preliminary research on the impacts of the country's Biofuels Program has shown mixed outcomes (see Box 4). The programme involves five feedstocks – coconut and jatropha for biodiesel, and cassava, sugarcane and sweet sorghum for bio-ethanol. Coconut and sugarcane are among the country's major export crops and cassava is primarily a food crop with more than 80 per cent of the two million metric tons average annual production normally processed into various food items. The case suggests an unavoidable competition between food production and biofuels production for available feedstock, with the exception of jatropha.[116]

In 2009, the government of Mozambique adopted a National Policy and Strategy for Biofuels, establishing guidelines for both the public and private sector to better participate in the biofuel industry. Concerns over food security issues were discussed in parliament and the government pledged to produce biofuels without compromising food production. The objective for the policy measure according to the government is to reduce the country's dependence on imported fossil fuels. Other factors, such as the need to ensure energy security, advantageous conditions for agriculture, and the need to promote sustainable economic growth, were also cited as motivating factors.[117] In an effort to promote the development of biofuel production, Mozambique has engaged with governments and businesses in other countries (including biofuels giant Brazil) and has concluded agreements on trade cooperation, investment, and technology transfer, giving the country an advantage over other African countries, such as Angola, which have also shown an interest in biofuel production.

3.3.3 Feeding livestock

The diversion of cereals from human consumption to animal feed has increased from a fifth of developing countries' cereal output in the 1979–81 period to nearly a third of their cereal output 20 years later. Such diversion is projected to climb to almost 40 per cent of total cereal production in 2015 and one-half of the entire cereal output by 2030.[118] Some question the rationale for the conversion of grain into meat to fulfil the human nutritional requirement, pointing out that 5kg of cereals are needed to produce just 1kg of meat.[119] With regards to Africa, this trend could affect the quantities and price of cereal imports.

Many feedstuffs are available to livestock producers, including crop residues, processing co-products and new or alternative grains and forages, as well as more traditional grains and forages.[120]

3.3.4 Migration and rural development

The difficulties of making a living in the rural areas of developing countries have resulted in internal migration to the cities and to neighbouring countries as well as overseas, as can be observed in many African countries. This is particularly true for West African countries where agriculture has deteriorated considerably, an example being the cotton farming sector in Mali. Examples have shown that when agriculture is doing well, migration is reduced and in some cases is even reverted, as has been the case in Brazil. The northeast of Brazil, the poorest area of the country, is characterized by a semi-arid agro-ecological system. The difficulties for the agricultural sector resulted in a massive rural exodus towards southern, more developed regions of the country over the last decades. However, there was a reversal in the last decade with the implementation of an agri-export fruit sector in the valley of São Francisco River. A well-developed package of tropical technologies for the fruit sector is transforming the region, turning it into a major exporter of fruit to Europe, other South American countries, Japan and the United States. Many of those who migrated south particularly to Rio de Janeiro and São Paulo are now returning to their native regions to work on farms or take up jobs in the tourism and fruit sectors.

The government has played a key role in this process by ensuring that economic stability and social programmes such as the National Programme for Family Agriculture (PRONAF) are efficiently implemented in order to boost the modernization of small-scale farming. Brazil provides a valuable model of how to succeed in integrating small-scale farming into agri-export business without incurring huge losses.

Box 4: Impacts of the Philippines Biofuels Program[121]

The Philippines Biofuels Program has been promoted not only as a way to deal with mounting energy prices but also as a means of providing alternative income generating opportunities for rural households. A 2007 study looked at the impact of the programme on food security and focused particularly on two feedstocks: sugarcane and coconut. The initial results of a modelling exercise produced the following findings:

a. **Gross value-added in agriculture:** As a whole, the modelling results point to relatively large increases in the value-added of the agriculture sector. As expected, value-added in food processing declines, but by a lower amount compared to the increase in the sectors producing feedstock.

b. **Employment:** Total employment in agriculture also expands, and the increase comes primarily from the sugar and coconut production.

c. **Food crops output:** There is a perceptible decline in the value-added of rice and corn. This suggests that, due to the change in relative prices, variable inputs tend to move towards the production of biofuel feedstock. Large increases are expected in the price of sugar and coconut.

d. **Household income:** The results suggest that household income tends to increase.

e. **Profits:** Profitability of jatropha production is comparable to rice and corn. If, as claimed by those promoting jatropha, the crop does not displace others currently in the cropping system, it will bring about net economic benefits to rural areas. Farm operators will earn $115 per hectare per year on the third year, and additional employment equivalent to 40 man-days per hectare will be generated.

The experiences of Brazil in reverting migratory flux can provide valuable lessons for Africa. A number of factors are contributing to migration in Africa aside from under-developed agriculture. The economic meltdown, subsidies for agriculture in the developed world, climate change and political instability are but some of the elements that pose challenges for the future. On the other hand, remittances represent a positive contribution to agricultural and rural development, particularly in West Africa where a large proportion of migrants have direct or indirect links with the rural sector.

3.4 THE ROLE OF AGRICULTURAL TRADE IN FOOD SECURITY

3.4.1 Africa's agricultural trade deficit and policy linkages

The continent maintained a positive agricultural trade balance through the 1960s and 1970s, but saw a sudden and dramatic shift in the early 1980s (see Figure 6). A sharp decline in agricultural exports caused the deficit, which stood at $4.7 billion in 1997. Structural adjustment policies and restricted market access, coupled with the escalation of domestic and export subsidies in developed countries (leading to depressed world prices) contributed to deteriorating terms of trade and to a persistent trade deficit.

Research and analysis should propose opportunities for investment by identifying the affected populations, the food crops with large trade deficits, and the role that specific crops have in enhancing food and livelihood security.

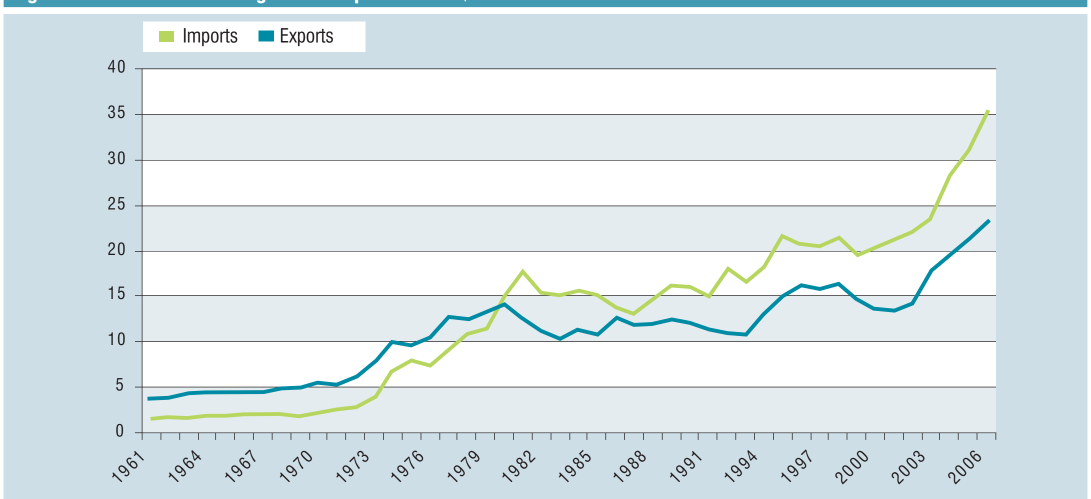
3.4.2 Trade and agriculture policy linkages

Trade policy linkages are paramount in determining the supply, accessibility and nutritional stability of food. Promoting food security in trade policy formulation and negotiations entails addressing issues related to availability, accessibility or affordability, and stability of food prices. This debate is even more critical to net food-importing countries.

Policy oriented research is needed to define the specific situations facing small and vulnerable economies (SVEs), landlocked countries and least developed countries (LDCs). Such research must go beyond merely noting how such countries might be affected by further trade liberalization and must also probe how they can improve their overall productivity and competitiveness.

The current realities of global trade, the declining value of the dollar, and rising food prices has encouraged some countries to take short-term trade policy responses, including controversial measures such as export taxes and restrictions, as well as consumer subsidies.

Figure 6. Africa's trade in agricultural products in $ billions



Data Sources: FAOSTAT (2006) elaborated by ATDF.

3.4.3 Trade policy in the wake of the food crisis

Since the intensification of food price hikes, African policy-makers have been considering ways to make food more affordable for vulnerable populations. A number of countries realize that, besides the goal of food security, food sovereignty is also worth considering, in light of the risks associated with over-reliance on unstable global markets. The measures taken by different countries range from food subsidies for consumers to incentives for farmers to increase production. For example Nigeria, Burkina Faso and Ethiopia lowered prices by releasing emergency grain reserves onto the market. Senegal and Ethiopia dropped tariffs on food imports and introduced food subsidies. Ethiopia banned the export of its cereals and added a ten per cent surtax on luxury imports to fund wheat subsidies for the poor.

Some are of the view that African countries may stand to gain from the food crisis. Among them the president of Uganda has argued that, overall, the crisis is good news for some farmers in Uganda. Over the years the country has increased its production of maize, bananas, potatoes, sweet potatoes, cassava, rice, wheat, and animal products such as milk, beef, etc. In addition, while much of the food crisis discussion is dominated by grains and other internationally traded commodities, it should be realized that roots and tubers form an important part of the diet in Africa and these crops have been relatively untouched by the crisis. Indeed, investing in the production of root and tuber crops can help provide a buffer and avert future food crises in sub Saharan Africa.

An appropriate trade policy response to the food crisis would need to incorporate a coherent approach to biofuel production, adaptation to climate change and mitigation, measures to ensure that price increases actually benefit small-holder farmers, and measures to enhance productivity and competitiveness in developing countries (potentially including, but not limited to, the existing 'aid for trade' mechanism under discussion at the WTO). The ongoing Doha Round negotiations on issues such as new food aid disciplines are also relevant.

3.5 SUMMARY

Achieving food security means much more than simply producing more food. Without policies to improve poor consumers' access to food, policies that increase the availability of food only will not ensure national food security.

In Africa, improving the availability of and access to food demands strengthening local productivity and production. This is because, in Africa and other developing country regions, the vast bulk of food is produced and consumed locally. A lesson from the recent food crisis is that as food import prices rise and global stocks drop, the need to improve local production becomes more acute.

There are four main ways to improve local food production:

(a) expanding arable land;

(b) achieving higher levels of cropping intensity;

(c) increasing yields; and

(d) implementing agricultural policy reforms.

Increases in cropping intensity are, however, strongly dependent on increasing the availability of irrigation.

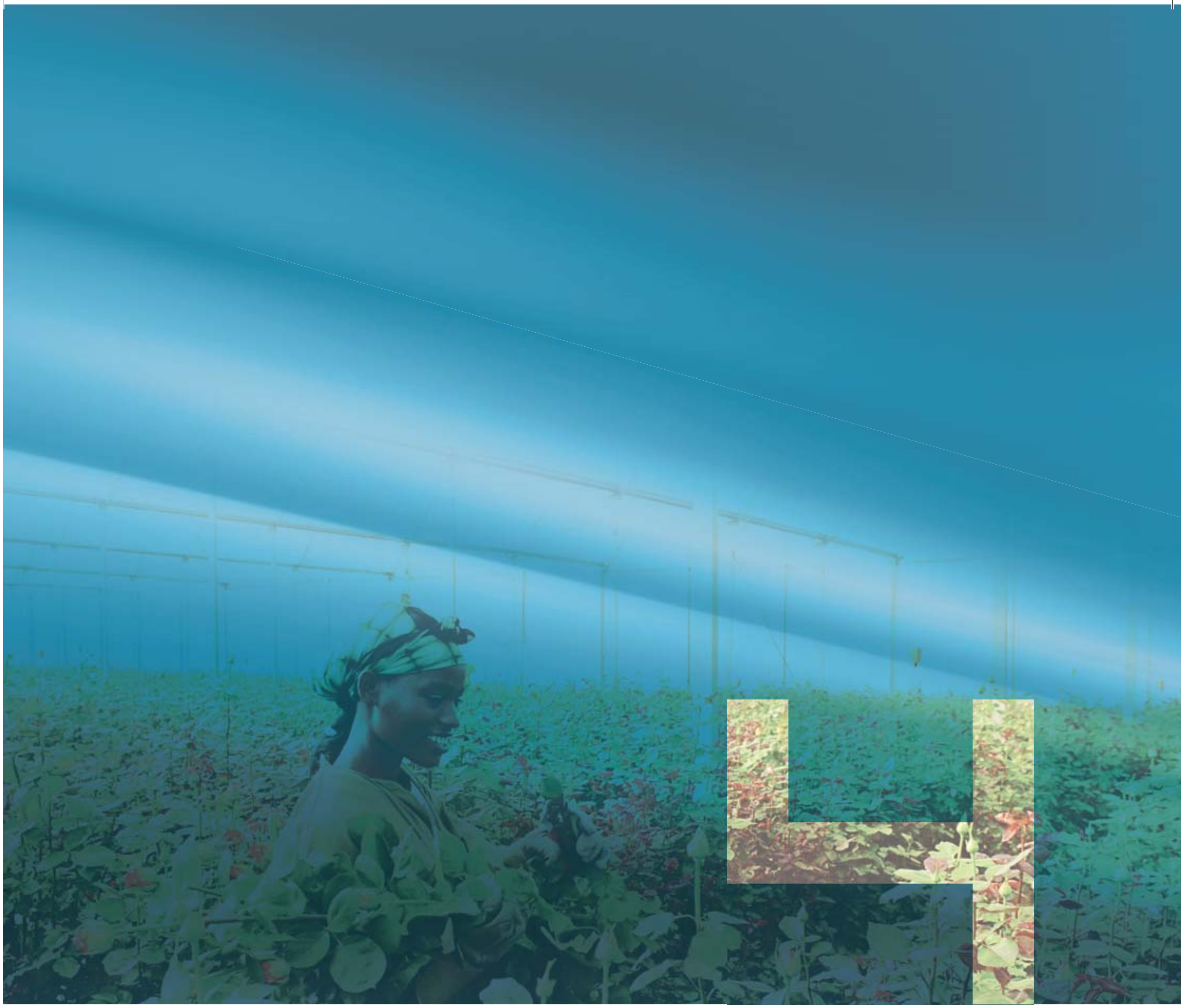
Yet the gains made through such strategies remain vulnerable to a variety of new challenges, particularly soil degradation due, among other factors, to climate change. Desertification is estimated to put the food security of one billion poor people at risk, particularly in dryland areas of Asia and sub-Saharan Africa.

Other important risks include the hollowing out of potentially productive rural communities caused by mass migration to the cities. While the explosive transfer of population from rural to urban settings can weaken the productive capacity of vulnerable agricultural sectors, experience suggests such trends can be slowed and even reversed by well designed policy interventions to improve the attractiveness of agriculture and rural livelihoods.

The failure of developed countries to recognize the negative impacts of their policy actions on food production and demand in the developing countries has in some instances resulted in suboptimal policy choices. To preserve policy coherence, renewed attention to agriculture must go hand-in-hand with the removal of farm and export subsidies for key commodities (cereals) in developed countries, to avoid depressing the prices that small-holder farmers receive in developing nations.

Competition for the use of land from biofuels poses yet another new risk for food security, as acreage that might have been devoted to producing food for human consumption is diverted to the production of biofuel feedstocks. Evidence is mounting that competition over the use of land from biofuels has contributed strongly to the current food crisis. Competition for land to raise livestock and produce animal feed similarly tends to decrease the amount of food available locally for food consumers.

This chapter has established the evolving nature of food security and how it goes beyond increasing production and relates to other policy areas. The next chapter discusses the challenges to achieving this in Africa, and explains why the call that is sometimes made for Africans to reproduce the Asian Green Revolution in their continent will not provide a solution to the need for rapid African agricultural development. It argues that any 'revolution' in African agriculture must be fundamentally different in nature.



4

CHALLENGES AND OPPORTUNITIES TO ACHIEVE FOOD SECURITY

4.1 AGRICULTURE AND DEVELOPMENT: REGIONAL COMPARISONS

Solving problems of agricultural production and access to food requires an assessment and identification of where additional investment dollars are most likely to have the strongest impacts. This chapter therefore draws some lessons and caveats from the Green Revolution. Some of the most important lessons learned relate to tenancy rights, the role of public institutions, the equitable distribution of resources, the investment gap in agriculture and the role of development assistance. Brief case studies on India and Brazil and a comparison of productivity gains in Asia, Latin America and Africa are provided to draw lessons for a strategy for African agricultural development.

Africa's development is, to a large extent, reliant on its progress in the agricultural sector. This is particularly the case in sub-Saharan Africa, where over 80 per cent of the poorest people live in rural areas and some 300 million people are undernourished.

Table 5. Agriculture and development in Africa, Asia and South America 2006[122]

Indicator	Sub Saharan Africa	Asia	South America
Percentage total labour force in agriculture	61%	55%	16%
Percentage GDP from agriculture	16%	6%	10%
Agricultural inputs			
Fertilizer-use intensity (kg/ha)	12	146	89
Percentage agricultural area irrigated	0.7%	15.1%	1.8%
Crop yields (kg/ha)			
Cereals	1,101	3,467	3,314
Pulses	472	785	849
Roots and tubers	8,.029	17,518	13,715
Hunger and poverty			
Kilocalories per day	2.262	2.682	2.851
Percentage children underweight	28%	31%	6%
Population living on less than US$1/day	44%	31%*	9%**

** South Asia only*
*** Estimate includes all of Latin America and the Caribbean*

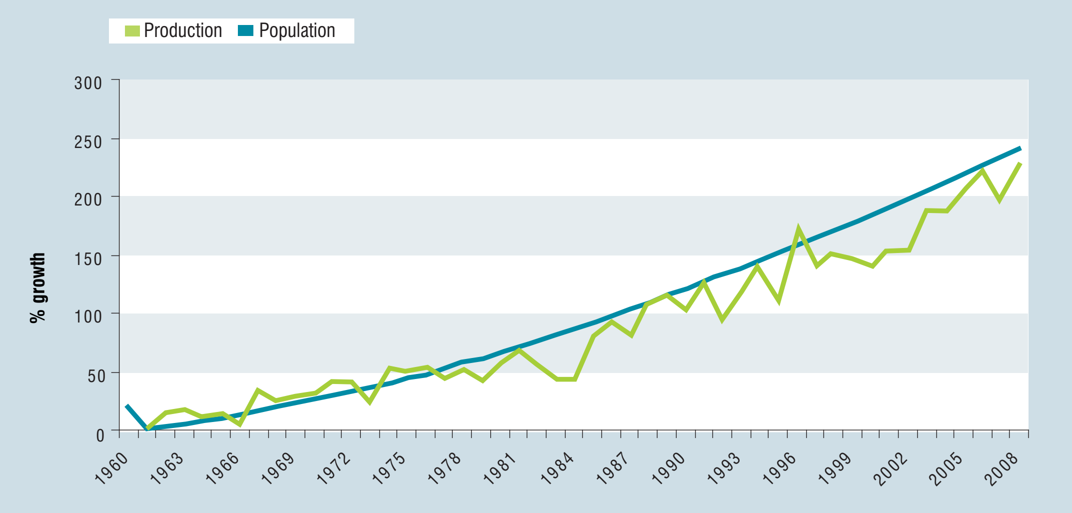
Small-scale farming in this part of the continent accounts for nearly 96 per cent of the total farming community and the majority of the small-scale farmers and rural workers are women struggling to improve living conditions in fragile and low-profit, semi- or full subsistence farming systems. African agriculture, for many reasons which will be examined in this report, has not taken part in the Green Revolution that so vastly improved life in Asian and Latin American countries in the late 1960s and early 1970s. The resulting gap between Africa on the one hand, and Asia and Latin America on the other is summarized in Table 5 below.

It could be argued that coming late to the Green Revolution has created a unique opportunity for Africa, as the continent has the chance to learn from the experiences of other parts of the world in adopting particular agricultural packages. There is now a better understanding of the conditions under which the Green Revolution and similar yield-enhancing technologies are likely to have equitable benefits among farmers. These conditions include a scale-neutral technology package that can be profitably adopted on farms of all sizes, an equitable distribution of land with secure ownership or tenancy rights, efficient input, credit, and product markets so that farms of all sizes have access to modern farm inputs and information and are able to receive similar prices for their products, and, finally, policies that do not discriminate against small farms and landless labourers (such as subsidies on mechanization and scale biases in agricultural research and extension).[123]

4.1.1 Growing food demand and shrinking supply of arable land

Since the 1970s, the population in sub-Saharan Africa has been growing faster than in any other region in the world, placing ever greater strains on food security and forcing farmers to intensify production beyond the point of environmental sustainability. With the population of sub-Saharan Africa expected to increase by nearly 400 million by 2025, the question being asked is: What technologies are most capable of meeting this increasing demand for food? Figure 7 shows that, since the late 1970s, cereal production has consistently failed to keep pace with population growth in Africa.

Figure 7. Growth in cereal production and population in Africa, 1961–2008[124]



Source FAOSTAT (2010) and United Nations Population Division

The issue of diminishing supply of arable land is an important one for Africa, especially as the continent could lose 247 million acres of farmland by 2050 due to climate change.[125] Small changes in temperature can cause a significant reduction in production. The National Academy of Sciences in the United States estimates that for every one degree Celsius increase, wheat, rice, and corn yields decline by 10 per cent. This will significantly reduce the global production of grains and put pressure on the supply and demand of farmland globally.

Another factor in the loss of arable land is the increase in pasture land. Meat consumption in developing countries is almost double that of developed countries. Increase in animal stock means additional land for grazing of farm animals.

All these factors have contributed to a downward trend in productivity. This is illustrated by figures showing that domestic production could meet 90 per cent of the demand for food in developing countries in the periods 1979–81 and 1997–99 but is expected to meet as little as 86 per cent of demand over the next two decades.[126] While wheat and rice together make up for over half of the global cereal consumption, coarse grains (maize, sorghum, barley, rye, oats, and millet) account for 80 per cent of human consumption in sub-Saharan Africa.[127]

4.1.2 The impacts of climate change on agriculture

Professor Rashid Hassan, co-author of a comprehensive study covering all the key agro-climatic zones and farming systems in Africa concluded that: *"Climate change is not an academic fallacy, but a real concern which is affecting the masses, especially the poorest of the poor who depend on agriculture for survival. It is a reality that is affecting real lives. It is imperative to note that this is not an issue that is going to disappear anytime soon. Information, education and resources need to be dispersed to the vulnerable laymen so that they can prepare themselves for its effects. It is the duty of individuals, governments and authorities to invest more into research that can help alleviate this and shed more light on this matter."* The study report argues that the highest risk of future climate change damage is associated with specialized crop and livestock farming (mono systems) particularly under dryland conditions in arid and semi-arid regions.[128]

While most vulnerable developing countries such as LDCs, SVEs and SIDS represent only a small portion of world trade, their key production and trade sectors – including agriculture – will be particularly affected by climate change impacts such as drought and flooding. The cumulative impacts of climate change on agricultural production are likely to translate into negative spillovers on employment, food production, food security, and income generation.

4.1.3 Tenancy rights and access to credit

Tenancy rights and access to credit go hand-in-hand. The possession of legal titles was found to lead to greater credit access for poor farmers in Peru.[129] These relate to investment in agriculture through demand and supply-side effects. On the demand side, land tenure security increases farmer demand to improve the productivity of the land in the medium and long term. In the presence of credit markets, technologies and farm inputs, improved tenure security leads to higher investment.[130] The transferability of land rights also plays an important role. Transferability of land rights may improve the creditworthiness of the land-holder, especially for long-term credit. This enhances the land's collateral value and lenders' expected return. In sum, investment may be encouraged by better land tenure security, the easier convertibility of land into liquid assets and the emergence of a credit market.[131]

The government of Mali considers land tenure as one of the crucial issues that is slowing down the country's agricultural development. The Agricultural Guidelines Law that was passed in 2006 aims to provide land tenure security through:

- equitable and easy access to land resources, particularly for women, youths and vulnerable groups;
- recognition of customs and habits;
- the creation of local land commissions;
- the introduction of a land register at commune level;
- involvement of farmers and their organizations in land management; and
- putting in place a law on agricultural land policy with preferential selection for women, youths and vulnerable groups.[132]

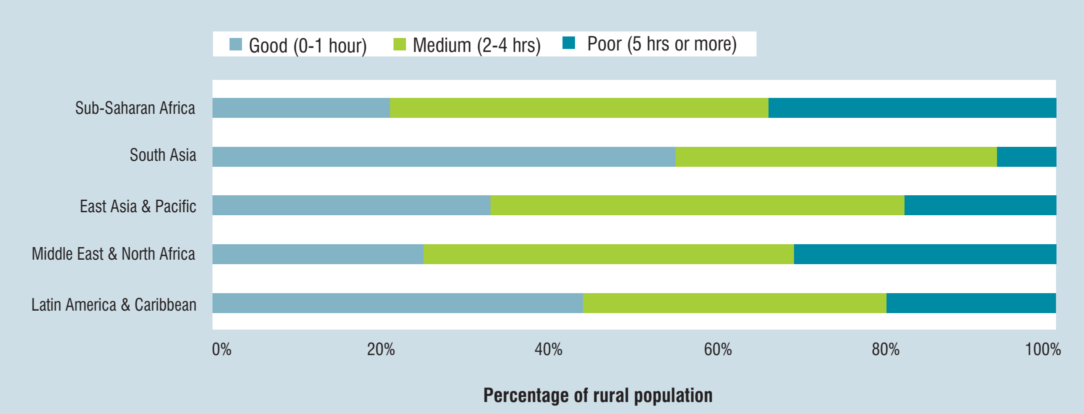
4.1.4 The role of public institutions

The first Green Revolution was introduced with substantial help from huge state-run support systems. Governments provided training, credit, research and extension, marketing, processing and distribution services to farmers who adopted Green Revolution technologies. These state subsidies created a market for private sector entry into the seed, fertilizer, machinery and trade activities in the Green Revolution. Few of these services are available today.[133]

Only a fifth of the rural population in sub-Saharan Africa has easy access to markets, compared to 60 per cent of Asian rural dwellers (as shown in Figure 8), making fertilizer procurement costs exorbitant for the former while facilitating the rapid spread of the Green Revolution in the agricultural fields of the latter. This is dramatically demonstrated by figures showing the impact of timely investments in rural roads by India, which contributed 25 per cent of the growth in its agricultural output in the 1970s.[134]

It should also be noted that the market and the private sector are increasingly driving agriculture productivity and income generation. This evolving reality must be harnessed to the benefit of small-farmers in developing countries.

Figure 8. Ease of access to markets in rural areas[135]



Box 5: Where best to invest: the case of India[137]

In the case of India, the three government expenditures found to be most effective in increasing agriculture production and alleviating rural poverty are:

1. **Government expenditure on roads:** An additional Rs100 billion invested in roads would increase productivity growth by more than 3 per cent. Road building has the largest positive impact on rural poverty, increased non-agricultural employment opportunities and wages. Of the total productivity effect on poverty, 75 per cent arises from the direct impact of roads on incomes, while the remaining 25 per cent arises from lower agricultural prices and increased wages.
2. **Government investment in research and extension** has the second largest impact on rural poverty, but the largest impact of any investment on productivity growth. Another Rs100 billion of investment in R&D would increase productivity growth by about 7 per cent and reduce the incidence of rural poverty by about 0.5 per cent. R&D has a smaller impact on poverty than roads because it only affects poverty through improved productivity, and India has not targeted R&D specifically to improve the lot of the poor.
3. **Third ranked is government spending on education**. An additional Rs1 million spent on education would raise 32 poor people above the poverty line, mostly by increasing non-farm employment opportunities and wages. However education, at least as measured here by a simple literacy ratio, has only a modest impact on agricultural growth.

Government expenditures on rural development, irrigation and power make up the rest of the list. It needs to be borne in mind that irrigation and power are more readily available in India compared to sub-Saharan Africa.

In conclusion, in order to reduce rural poverty and stimulate growth in agricultural productivity increased spending on rural roads, agricultural research and extension and education are needed to complement investments in agricultural inputs such as fertilizers, seeds and irrigation.

4.1.5 The investment gap in agriculture

Deploying technology and innovation to increase agricultural productivity will require increased investment in agricultural research and advisory services. A study by IFPRI calculated the public investment requirements that sub-Saharan Africa will need to invest in order to meet MDG1 (including investments in agricultural administration, research and extension, irrigation, and small rural infrastructure such as unpaved feeder roads). Table 6 summarizes the results of this study and shows that the investment gap is widest in sub-Saharan Africa.

These results suggest that SSA countries will need to boost their annual agricultural growth to 7.5 per cent per year in order to achieve MDG1. If SSA countries fulfil their commitments under the Maputo Declaration to allocate 10 per cent of their budgets to agriculture, the MDG1 target would require additional or incremental spending of $4.8 billion per year.

Table 6. Annual total agricultural spending required to meet MDG1 in Africa by 2015[136]

	Annual total agricultural spending (US$ billion in 2008) required to meet MDG1			
	Sub-Saharan Africa	West Africa	East Africa	Southern Africa
Total	13.6	9.06	3.79	0.83
Additional/ incremental	4.77	2.77	1.96	0.04

Yet prospects for additional financing have been curtailed by the world financial crisis. For the past year and a half, the world economy has experienced a downturn with job losses surging, stock markets at record low levels and investors around the globe holding on to their money. As the credit squeeze further intensifies there is pressure on governments to cut budget deficits. With this, the need to target spending more efficiently to achieve agricultural growth and food security is becoming even more important. Box 5 highlights the top three government expenditures for increasing agricultural production in India.

In sub-Saharan Africa, public spending for farming is only four per cent of total government spending. In addition the agriculture sector is taxed at relatively high levels.[138]

In the last three decades of the last century, developing countries consistently underinvested in their innovation systems. In 2000, overall public research intensity in developing countries, measured as the percentage of agricultural GDP invested in public agricultural research, remained low, at only 0.53 per cent.[139]

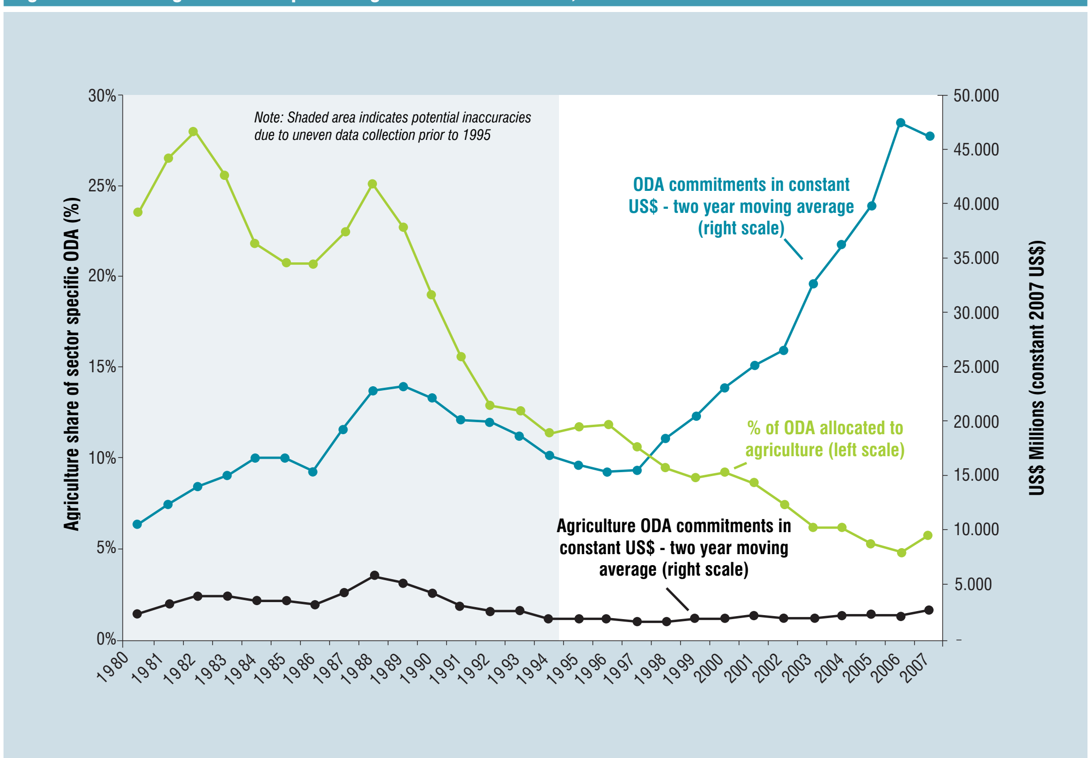
4.1.6 Development assistance

The productivity of African agriculture is also partially linked to development funding. International development assistance to agriculture has been declining (see Figure 9).[140] Aid to agriculture, which typically accounted for close to 20 per cent of bilateral sector commitments in the 1970s and 1980s had fallen to 12 per cent in 1993 and 1994. Over the last 15 years, the volume of aid to agriculture in Africa decreased both in absolute terms (from $2.6 to $2.0 billion), and as a share of total official development assistance (from 11 to 5.4 per cent).

Only three per cent of science-, technology- and innovation-related aid is destined for agricultural research in least developed countries (many of which are in Africa). As a result, Africa is one of the only regions in the world where agricultural research and development spending has actually declined since the early 1980s.[142] Research and development must be intensified with a focus on increasing crop tolerance of abiotic stress (such as drought, flooding and salinity) and resistance to pests and disease.

The shift towards structural adjustment lending that emphasized economic liberalization led to a sharp decline in aid to agriculture since the early 1990s. This decline has been attributed to a number of factors. For example, some point to the Heavily Indebted Poor Country (HIPC) Initiative, an agreement among official creditors to help the poorest, most heavily indebted countries escape from unsustainable debt. Due to sustained political pressure by civil society groups, the HIPC Initiative to help poor countries move on to a sustainable faster growth path, focused on the provision of poverty-reducing spending, such as on health and education[143] .

Figure 9. Aid for agriculture as percentage of total annual ODA, 1980–2007[141]



Source: OECD

The composition of aid has changed over the past three decades with large shifts in ODA allocations towards the social sectors (health, education, governance), and emergency assistance and reconstruction activities. The share of ODA devoted to the social sector grew from nearly 13 percent in 1979 to 44 percent of all ODA in 2007. In contrast, productive sectors (agriculture, industry, mining,) and economic and infrastructure sectors (communications, banking, transport, energy) have experienced declining ODA allocations. Around 58 percent of ODA in 1979, economic and productive sectors received slightly more than 23 percent of ODA in 2007.

More assistance according to some is being allocated to health and education because these sectors offer development agencies a number of attractions. For a start, aid can be channelled through large, public-sector entities, thus minimizing transaction costs. More importantly, assistance can be clearly linked to increased delivery of basic services which, in turn, can be easily associated with progress towards achieving internationally agreed development targets such as the MDGs. Aid to agriculture (and indeed to other productive sectors) on the other hand often has long gestation periods and lacks the same clear relationship between expenditure and outcomes.[144]

4.1.7 Emergency aid

Others argue that aid, especially food aid, is not a sustainable solution and can in some instances even be part of the problem. Badly administered, it has the potential to damage and disrupt incentives for local farmers to produce crops, for example by distorting local markets. In addition, food aid is also a disincentive for farmers to invest in marketing. As a result, it reduces farmers' incomes and may contribute to the marginalization of agriculture that then puts in motion a vicious circle in which communities depend on food aid because their returns are low. One way of reducing this risk is to secure a return on production through the provision of inputs (seeds, fertilizers and infrastructure and cash).

4.1.8 Following through on pledges

The New Partnership for Africa's Development (NEPAD), through its 2003 framework for a Comprehensive Africa Agriculture Development Programme (CAADP), is attracting renewed political interest in supporting agriculture. The 2003 African Union (AU) Maputo Declaration directed all AU member countries to increase investment in the agriculture sector to at least 10 per cent of the national budget by 2008. So far, only Ethiopia, Comoros, Madagascar, Malawi, Mali, Niger, Senegal and Zimbabwe have met this goal. Benin, Chad, Mauritatia, Nigeria, Sao Tome and Principe, Sudan, Swaziland, Uganda and Zambia allocate between five and ten per cent of their national expenditure on agriculture.

The World Bank is also proposing that the shares of public investment and foreign aid to agriculture be increased from four to ten per cent in sub-Saharan Africa. This would bring investment in the region to a level similar to that of India and China. Yet the bank's own lending to African agriculture fell considerably, from an annual average of $658 million in 1988-92 to $247 million during 1993-97.[145]

Total levels of investment are only part of the story. It is also important to channel an appropriate proportion of these funds to technology and innovation. Investments must also be carried out in tandem with efforts to address barriers to the development of the agricultural economy in sub-Saharan Africa, encouraging new technologies and their dissemination, and adapting innovative farming systems that are less vulnerable to the effects of man-made changes such as climate change.

Since the food crisis, several high-level meetings and pledges to revive agriculture in developing countries have taken place. A summary of meetings and their objectives can be found in Table 7. What is missing from this list is an event or initiative that focuses on how best to develop science, technology and innovation capacities for Africa's main food crops and farming systems.

Table 7. Major pledges to boost food security in Africa (2008/2009)[146]

World Bank	The World Bank has made an additional $1.2 billion available through its Global Food Crisis Response Program (GFRP). In April 2009, the WB's Board of Directors approved a new ceiling passing to $2 billion. On the immediate to longer-term food challenges, the World Bank Group said it would boost its overall support for global agriculture and food to $6 billion next year up from $4 billion, and would launch risk management tools, and crop insurance to protect poor countries and small-holders. In January 2010 the Global Agriculture and Food Security Programme (GASFP) was approved by the World Bank Board of Directors with donations expected to reach $ 1.5 billion in three years. The United States, Canada and Spain committed money to the mechanism.
EU	The European Union launched a €1 billion Food Facility in December 2008 to be spent over three years, notably through food aid, emergency aid and redeployment of funds. This is in addition to €800 million in 2008 and 2009.
United States	In 2008, the United States announced an additional funding for food aid of about $770 million for fiscal year 2009. In November at the World Summit on Food Security in Rome, the United States announced it would invest $3.5 billion over three years to spur "agricultural growth in a sustainable, environmentally friendly way".
FAO Summit	At the FAO High Level Conference on Food Security in 2008, pledges were made by various countries, including France, $1.5 billion (over five years); Germany, $750 million; Japan, $150 million; Kuwait, $100 million; the Netherlands, $75 million; New Zealand, $7.5 million; Spain, $773 million; United Kingdom, $590 million; Bolivarian Republic of Venezuela, $100 million. About 22 billion dollars were pledged after the summit.
Madrid Summit	At the Madrid High Level Meeting on Food Security for All held in January 2009 countries supported the need to create a Global Partnership for Agriculture, Food Security and Nutrition. Spain pledged an additional €200 million per year for the next five years.
Japan	Japan announced in 2008 just before the fourth Tokyo International Conference for Africa Development (TICAD) that it would double its average ODA to Africa over 2003-2007 (excluding debt relief) over the next five years (2008-2012). In the agriculture sector, Japan announced it would help African nations double rice production within a decade. This will be achieved in part by increasing the use of NERICA, or New Rice for Africa. TICAD underscores the importance of South-South cooperation, especially the development of trade and investment between Asia and Africa.
Brazil	At the African Union Summit in July 2009, Brazil signed a complementary cooperation agreement with the AU for the implementation of projects in the areas of agriculture and livestock. Brazil has established an office of the Brazilian Agricultural Research Corporation in Accra, Ghana calling for more involvement of South-South and triangular cooperation for the development of agriculture in the African continent. The Cotton 4 project has a budget of $4 million, including $3.5 million directly for agricultural projects.
China	China supports many infrastructure and agriculture and rural development projects in Africa. Recently it has announced the establishment of 14 centres of agricultural research in the continent and over 100 agricultural scientists are working in Africa. China has given important market access preferences for Africa, and it has become a major source of FDIs and an important creditor and debt relief. China announced eight new measures during the China-Africa forum in Egypt in November 2009. They included a commitment to enhance cooperation on science and technology, capacity building, education and training. Specifically, China will increase the number of agricultural technology demonstration centres in Africa to 20. It will be send 50 agricultural technology teams to Africa and train 2,000 African agricultural technology personnel to strengthen the continents ability to addressing food security.
India	In April 2008 India convened the First Summit Africa-India signing a cooperation agreement on the agricultural sector. The meeting also marked the announcement of a zero tariff for 98 per cent of imported products from LDCs including agricultural products. The next Africa-India Summit will be held in 2011 in Africa. India is the first developing country to announce the zero tariffs which is part of the Doha Round Package, agreed in the WTO Hong Kong (China) Ministerial in 2004.
African Agriculture Fund (AAF)	Established in April 2009, the AAF expects to raise €200 million during its first phase and has a final target of €500 million. The Fund will target private companies and cooperatives that implement strategies to increase and diversify agricultural production in Africa.
Regional Development Banks	The Asian Development Bank announced $0.5 billion for immediate budgetary support to tackle rising food costs and increased lending to agriculture by $1.0 billion for 2009. The African Development Bank added $1.0 billion to its agriculture portfolio which totals $4.8 billion now. The Inter-American Bank allocated $1.5 billion to the Jeddah Declaration on Assistance for Least Developed Member Countries Affected by the Global Food Crisis scheme. IADB also made available a $0.5 billion credit line
United Nations System	IFAD has made $200 million available in its response to rising food and energy prices. FAO presented a $1.7 billion Initiative on Soaring Food Prices (ISFP) during its High Level Conference on Food Security in June 2008. The WFP received $960 million as a result of its $755 million appeal to offset its increased costs for food and fuel.
G8 2005, Gleneagles, United Kingdom	G8 leaders committed to increase aid to developing countries by around $50 billion a year by 2010 of which at least $25 billion is expected to go to Africa.
G8 2008, Hokkaido, Japan	Reiteration of the commitments already made on Africa and Food Security. G8 members announced a collective spending of $10 billion to face the food crisis.
G8 2009 Aquila, Italy	L'Aquila Initiative on Food Security was launched where $ 20 billion was pledged to address issues of food security and putting food security, nutrition and sustainable agriculture, nutrition at the core of the international agenda. The negative impacts of climate change on agriculture and on the availability of water was also recognized.
G20 London	At the G20 Summit in London in April 2009 the United States announced a plan designed, in part, to combat the global food crisis. The initiative allots $448 million to address immediate aid concerns in Latin America and Africa, and allocates another $1 billion for the development of a long-term food security strategy. The President announced he intends to double U.S. assistance for global agricultural productivity and rural development.
Monterrey Consensus	The Monterrey Declaration, the outcome of the Financing for Development conference held in Mexico in 2002, stated that developed countries that have not done so should make concrete efforts towards the target of 0.7 per cent of gross national product (GNP) as ODA to developing countries and 0.15 to 0.20 per cent of GNP to least developed countries.

AGRA	AGRA (Alliance for a Green Revolution in Africa) was created in September 2006 with initial support from the Rockefeller Foundation and the Bill & Melinda Gates Foundation. The United Kingdom Department for International Development joined as a funding partner in 2008. AGRA budget varies according to the donations it receives and is aimed particularly at SSA.
United Nations Task Force Food Security	On 28 April 2008, the United Nations Secretary-General established the High Level Task Force on the Global Food Security Crisis under his chairmanship. To date, the Task Force has produced elements for a Comprehensive Framework for Action (CFA) as a guide for global and local actors, both institutions and governments, and a catalyst for action that needs to start now. The CFA provides a brief analysis of the global food crisis and the threats it represents, and outlines opportunities in several areas to improve global food security and further poverty reduction.

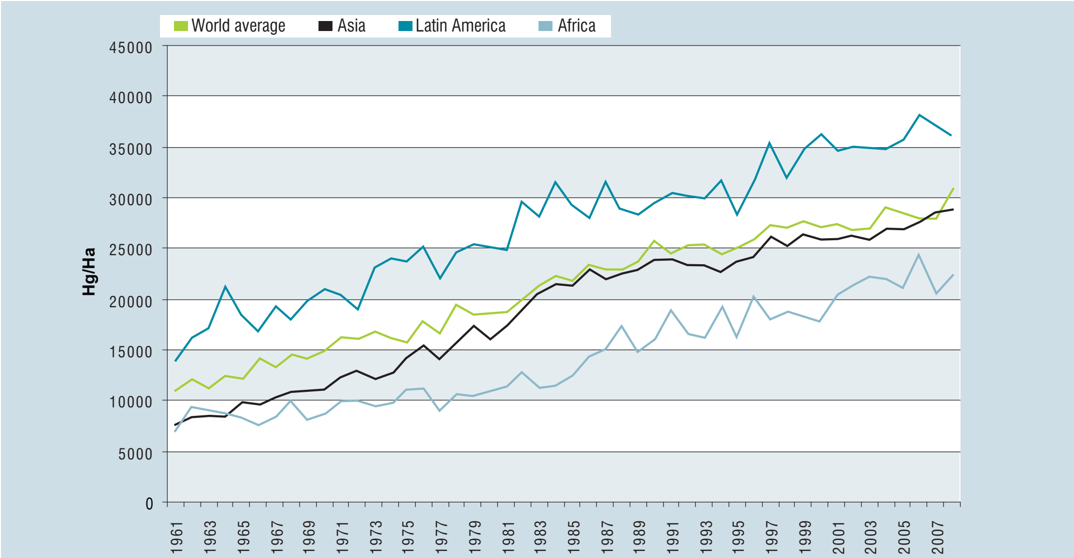
4.2 THE GREEN REVOLUTION: A BRIEF REGIONAL COMPARISON

Since the start of the latest food crisis, there have been increasing calls for a new Green Revolution, particularly for sub-Saharan Africa. Implicit in these calls is the recognition that the original Green Revolution in Asia was largely responsible for the aggregate increase in the yields of staple food crops in the region.

A comparison of African, Asian and Latin American productivity increases from the 1960s to the 1980s in wheat, rice and maize suggests that the Green Revolution in Latin America started earlier than in Asia. The Latin American Green Revolution started in the 1940s, with a programme funded by the Rockefeller Foundation aimed at assisting poor farmers in Mexico. Within two decades, high-yield dwarf wheat that resisted a variety of pests and diseases and yielded two to three times more grain than traditional varieties had been produced. The programme was expanded in the 1960s, teaching farmers in Pakistan and India to cultivate the new wheat. Pakistan produced 8.4 million tons in 1970, up from 4.6 million in 1965 and India's production was 20 million tons in 1970, up from 12.3 million in 1965. The Green Revolution then spilled over to China in the 1980s. By 1960, wheat yields in Mexico had already doubled from their 1940 level and have remained higher than the world average, and far higher than in Asia or Africa ever since (see Figure 10).

At the centre of the Green Revolution in Asia was a specific package of technologies – new, higher-yielding varieties of wheat, maize and rice, chemical fertilizers, and irrigation – that was designed to bring about a rapid increase in productivity of staple crops and help avert the threat of famine. The innovations developed changed the traditional methods of work and farming systems, transforming the socio-economic conditions of farming communities.

Figure 10. Wheat yields in Asia, Africa and Latin America, 1961–2008



Source: Faostat

Figure 11. Rice yields in Asia, Africa and Latin America, 1961–2008

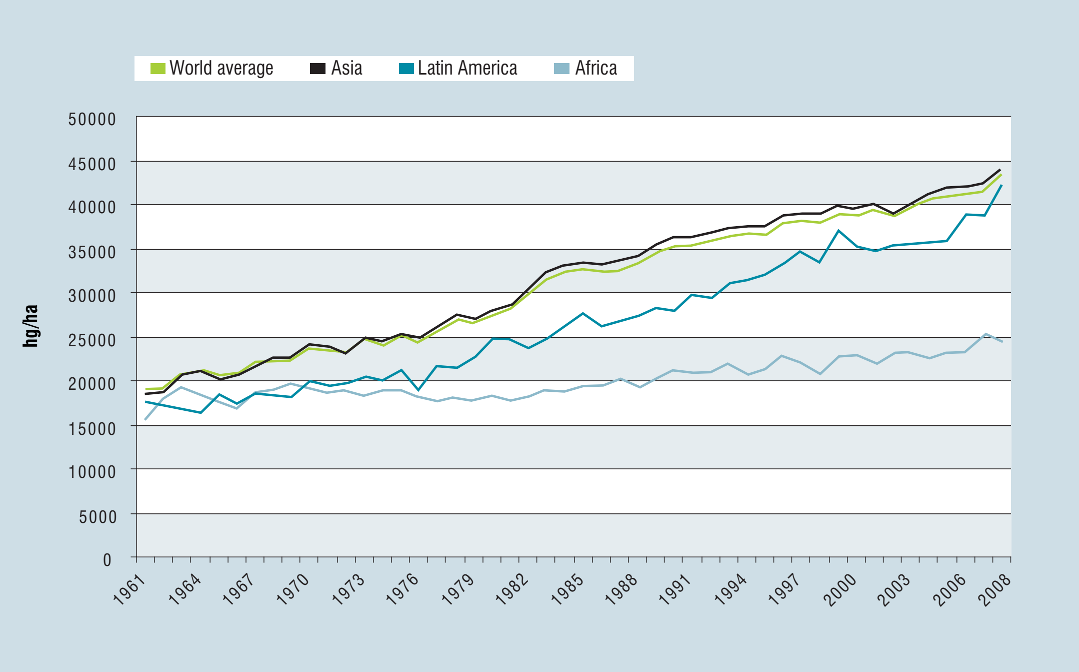
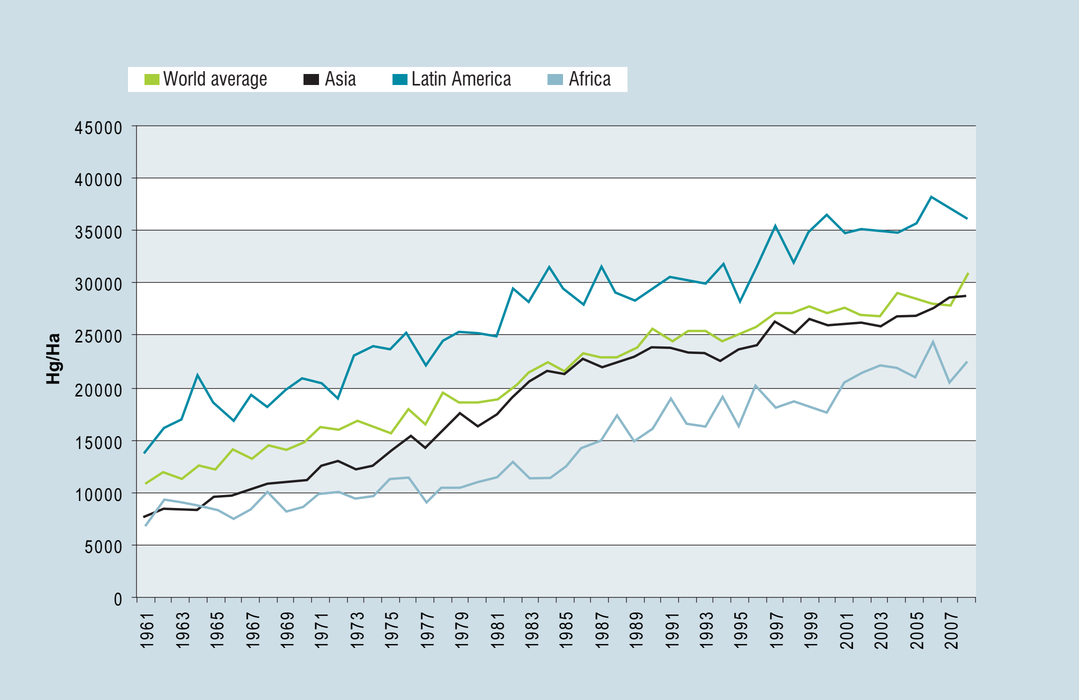


Figure 12. Maize yields in Asia, Africa and Latin America, 1961–2008



As Figures 10 and 11 show, yield increases in Africa for wheat and rice have failed to match the pace seen in other regions. Figure 12 shows that the same is true for maize, which is the most widespread of the three Green Revolution crops in Africa.

4.2.1 Yield versus harvested land

Figures 13, 14 and 15 show the growth of cereals production compared to harvested land in Asia, Latin America and Africa between 1962 and 2007. These figures show that productivity in Asia and Latin America resulted from yield increases while Africa's production increases have been a result of increased land use. An assessment by FAO and the International Institute for Applied Systems Analysis suggests that a further 2.8 billion ha of land are to some degree suitable for rainfed agricultural production. This is almost twice as much as is currently farmed. However, much of this potential land is locked up in other valuable uses. Some 45 per cent is covered in forests, 12 per cent is in protected areas and 3 per cent is taken up by human settlements and infrastructure.

While FAO studies suggest that there are no shortages of suitable agricultural land at the global level, some regions already face serious shortages. In densely populated South and East Asia for example, more than 80 per cent of the increase in food production will have to be secured from yield increases as only 5 or 6 per cent can be obtained from the expansion in arable land.

Although increased productivity in Africa has come as a result of increased land use, this does not mean that all African countries are running out of farmland. Benin for example exploits only eight per cent of its potential farmland. Where land is in short supply, the use of new high-yielding varieties will help address this constraint. For example by boosting the high-yielding NERICA rice varieties, West Africa would not only use land more efficiently but would also reduce its dependence on imports. This would be a significant factor in a region that is expected to import 11 million tons by 2010 against 6 million imported in the beginning of the decade.

Figure 13. Growth in cereal production and harvested land in Asia, 1962–2008[148]

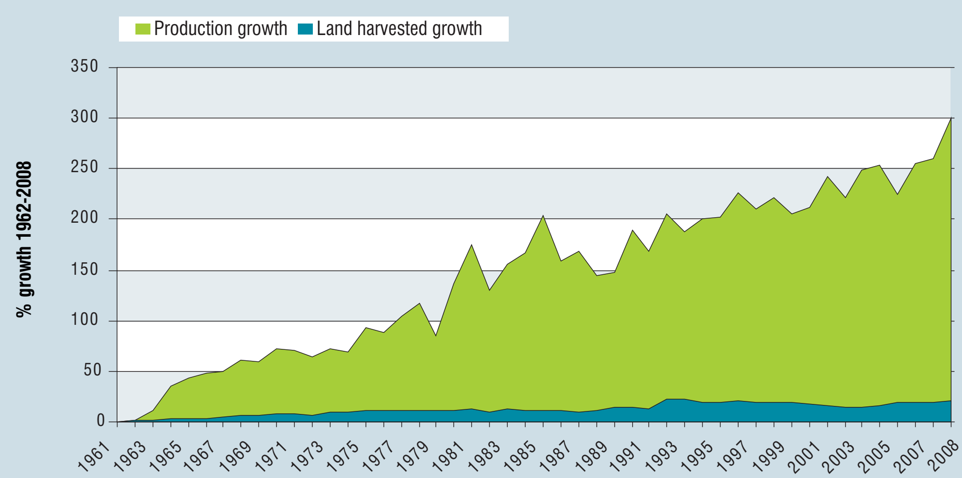


Figure 14. Growth in cereals production and harvested land in Latin America, 1962–2008[149]

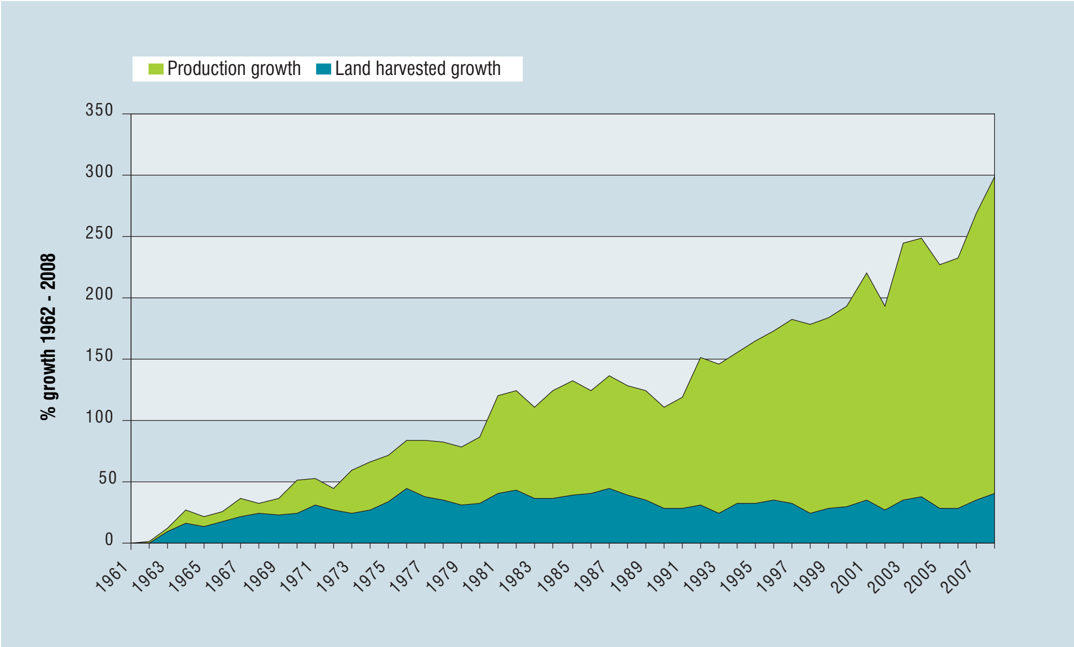
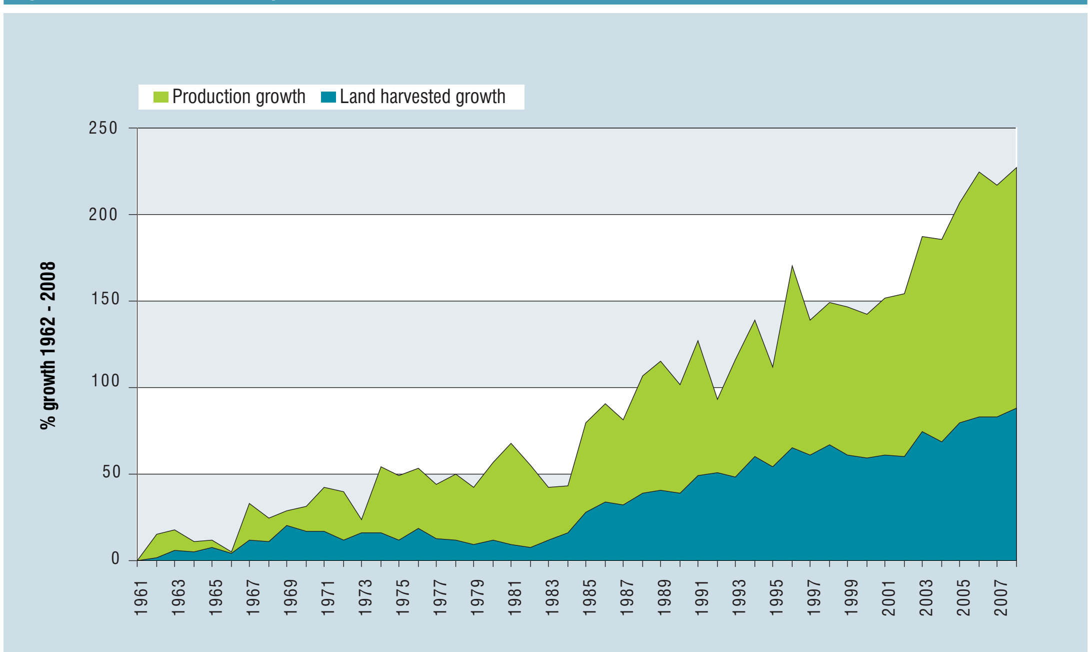


Figure 15. Growth in cereals production and harvested land in Africa, 1962–2008[150]



4.2.2 Regional differences and unequal productivity

Alarmingly, annual growth in crop yields has been declining globally from two per cent during 1970-90 to only one per cent during 1990–2007, with bleak prospects of any improvement in the future. Rice scientists and policy-makers are becoming concerned about the fact that rice yields seem to be levelling off in Asia. It may well be that the Green Revolution technologies are now almost exhausted of any further productivity gains. Among the reasons for this decline in Asia's rice production increases are long-term degradation of the paddy resource base and the shrinking of rice lands under pressure from industrialization.[151] Scientists attribute the net drop in Asia's total irrigated area to soil salinization and water logging associated with intensive rice cropping. This is expected to get worse due to the decline in quantity and quality of water available for rice growing. Furthermore, water and wind erosion are estimated to affect some 400 million ha of the region's farmland, while another 47 million ha are subject to chemical and physical degradation.

Others however warn that some temporary decreases in yield have been confused with yield decline. For example, in central China lower yields were found to be caused by unsuitable varieties and inadequate use of organic matter, while in India the causes identified ranged from cyclones to the removal of fertilizer subsidies. There needs to be a better methodology to quantify deceleration, stagnation and decline processes and delineate affected areas as accurately as possible.[152]

These experiences are informing Africa's approach to addressing agricultural productivity and food security. The following section looks at the elements of such an approach.

4.2.3 Lessons from the Green Revolution and relevance to Africa

IFPRI assesses the impacts of the Green Revolution as follows: "*The Green Revolution was a major achievement for many developing countries and gave them an unprecedented level of national food security. It represented the successful adaptation and transfer of the same scientific revolution in agriculture that the industrial countries had already appropriated for themselves. The Green Revolution also lifted large numbers of poor people out of poverty and helped many non-poor people avoid the poverty and hunger they would have experienced had the Green Revolution not occurred. The largest benefits to the poor were indirect, in the form of lower food prices, increased migration opportunities, and greater employment in the rural non-farm economy. The direct benefits to the poor through their own on-farm adoption, greater agricultural employment, and empowerment have been more mixed and depend heavily on local socioeconomic conditions. In many cases inequalities between regions and communities that adopted Green Revolution technologies and those that did not also worsened. At the same time, the Green Revolution had many negative environmental impacts that have still to be adequately redressed*." [153]

While the Green Revolution was successful in increasing the yield of rice, wheat and maize it did have some serious shortcomings. For example, it did not address the issue of malnutrition, or the negative impacts it had on the environment as high levels of fertilizer inputs for rice affected the structure of the soil and the ecosystem.

The particular characteristics of African farms pose significant problems in realizing an Asian-type Green Revolution. The features that set Africa apart include:

- lack of a dominant farming system on which food security largely depends;
- predominance of rainfed agriculture as opposed to irrigated agriculture;
- heterogeneity and diversity of farming systems and the importance of livestock;
- key roles of women in agriculture and in ensuring household food security;
- lack of functioning competitive markets;
- under-investment in agricultural R&D and infrastructure;
- dominance of weathered soils of poor inherent fertility;
- lack of conducive economic and political enabling environments;
- large and growing impact of human health on agriculture exacerbated by diseases such as Aids and malaria;
- low and stagnant labour productivity and minimal mechanization; and
- predominance of customary land tenure.[154]

Today's African farmers could easily produce far more food than they do, but they are constrained by their lack of access to credit to cover production costs and difficulties in finding buyers and obtaining fair prices to give them a minimal profit margin. Under such circumstances, what difference will a new technology package make? Without addressing the underlying reasons why African farmers leave farming or why they under-produce, most initiatives will have little impact on this trend.[155]

As this report has stressed, it is important to focus on yields because yield gains have a significant impact on poverty reduction – a one per cent increase in yield translating into a 0.5 per cent to 0.8 per cent reduction in poverty. The need to revive and sustain crop yield growth is vital to attaining the MDGs.

4.3 TOWARDS A RAINBOW REVOLUTION IN AFRICA

Calls for a new technology paradigm for African agriculture have been made by NEPAD, the World Bank, AGRA and other institutions and initiatives. The 4th Pillar of the NEPAD Comprehensive Africa Agriculture Development Programme (CAADP) stresses the need to enhance the rate of adoption of new technologies to increase productivity (through better delivery systems and mechanisms that reduce the costs and risk of adopting new technologies), and the need to strengthen the ability of the research systems to generate and adapt new knowledge and technology. The 2008 World Development Report considers science and technology as the lynchpin to Africa's future productivity growth, stressing the importance of technologies such as conservation tillage, integrated pest management, and new crop varieties. The report calls for ensuring that innovations and benefits from new technologies target the poorer segments of society more precisely and that relevant food crops are planted to ensure that small-scale farmers receive greater direct benefits from technology and innovations. This means reengineering systems to cope with the unique characteristics of smallholders, including low capital availability, low risk tolerance, and the relatively low opportunity cost of family labour.[156] AGRA calls for an "African consensus" on policies to rapidly trigger agricultural productivity growth through a uniquely African Green Revolution – one that promotes equity, protects the environment, and brings about comprehensive change across the agricultural system. To move towards an agriculture of the future better suited to feeding the world also means producing more food in ever smaller extensions of ever less fertile land by large groups of subsistence farmers who will face growing obstacles to producing substantial surpluses and may need to be encouraged to partner with, or become, commercial farmers. A broader and more integrated perspective is needed for African agriculture, one that focuses on the entire farming enterprise – food and cash crops, livestock and value-added processing.[157]

Since the Green Revolution, successful agro-ecological approaches have been created to help sustain agricultural development.[158] It has been demonstrated that yields for the crops that the poor rely on most – such as rice, beans, maize, cassava, potatoes and barley – can increase several fold by relying on local biodiversity, family labour and new and traditional agro-ecological knowledge.

African agriculture according to a panel of African experts "*is more likely to experience numerous 'rainbow evolutions' that differ in nature and extent among the many systems, rather than one Green Revolution as in Asia.*"[159] The alternative will be based on agro-ecology, where the objectives are higher yields together with improved soil conditions and decreased dependence on water and irrigation. National policy and investment decisions must be taken that target scarce resources at specific national development goals. The implication here is that, unlike the standard technology packages of the earlier Green Revolution, a future transformation of agricultural systems in developing countries is likely to be based on tailor-made solutions for different countries, and even local contexts. Hence, the term 'Rainbow Revolution'. The following are two examples from India and Brazil that emphasize the need for tailor-made interventions to increase productivity and access.

4.3.1 The Case of India: approach to a second Green Revolution

The first-ever national agricultural policy that was referred to as the "rainbow revolution" was launched in India in 2000.[160] The policy objective is to achieve a growth rate in agriculture of over four per cent per annum in the next two decades with total GDP growth being sustained at 6.5 per cent. The policy calls for stepping up public investment to narrow regional imbalances and for accelerating the development of infrastructure that supports agricultural and rural development, particularly rural connectivity.[161] The major components of the policy include:

- Formulation of a timebound strategy for rationalization and transparent pricing of inputs to encourage judicious input use and to generate resources for agriculture. Input subsidy reforms will be pursued as a combination of price and institutional reforms to keep costs under control. A conducive climate will be created through a favourable price and trade regime to promote farmers' own investment and investments by industries that produce inputs and other agro-based industries.

- Encouragement of private sector investment in agricultural research, HRD, post-harvest management and marketing. All distortions in incentives will be removed. Rural electrification will be given high priority for adequately meeting the demand of agriculture in a cost-effective manner. All on-going irrigation projects will be completed and modernized and an integrated plan for augmenting and managing national water resources will be launched.

- Upgrading of marketing infrastructure and development of modern techniques of preservation, storage and transportation. Producers' markets will be encouraged, as will the setting up of agro-processing units in producing areas. Collaboration between producer cooperatives and the corporate sector will be encouraged in the processing industry. The Small Farmers Agro Business Consortium (SFAC) will be energized to cater to the needs of farmer-entrepreneurs and to promote public and private investments.

- Consolidation of land holdings on the pattern of north-western states. There will be redistribution of ceiling surplus lands and wastelands to landless farmers and unemployed youths with initial start-up capital, tenancy reforms to recognize the rights of tenants and sharecroppers, development of lease markets for increasing the size of land holdings by making legal provisions for contract farming. Land records will be updated and computerized and land pass books issued to farmers.

- Progressive institutionalization of rural and farm credit. Distortions in priority sector lending by commercial banks will be removed and cooperative banks will be revamped and given more autonomy to function professionally. The National Agriculture Insurance Scheme will be made more farmer-specific and effective and will provide package insurance policy from sowing to post-harvest operations. Contingency agricultural planning against natural disasters will be taken up.

In short, the policy entails encouraging value-addition, removing curbs on movement of agro-producers within the country, protecting farmers against cheap imports through tariffs and making available credit and finance.

4.3.2 The Case of Brazil: from a technology taker to technology exporter

Brazil is now one of the leading countries in the development of tropical agricultural technology. This position is a result of more than three decades of public and private investment in the development of technological packages tailored to its own soil and agro-ecological conditions. The technology developed in Brazil has been applied to both large and small-scale farming, with important results for both sectors.[162]

The country's tropical agriculture has overcome the difficulties of the 1970s, which were marked by low production, poor diversification and several food crises. Too often, shortages of basic staples such as rice, maize and wheat resulted in high prices and consequently high inflation and an increase in poverty. The 1970s were also characterized by low productivity and a lack of specific knowledge, as well as an institutional void in agricultural research and education, and the lack of an efficient domestic market and strong government institutions.[163] The challenge at the time was to move away from applying standard agricultural models to tropical agriculture towards developing locally relevant agriculture technologies that could address local conditions. At the same time, there was a great need for public policies on agriculture and food security to be articulated and implemented and knowledge institutions to be developed.

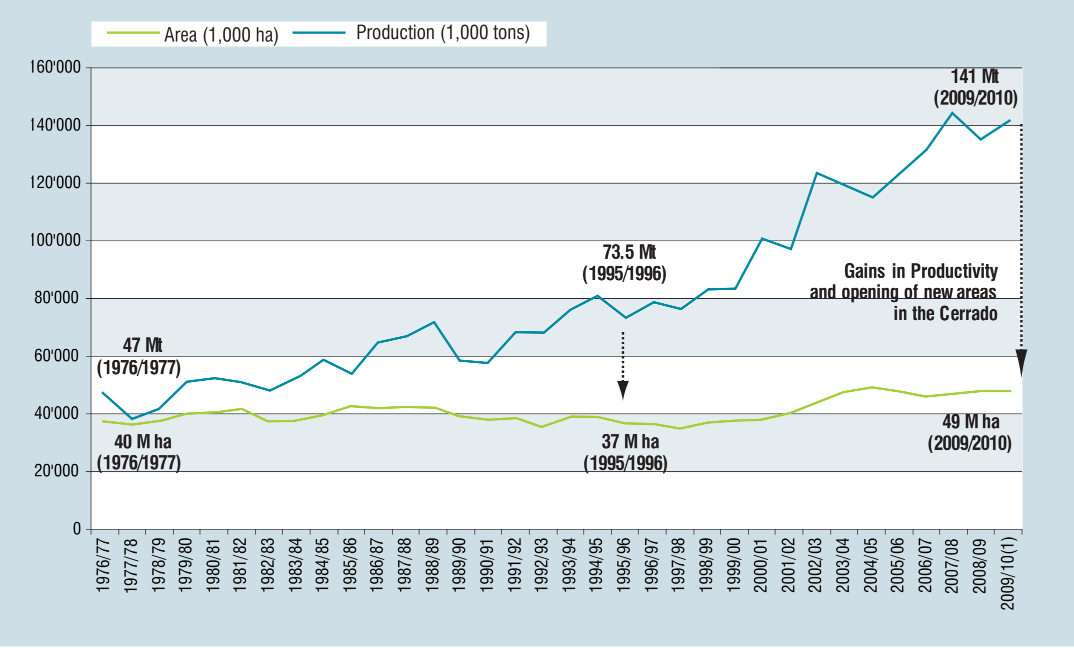
The development of suitable technologies and improvement in yields in Brazil has been the result of a mix of developments in domestic public policy, international cooperation, private investment, and the amount of land available for agriculture. The public policies required included agricultural credit, land technology, agricultural market policies (minimum prices), investment in infrastructure, storage facilities, agricultural research, education and rural extension.

The establishment of the Brazilian Agricultural Research Cooperation (Embrapa) in 1973, a public institution linked to the Ministry of Agriculture and Food Supply, played a central role in the development of Brazil's agriculture in recent decades. Its efforts have been complemented by a series of critical public, private and institutional reforms, including the reorganization of production chains, the establishment of farmers' associations and the development of a vibrant agro-industry to meet the needs of a diversified group of farmers, not only those of larger farmers. Cooperatives also played an important role in the development of small-scale family farming.

In the last two decades, grain production in Brazil soared from less than 60 million tons in 1990/1991 to over 140 million tons in 2007/2008 (as shown in Figure 16), thereby improving food security and creating a surplus for the export of a range of products. Productivity in this period almost doubled from 1.5 tons/ha to nearly 3.0 tons/ha. In the meat sector, genetic improvements and other production techniques led to a drastic increase in the production of beef, rising from 5.5 million tons in 1991 to nearly 10 million tons in 2008. The production of pork meat nearly tripled from 1.1 million tons to 3.1 million tons in 2008 and the production of poultry meat rocketed from 2.7 to a stunning 11.3 million tons. The country has managed to achieve not only food security but also a situation of surplus and, in the process, has become a major exporter of agricultural products, and recently, of processed agricultural products, to the developed and the developing world. In 2008 Brazil exported grains and meat to nearly 100 countries.

The successes as well as the failures of Brazilian agriculture are now being shared with other countries especially in Africa, as Brazil has signed cooperation agreements with a number of developed and developing countries.

Figure 16: The evolution of grain production in Brazil [164]



Source: CONAB - Brazilian Company for Food Supply, Fourth Survey Year Crop 2009/10, published in January 2010 (1) Forecasted

4.4 IMPLEMENTING A UNIQUELY AFRICAN GREEN REVOLUTION

Given the unsuitability of the Asian model of Green Revolution to African realities, this report sketches out a different approach to the problem of food security, one that centres on the need to revive sub-Saharan Africa's depleted soils, improve the sustainability of small-scale farming, raise the yields and incomes of poor farmers, and help protect the natural resource base of soil and water. Water management is particularly important as only 30 per cent of land in Africa is adapted to rainfed production.[165]

Achieving these goals will require increased and targeted investments in agricultural inputs that targets Africa's diverse agro-ecologies. Unlike the Asian Green Revolution whose technologies focused on a limited range of cropping systems and irrigation, a new approach must target research and development investment into neglected crops such as sorghum, millet, maize, cassava, cowpea to help increase their yields. All this must be coupled with innovations in policy, market structures and regulations.

The hope for a 'Rainbow Revolution' in 21st Century agriculture, in the wake of the food crisis, must be conditioned in three ways:

- The lessons that can be drawn from the earlier Green Revolution in Asia;
- The new opportunities that have emerged in recent decades, particularly those that are related to the enabling environment, the new scientific and technological developments; and
- The present and anticipated challenges to agricultural production, including land and water management, the impacts of climate change, and the issues of access to and sustainable use of new agricultural technologies (especially, biotechnology).

It has been argued that an African Green revolution can be triggered by concerted and synchronized efforts on two fronts: first by working with African farmers and other stakeholders to redesign and modernize the complex African subsistence farming systems, and second by applying modern science and technology to produce robust technologies tested at farm level and adapted to the respective agro-ecological zones in Africa.[166] A third front that this chapter adds is to reduce crop losses by applying post-harvest technologies and innovative management systems. All of the above are not without serious implementation constraints. The Windhoek High-Level Ministerial Declaration on African Agriculture in the 21st Century recognizes these constraints and takes up the now familiar call for an African Green Revolution to help boost agricultural productivity, food production and national food security.

However African ministers went beyond the Asian Green Revolution and noted that an African reprise need not depend only on improved seed and fertilizer but should also be built on a range of complementary investments in rural development, including roads, electricity, health and education. These aspects are now being taken into account. For example, African Heads of State and governments have endorsed a vision for the restoration of agricultural growth, food security, and rural development in Africa better known as the Comprehensive Africa Agricultural Development Programme (CAADP). One of the pillars of this programme is NEPAD's strategy for revitalizing, expanding and reforming Africa's agricultural research, and technology dissemination and adoption efforts. The three other pillars include: (a) extending the area under sustainable land management and reliable water control systems; (b) improving rural infrastructure and trade-related capacities for improved market access; and (c) increasing food supply and reducing hunger. Each of these pillars incorporates policy, institutional reform and capacity building. The goal is to attain an average annual growth rate of six per cent in agriculture. In Ghana, the current sector development policy guideline (2008–2010) targets reducing rice imports by 30 per cent by increasing production levels to 370,000 tons per annum. Specific measures to reach this level of production include, among others, increased mechanization, increased cultivation of inland valleys, efficient utilization of existing irrigation systems and use of improved and high-yielding varieties.[167]

Advances in Africa's agricultural research, technology dissemination and adoption will require significant changes in three areas: (a) strengthening Africa's capacity to build human and institutional capacity; (b) empowering farmers, and (c) strengthening agricultural support services.[168] Box 6 outlines some suggestions for the principles on which efforts to boost Africa's agricultural productivity should be based.

Box 6: Evolution and reform of agricultural institutions and services[169]

In order for Africa's agricultural productivity efforts to be successful, they should reflect the principles of:

- Empowerment of end-users to ensure their meaningful participation in setting priorities and work programmes for research, extension, and training to ensure their relevance;
- Planned subsidiarity to give responsibility and control over resources for agricultural research, extension, and training activities at the lowest appropriate level of aggregation (local, national and regional);
- Pluralism in the delivery of agricultural research, extension, and training services so that diverse skills and strengths of a broad range of service providers (e.g. universities, NGOs, public and private sectors) can contribute to publicly supported agricultural productivity operations;
- Evidence-based approaches with emphasis on data analysis, including economic factors and market orientation in policy development, priority setting and strategic planning for agricultural research, extension, and training;
- Integration of agricultural research with extension services, the private sector, training, capacity building, and education programmes to respond in a holistic manner to the needs and opportunities for innovation in the sector;
- Explicit incorporation of sustainability criteria in the evaluation of public investments in agricultural productivity and innovation programme (fiscal, economic, social and environmental);
- Systematic utilization of improved management information systems, in particular for planning, financial management, reporting, and monitoring and evaluation;
- Introduction of cost sharing with end-users, according to their capacity to pay, to increase their stake in the efficiency of service provision and to improve financial sustainability; and
- Integration of gender considerations at all levels, including farmers and farmer organizations, the private sector, public institutions, researchers and extension staff.

4.5 SUMMARY

Financial resources are badly stretched in most African countries. Policy-makers need to invest in the most productive manner possible, putting resources into areas that are most likely to have a large impact on increasing smallholder productivity and improving national food security. Nevertheless, there is also a need for African countries to increase their investment in agricultural development. A combination of smart targeting of investment and greater overall levels of public support for agriculture is needed. Today, only a handful of African countries devote the agreed target of 10 per cent of GDP in public expenditure in agriculture.

Some research from India points to investment in rural roads, research and extension and education as the most effective investments to combat rural poverty, but other evidence suggests that sub-Saharan African countries should also pay close attention to irrigation and rural electrification.

Unfortunately, the international community has shown decreasing interest in support for African agriculture over the past 30 years. Support for agriculture as a proportion of total international development assistance to African countries has fallen by as much as two-thirds from its peak in the early 1980s, as a result of the shift towards structural adjustment lending with an emphasis on liberalization. This has left many African countries badly positioned to face the challenges posed by volatile prices for agricultural inputs and food products and the impacts of climate change.

There are strong structural impediments to replicating an Asian-style Green Revolution in Africa. The heterogeneity of staple crops, farming systems and the paucity of rural infrastructure make it clear that no mechanistic replication of the Green Revolution technology package is possible, or even desirable, in Africa. Specific African challenges and conditions, and the need to pursue sustainable agricultural development, mean that a truly African Green Revolution should be very different from the Asian Green Revolution of the 1960s and 1970s. The package of measures needed must also go beyond appropriate technology mixes and address other constraints to smallholder farmers building stronger technological and innovation capabilities.

For too long, African agriculture has lagged farther and farther behind other developing regions in nearly every measure of agricultural productivity and production. African production growth has tended to rely on unsustainable increases in the area under cultivation, while yields stagnate. A new agro-ecological approach, sometimes dubbed the Rainbow Revolution, is needed to reverse these trends. The interventions needed range from the tried-and-true (increases in land under irrigation) to the use of appropriate innovations to radically increase productivity in African agriculture.

What has become clear, however, is that no intervention can hope to succeed unless African smallholder farmers are brought into the process. Their ability to participate, however, depends on much more than what happens on the farm. Which brings us to the next set of concerns: the need to understand and radically overhaul the enabling environment surrounding food production and extending outwards into financing agricultural investment, agricultural research, transport and education systems, distribution and storage: the panoply of food-related activities that take place outside the farm itself that connect consumers with the food they need.

This chapter has outlined the main challenges to attaining food security in Africa and argued that the solution cannot be a simple reproduction of the Asian Green Revolution in Africa. Such an approach will not achieve the same results in Africa, and that model needs refinement in any case to make it more sustainable. A different set of approaches is needed in Africa, geared to the diverse circumstances of African smallholder farmers that are not only effective in raising productivity but also meet more stringent conditions on sustainability, especially in water and energy use. We might refer to this as a uniquely African revolution in agriculture, an ‘African Rainbow Revolution’.

5

TRANSFER AND DIFFUSION OF AGRICULTURAL TECHNOLOGY

5.1 INTRODUCTION

This chapter discusses the different ways of how technology is transferred and which process is best suited to increase the productivity of smallholder farmers. It points at the need for acquiring technologies that are adapted to the local agro-ecological system as a key part of any serious strategy for achieving food security.

There is a well-recognized, acute need for smallholder farmers to utilize more productive farming inputs, tools and techniques. However, technology transfer and diffusion in developing countries represents a formidable challenge for a variety of reasons. These include a lack of resources, the logistical and communication difficulties of reaching the intended recipient, extreme climate and poor soil conditions, the lack of infrastructure, and the high incidence of health issues and political instability. Together, these constitute a major problem for anyone involved with disseminating agricultural technologies. In addition, our understanding of how new ideas, knowledge and technologies are introduced into agricultural practice remains incomplete. The traditional 'technology push models' – linear, research-dominated models represented by technology pipelines – have given way in recent years to more systems-oriented approaches. The innovation systems approach is increasingly being applied to the analysis of innovation capabilities, and broader STI capabilities, in manufacturing and even services, and provides a useful framework of analysis for STI capabilities in agriculture as well, using the concept of agricultural innovation systems (AIS). This concept builds directly on established work on innovation systems and applies the framework to agriculture. Accordingly, the AIS framework maps the network of relations between the organizations, institutions and policies in the agricultural system of a country and examines the linkages among them. Figure 2 in Chapter 2 presented the main elements of an AIS. The AIS provides a convenient structure for discussing the development of innovation capabilities in agriculture in developing countries, even if we accept that many of these countries may not actually have fully functional AIS.

The movement towards more systems-oriented approaches to research and technology development is illustrated in Table 8, which highlights the proliferation of more participatory approaches that place farmers firmly within the research and technology development processes as a central actor. This approach highlights both the importance of research and knowledge as inputs into agricultural production and that of linkages to markets. Both are key considerations to developing effective policies for agriculture. What is important is that appropriate policies to promote technological learning and innovation are different during the different stages of the process and particular policy measures are required to promote initial acquisition of foreign technology, local diffusion and upgrading.[170] It is important that in the early catch-up phase countries not only develop their adaptive research capabilities for agriculture, but also seek to capitalize on the potentials of the traditional knowledge of farmers. Addressing coordination failures which arise in adoption of new commercial practices requires institutional innovations.[171]

Table 8: Evolution of approaches to agricultural research since 1900[172]

Period	Methodology	Objective	Result	Observation
1900–1970 'top-down' approach	Researchers conducted on-station experiments and passed on technology recommendations to extension departments, and thence to farmers.	To produce technologies for farmers.	Worked well for large-scale commercial agriculture, but not for smallholder farmers.	The technologies passed on did not address the specific needs and circumstances of small-holder farmers.
1970–1990 On-farm farming systems research	Emphasis shifted from the research station to farmers' fields. Experiments were conducted mostly on smallholder farms.	To produce more relevant technologies with higher adoption rates.	Relevant problems that farmers faced were identified.	Researchers still controlled the R&D process.
1990–present Participatory methods	Farmers and other stakeholders involved at all stages of research.	Problem identification, planning and design of experiments and dissemination.	Farmers acquire a sense of ownership.	Improved dissemination of technologies.

5.1.1 The evolution of approaches to agricultural research

Experiences in the identification, development and transfer of agricultural technology and diffusion can be divided into the three broad approaches that evolved over time since 1900 (see Table 8).

The farmer-participatory method of research is generally well suited to Africa, with its variety of food crops, diverse agro-ecological patterns and varying socio-economic conditions. The participatory method helps researchers to reach distinct constituencies of farmers and provide each with the technologies most relevant to its circumstances. The process encourages ownership, enhancing the adoption and dissemination of the new technologies. The Framework for African Agricultural Productivity (FAAP), developed by the Forum for Agricultural Research in Africa (FARA) and its partners, also advocates putting farmers at the centre of agricultural innovation systems by empowering them to be active players in improving agricultural productivity, not just in terms of increasing their yields, but also in decision-making on how programmes and policies are shaped.

National agricultural research systems in sub-Saharan Africa require more efforts towards training, education and revamping the extension services. Many including FARA recognise that the role of extension systems must shift from prescribing to facilitating. Moving towards more participatory agricultural extension will allow greater responsiveness to farmers' needs and facilitate learning on how they can increase their own productivity, raise their incomes, collaborate effectively with one another (and with partners in agri-business and agricultural research), and become actively involved with major stakeholders in determining the process and directions of innovation, including technology generation and adoption.[173]

At this early stage, the strategic acquisition of agricultural technology in all its forms represents the best hope for improving agricultural productivity and eradicating hunger and poverty in many developing countries. Of course, technology cannot achieve such lofty goals by itself. That is why it is vitally important to consider the technology transfer process as a whole to ensure its adoption by large groups of smallholder farmers and local agri-businesses.

To facilitate this process, in recent years, many countries have adopted a decentralized technology diffusion model in order to increase awareness and responsiveness regarding district-level opportunities. This model should be seen as complimentary to, and not a replacement for, a strong national-level technology acquisition option. It should also be noted that not all technologies are embodied in products or processes, which may (or may not) be protected by intellectual property law. Some technologies are disembodied and exist within the mindset of individuals and the routines of organizations, demanding a solid commitment to education and training in order to develop a national culture of innovation and discovery.

Before discussing the enabling environment that facilitates the transfer and dissemination of technologies, it is important to briefly mention the models of technology transfer that currently exist. To a large extent there is an ongoing disparity between the developed and developing world. It is therefore important to acknowledge that the developing country perspective differs substantially from the view of technology transfer that exists in developed economies, which is mainly focused on the commercialization of new high-tech inventions either through technology licensing agreements or the creation (and flotation or sale) of spin-off companies. In developed countries, invention has become the common currency of business, so much so that a substantial international trade has developed for commercializing patent rights in many business sectors, including agriculture.

5.2 TRANSFER OF TECHNOLOGY

Developing countries, and particularly LDCs, can benefit greatly from foreign technologies and knowledge, assuming they are able to absorb them effectively. Our understanding of the process of 'transfer of technology' has evolved, in part because several decades ago its usage commonly implied that access to a technology meant that the technology was automatically absorbed by the recipient with little effort or cost. This idea has been refuted and discarded by most analysts and there is today a general recognition that a degree of technological effort by, and cost to, a firm or a farmer is required for a technology to be absorbed. The cost and effort involved may be substantial, and generally requires some degree of existing STI capabilities on the part of the recipient, including a basic ability to learn and understand the technology. There is also a risk involved in absorbing the technology given that an investment is required while the return on investment may not be known and the user may prove unable to successfully absorb the technology. A second important caveat is that successful technological innovation based upon the acquisition of a new technology from abroad may require additional effort to adapt the technology for local circumstances. For these reasons the term 'transfer of technology' must be used with a clear realization of these important caveats.[174]

Technology transfers can take place via many different channels. These channels can be either market-based (through trade, FDI or licensing) or non-market-based (through technical assistance projects or NGOs, among others). UNCTAD found that the most important sources of technological innovation for firms in developing countries included new machinery or equipment, key personnel, internal R&D, collaboration with customers, trade fairs, and collaboration with suppliers and consultants.[175] New machinery and equipment was by far the most important source, which implies that trade (that is, imports of capital goods) is likely the most important source of such innovation for these countries. However, UNCTAD cautions that the effectiveness of imported foreign technologies such as imported seeds, plants, animals and machinery may have be limited by the local agro-ecological conditions. As outlined in Chapter 3, these conditions vary widely in Africa. Adaptation may indeed prove unsuccessful if local agro-ecological conditions are very different (in terms of climate, rainfall and soil quality) and as a result poorly suited to the foreign technology.

Looking at developed country models, it could seem natural to assume that the high-tech industrial approach is best. However, in developing countries even the most basic foundation technologies, which are taken for granted in the developed world, cannot be assumed. A much-quoted example of the way governments can succeed by addressing concerns taken for granted in developed countries is the targeted voucher scheme for small-holder farmers to buy fertilizer in Kenya, which was mentioned in Chapter 4. What matters most in developing countries and LDCs in particular is the set of domestic knowledge systems which enable (or constrain) the creation, accumulation, use and sharing of knowledge.[176]

The process of ***acquisition*** involves looking at the wide range of technologies available from various sources, and tries to identify the most appropriate mix of solutions. International sources are invaluable in this respect, including top companies and universities in the developed world. The CGIAR coordinates a large number of crop-specific research programmes and has been directly responsible for many breakthroughs, particularly in improving the quality of seed, techniques and tools.

Other emerging and developing countries are also an invaluable source of solutions, especially for addressing similar domestic development situations. The FAO's Special Programme for Food Security (SPFS) is a good example of the way techniques successfully employed in one country can then be transferred over to others. When SPFS was launched in the mid-90s, the programme was originally designed to disseminate simple low-cost solutions to improve yield and farmer income. Since 2002 however, the system has shifted towards working with individual governments to establish programmes for improving national food security. The main aim is to take the best elements of 'what works' and craft it into a custom-made plan for the host country. Over 100 countries are now engaged in the SPFS system, and over half of them have started implementing their customized national plans.

Adaptation is important to ensure that individual technologies are well suited to local conditions. In many cases, technologies may already be in a form that can be rolled out nationally without modification. Other technologies may require a careful evaluation phase to assess their compatibility and safety with respect to local conditions. It is essential that appropriate standards are developed and maintained to ensure that accreditation is enforced in line with national policies on biodiversity, toxicity, etc. Technology evaluation should be conducted under realistic conditions and not subject to conflicts of interest in the approval process. Local conditions may throw up a variety of issues that require addressing. For example, is local soil salinity likely to cause a new irrigation pump to rust? If it is, the design may need to be modified to incorporate non-corrosive materials.

Another vital consideration is whether a given technology represents good value in terms of the overall costs and benefits, making it suitable for adoption by smallholder farmers or local businesses. Modifying the design may be possible either to increase its performance or to reduce its manufacturing complexity or cost. In some cases, the necessary evaluation and adaptation work might be carried out by the national department of agriculture or university engineers, or may be contracted out to local enterprises. This process is especially critical in nurturing links with local manufacturers, and should be treated as a strategic partnering opportunity to fully engage local manufacturers as a precursor to their development of production-ready designs.

The question of how an individual technology will be used by local people or businesses is central to whether it will ultimately achieve widespread acceptance. 'Localization' is therefore often required before a technology can be successfully presented to the end-user. This might include translating instructions and training material into local languages or dialects and, in the case of ICT, devices may require menus to be configured or application-specific developments to be undertaken.

The question of local user requirements is especially important in regions where the population has been decimated by disease or violent conflict. For example, in some regions there has been a significant shift in farmer demographics toward older women and children, who may find it difficult to handle heavy traditional tools or inputs. This is a serious problem that underlines the importance of implementing a 'needs identification' feedback loop, both at the local and national levels, capable of rapidly developing practical strategies for modifying tools and techniques to fully reflect grassroots realities. Such concerns highlight once again the centrality of maintaining a joined-up 'smallholder-friendly' perspective that consciously prioritizes practical productive support over long-shot 'esoteric' research programmes.

5.3 TECHNOLOGY ADOPTION

Providing technically competent solutions well suited to local conditions is only part of the story. There are many examples of extremely promising technologies that have failed to gain acceptance by smallholder farmers due to the lack of an enabling environment (as discussed earlier) or poorly conceived or delivered dissemination campaigns.

5.3.1 Enabling environment for technology adoption

The power of technology in the hands of poor farmers has been demonstrated by farmers in many developing countries. In Malawi, for example, the government initiated a programme in 1998 to give the poorest farmers a 'starter pack' of free fertilizers and seeds, and this resulted in a national surplus of corn. However, the forced scrapping of the programme and selling of Malawi's strategic grain reserves under structural adjustment policies had tragic consequences until it was reversed by a new administration that reintroduced the fertilizer subsidy programme. The results again were staggering: bumper harvests for two years in a row, a surplus of one million tons of maize, and Malawi started to export corn to the region. This is a case where access to credit facilitated the use of an existing technology. Rwanda, the United Republic of Tanzania, Kenya and Nigeria are now following suit.[177]

In order for new tools and techniques to achieve widespread adoption, every aspect of the technology dissemination process requires careful consideration, including any field trials, the availability of samples or subsidies to encourage uptake, and farmer-friendly finance. Implementing a well-orchestrated communication and training programme plays a vital role in convincing the wider audience to make the switch to a different way of working. Ultimately, however, there is no substitute for a well-funded, well-prepared national extension services network. Given the wide range of technologies and the greater need for local autonomy, extension workers will be required to perform an increasingly difficult role, which demands full recognition and support at both the national and international level. The FAO has written a practical guide for policy-makers entitled '*Modernizing National Extension Systems*' which provides an excellent framework for improving the effectiveness of extension systems.[178]

In most cases the successful dissemination of technology is also strongly reliant on other parties, especially agriculture research institutions, the private sector, farmers' groups, NGOs and civil society groups. The complexity of the international development community requires careful planning and coordination in order to ensure that compatible messages and solutions are being delivered at the local level.

The more 'modern' model of a decentralized, demand-driven technology transfer process requires not just decentralization of funding and control, but also decentralization of the information resources that are essential for a self-sustaining agro-economic system. Proactive strategies for nurturing agri-business innovation links are therefore of key importance, and should utilize as much as possible existing networking structures (i.e. including both real and 'virtual' communities).

Nurturing local businesses, especially those involved in agricultural input distribution, is an essential ingredient for disseminating improved technologies. As mentioned in the previous chapter, the Alliance for a Green Revolution in Africa (AGRA), working with support from the Bill & Melinda Gates Foundation, has implemented an Agro-Dealer Development Programme to help African farmers increase yields on limited land. A strong agro-dealer system is crucial to farmers' success because these local retailers serve as the primary conduits of farm inputs, such as seeds and soil nutrients, and knowledge about their safe and efficient use. Another important way to nurture local businesses is the process of match-making candidate technologies with existing or new domestic businesses. This might include making commercial farmers aware of new or improved seed strains, or educating local manufacturers and distributors about emerging product opportunities. This business networking function is of immense importance in 'wiring-up' supply chains critical to the success of efforts to diffuse technologies to smallholder farmers.

5.4 INTERNATIONAL COOPERATION: EMERGING MODALITIES IN AGRICULTURE TECHNOLOGY TRANSFER

The previous sections have discussed how national policies can help establish an enabling environment for the development of stronger technology and innovation capabilities in developing countries. While the domestic dimension remains the predominant one with regard to innovation in agricultural innovation policy, international cooperation represents a significant means of facilitating technology transfer. In this regard, South-South and triangular cooperation are becoming increasingly important channels for the diffusion of agricultural technologies and knowledge.

5.4.1 South-South cooperation

Bilateral and inter-regional South-South cooperation has a strong potential to enhance the effectiveness of international development efforts while improving national ownership. South-South cooperation in agricultural technologies facilitates the transfer of new and/or older (but more affordable and still efficient) technologies that are necessary for boosting agricultural productivity. The agricultural cooperation activities of countries such as Cuba, China and India in Africa are well established, in some cases going back to the times of the Bandung conference (the first major Afro-Asian conference) in 1955.

Several other developing countries, regional initiatives and funds are now becoming active partners for South-South technical and economic cooperation. These include, in addition to those mentioned above, Brazil, Indonesia, Malaysia and Turkey, to name just a few. In addition, inter-regional initiatives such as the IBSA Fund for Alleviation of Poverty and Hunger, created in 2003 under the framework of the India, Brazil and South Africa Forum are also active in South-South cooperation.[179] Also at the inter-regional level, the Africa-South America Summit agreed to exchange knowledge and to promote transfer of technology in a number of issues including agriculture. The 2009 Brazil, Russian Federation, India and China summit reaffirmed the countries' commitment to boost agricultural development in Africa by enumerating a number of measures for the coming years.

The number of South-South cooperation initiatives undertaken by single countries is also growing. The Africa-India Cooperation Summit launched in April 2008 aims to build stronger cooperation ties between Africa and India, an important actor in tropical technology. A similar summit was held with Turkey in 2008, also focusing on the development of African agriculture. The Republic of Korea launched its Initiative for Africa Development in 2006. Within Africa, South Africa is a key player in the transfer of technologies.

Many national and international programmes and information resources currently seek to facilitate access to improved agricultural technology. Programmes run by CGIAR, FAO, IFAD, UNDP Millennium Villages, USAID, DFID, Rockefeller, Gates / Buffet, CNFA, and others continue to provide a large number of practical solutions throughout the world. For example, in 2008, AGRA, JICA and NEPAD signed a joint initiative for doubling rice production in Africa by the year of 2018 from 14 million tons to 28 million tons including projects for dissemination of NERICA. The project is to be conducted under the framework of the Coalition for African Rice Development (CARD), a consultative group including donors, rice research institutions, and development entities working in 21 African countries. Since its establishment in 2008 it has established National Rice Development Strategies in 12 countries.

5.4.2 Africa's cooperation with China and Brazil

China, as the leading player among developing countries in development cooperation projects on the African continent has been heavily involved in supporting agricultural development for decades. China's different areas of support range from production, training, and infrastructure to trade. The Chinese development cooperation activities in Africa are expected to be strengthened at the IV Ministerial Conference of FOCAC (Forum China Africa Cooperation) in November 2009 when agriculture and food security will be a key theme. The FOCAC was created in 2000 in Beijing. At the 3rd FOCAC (Beijing, 2006) China announced its intention to double aid to Africa by 2009. The projects of cooperation are focusing to a great extent on the agriculture and infrastructure sectors. In 2009 for example, the country is building 14 centres for agricultural research in a number of African countries. Over 100 agricultural scientists from China are working in the field with African technicians in order to improve food security on the continent and generate export surpluses where it is possible. China is an important source of Foreign Direct Investments (FDIs) in Africa including in the agricultural sector.

Brazil is also becoming an increasingly important partner for African countries in the promotion of agriculture and rural development. The main vehicle for the transfer of Brazilian expertise in tropical agricultural technology to African countries is Embrapa, the Brazilian institution of agricultural research. While Embrapa has a long experience of international cooperation at a relatively small scale, in recent years it has undertaken more ambitious cooperation projects with the support of the Brazilian Cooperation Agency of the Ministry of Foreign Affairs. In 2006, Embrapa opened an office in Accra, Ghana.

Embrapa Africa is an initiative that envisages not only to transfer and field-test tropical technology know-how acquired by Brazil but also to learn from successful experiences in other developing countries. Projects in Africa were initially focused mainly on the Portuguese-speaking countries, namely Angola, Mozambique, Guinea Bissau and Cab Verde. Subsequently, a number of other African countries such as Ghana, Benin, the Democratic Republic of the Congo, Guinea, Kenya, and Ethiopia have signed technical cooperation agreements. Brazil is now working towards a broad partnership that includes all members of the African Union in technological transfer and agricultural capacity-building projects.

Another example, the Cotton-4 (C-4) project, helps to transfer technology to Mali, Chad, Benin and Burkina Faso in the form of genetic material, production systems, training on market and trade issues and other capacity-building. The C-4 project focuses on integrated soil management, the control of biological pests, and the management of plant varieties. The project has a total budget of $4 million, of which $3.5 million is devoted to agriculture and the rest to basic services. A first farming model project was implemented in Mali and the results will be distributed to other Cotton-4 countries as well as other African countries.

5.4.3 Triangular cooperation

The concept of triangular cooperation refers to South-South cooperation carried out in partnership with a Northern donor (or donors) or international organizations who provide financial and technical assistance. A growing number of donor countries are actively engaged in triangular cooperation projects. These include Canada, Japan, the United Kingdom, the United States and the EU.

Another example of triangular cooperation is the Pan-African Cassava Initiative (NPACI) launched by NEPAD in 2004. This project, created with funding from the W.K. Kellogg Foundation, focuses on the enormous potential of cassava in Africa for food security and income generation. The project is based on a transformation strategy that focuses on developing three interrelated components: market research and development, technology generation for development, and competitive and sustainable production.[180] Triangular cooperation could also play a significant role in the framework of the Comprehensive Africa Agriculture Development Programme (CAADP).

5.4.3.1 Japan and triangular cooperation

Japan's International Cooperation Agency (JICA) provides a number of successful experiences of triangular cooperation in agriculture. An example of this is provided by the NERICA project financed mainly by Japan and UNDP that aims at creating new varieties of rice that are drought resistant and offer higher productivity. NERICA rice is based on African drought-resistant varieties and high-yield varieties from Southeast Asia. NERICA has been proven to increase production of rice in Benin by 400 per cent and is now becoming widely cropped in Africa.

Another case of Japanese involvement in triangular cooperation is provided by the project being carried out in cooperation with Brazil in Mozambique, where agro-ecological conditions are very much similar to those of the Cerrados of Brazil, a region where Japan also contributed significantly to agricultural development in the 70s. The main purpose of the project is to transfer technology developed in Brazil over the last decades and at the same time to learn from Africa's experiences.

5.4.3.2 Multilateral organizations and triangular cooperation

Several multilateral institutions are working in the field of triangular cooperation, particularly in Africa. A good example is the FAO Special Programme for Food Security (SPFS) which provides transfer of tropical technology for many African countries on the basis of South-South transfer of technology, with contributions from a number of countries including China, Cuba, Egypt, India, Jordan, Morocco, Myanmar, Pakistan, the Philippines, Tunisia and Vietnam. UNIDO's centres for South-South Industrial Cooperation, which support the development of agro-industry in the South, are another example.

5.5 SUMMARY

Acquiring and adapting technologies new to the local agro-ecological system, either from abroad or from local sources (research institutes or universities, for example) is a key part of any serious strategy for achieving food security. Selection of technologies appropriate to the conditions within the host food system is crucial . State-of-the-art, high-tech solutions may not always be the most appropriate for the needs of smallholder farmers. Adopting a pragmatic mix of technologies (low-, medium- and high-tech) that best meets their needs is the ideal.

A balanced technology acquisition approach must balance the contrasting challenges of technology selection, adaptation and diffusion. It is not enough for a technique to be technically sound, it must also be adapted to suit the specific conditions found on the ground, and be made affordable and attractive enough to smallholder farmers to achieve wide diffusion. Models of public-private partnership that make not only public institutes but also for-profit enterprises into stakeholders for the diffusion model can be valuable in building a self-sustaining momentum behind dissemination efforts. Such a model stands the best chance of being demand-driven – succeeding because farmers demand its continuation, rather than due to a top-down bureaucratic decision.

International cooperation can also be a strong factor in helping relevant new technologies be adopted, adapted and diffused throughout host economies. In particular, a handful of South-South cooperation models have already proven their worth as mechanisms for ensuring the right technological tools are made available to African farmers. So-called triangular cooperation, where a Northern neighbour signs on as a sponsor to South-South technology-sharing efforts, has also shown promise as a model for the international diffusion of technologies.

Successful adoption and mastery of new technologies by smallholders requires adequate absorptive capacity on their part. Successful technology transfer is not necessarily easy to achieve and entails some cost on the part of the farmer to learn the technology. Still, the returns from successful technology transfer can be very large.

The next chapter discusses the important elements in choosing appropriate mixes of technologies in a manner suitable to the diversity of local agro-ecological conditions found in Africa.

6 TECHNOLOGY MIXES FOR SMALL-SCALE FARMING

6.1 INTRODUCTION

This chapter discusses some technologies that can be adopted by small-holder farmers to increase yield and generate a range of other potential benefits (such as poverty alleviation and environmental conservation). The chapter distinguishes between three broad types of (modern) agricultural technologies. First, there is *mechanical technology*, encompassing various degrees of mechanization of agricultural operations and ranging from simple traditional hand tools to animal- and engine-powered equipment, implements and farm machinery and irrigation systems that control the timing and volume of water. Second, there is *biological* or *biochemical technology*, composed of a package of high-yielding varieties of seeds, chemical fertilizers and pesticides. Third, is *biotechnology*, consisting of commercially acceptable techniques that use living organisms or parts thereof to make or modify a product; this includes improving, modifying or manipulating the characteristics of economically important plants and animals and their derivative products and developing microorganisms that act favourably on the environment for agricultural production.

This classification enables us to analyze the significance of each type of modern agricultural technology individually and to capture the interactions between them. As will be apparent from the analysis that follows, a combination of all three types of technologies is needed in order to attain food security. Again as pointed out earlier, for these technologies to be adapted by farmers will depend on their prior existing absorptive capacities.

6.2 MECHANICAL TECHNOLOGY

The technologies of agricultural mechanization can be classified broadly into hand-tool technology, animal-draught technology and mechanical power technology. In addition to the above classification, a discussion on mechanical technology must consider specific agricultural operations that are more susceptible to mechanization. For this purpose, *agricultural operations* can be grouped into two categories, power-intensive and control-intensive:

- Power-intensive operations require relatively large amounts of energy and include land preparation (use of tractors), pumping irrigation water (use of motorized pumps instead of bullock-drawn wheels) and thrashing of grain (rice or maize milling in place of hand pounding).
- Control-intensive operations depend relatively more on human judgment. These include seeding, fertilizer application, weeding, pest and disease control, winnowing (separating grain from chaff) and crop harvesting.

The more tedious, power-intensive operations tend to be mechanized first. This explains why African governments initially promoted large-scale mechanically powered technology. Government-run tractor hire services were introduced and commercial banks provided soft loans at low interest rates to purchase tractors. However, in the 1980s and the 1990s, the entire scheme collapsed and African countries redirected their policies to draught animal power (DAP).181

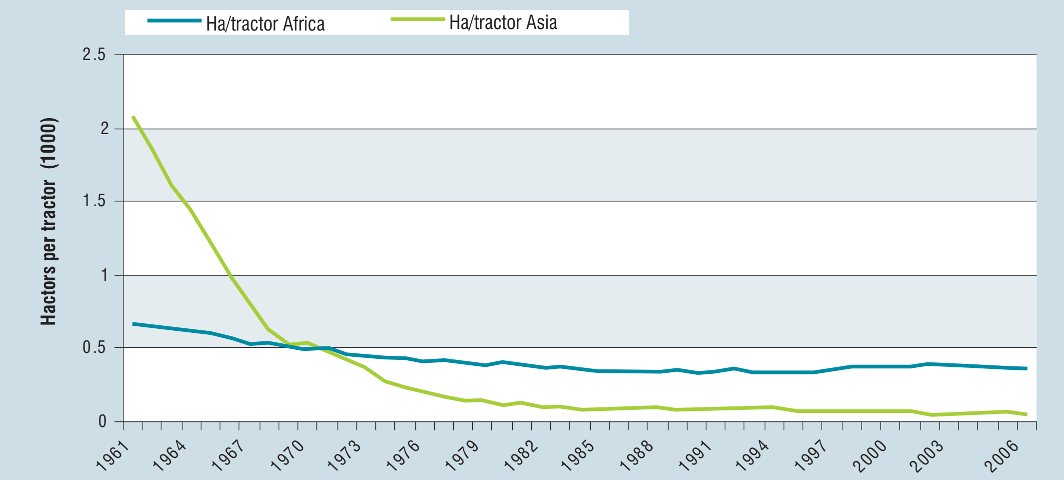
The new approach bore mixed results across Africa. In Mali, use of DAP increased the area under cotton cultivation nearly four-fold, raised yields six times over and animal traction adoption rates jumped to 80 per cent between 1968 to 1986.[182] Nigerian farmers using DAP derived supplementary income by renting them out to other farmers.[183] Similarly, in Kenya the use of DAP brought about higher yields and greater economic efficiency, including less weeding.[184] The use of DAP for inter-row weeding in the United Republic of Tanzania reduced the time spent on weeding from 48 hours per hectare to 30 hours per hectare.[185]

While the use of tractors in Asia increased from one per 2200 hectares to one for every 76 hectares in four decades, tractor use in Africa has remained relatively constant (see Figure 17).

In Africa, less than one per cent of farmland is worked by tractors and only 10 per cent is worked by draft animals. Thus nearly 90 per cent is worked by hand, from initial ploughing to planting, weeding, and harvesting.[187] It is however important to assess the advantages of moving up the technology ladder in terms of productivity gains and timeliness of cultivation, employment for the landless poor and increased cropping intensity. Direct comparison of the exact timing of critical agricultural operations between farms using tractors and draught animals in six Asian countries shows little or no timeliness advantage for mechanization.[188]

In addition, the potential labour-displacing effects of increased mechanization, in the context of a dominant small farm sector and land insecurity throughout the developing world, tends to make mechanization an emotive issue. An examination of the patterns of

Figure 17: Hectares of arable land per agricultural tractor in Asia and Africa[186]



farm equipment use in Eastern, Central and southern Africa suggests strongly that expanded use and local manufacture of simple but well adapted items of farm equipment can make a significant contribution to increases in productivity and incomes on family farms, the growth of rural-based manufacturing and the expansion of non-farm output and employment.

6.3 IRRIGATION SYSTEMS

In some developing countries, irrigation plays a major role in food production and food security, representing up to 95 per cent of all water use. Agriculture is by far the largest consumer of water, accounting for some 70 per cent of all water withdrawn from rivers for agricultural, domestic and industrial purposes worldwide. Yet only just seven per cent of African arable land is irrigated compared to ten per cent in South America, 29 per cent in East and Southeast Asia and 41 per cent in South Asia.

The agricultural development strategies of most countries depend on maintaining, improving and expanding irrigated agriculture. However, the steadily increasing demand on water resources means irrigation for agriculture is facing growing competition from other activities. Water is already scarce in many places and the imbalance between the availability of water and the pursuit of agriculture for food will likely be aggravated by climate change.

6.3.1 Irrigation technologies and management systems

Investments in irrigation and better management of existing systems have increased crop yields, creating jobs and raising rural economic growth in many developing countries. Irrigated lands now account for about 20 per cent of the world's farmed area and 40 per cent of global food production. Increases in irrigated areas, cropping intensity, and crop yields have helped stabilize food production per capita, even though population and per capita food intake have grown significantly. While the largest potential for increased yields in the near future comes from the 450 million smallholders in developing countries, most of these producers are poor farmers and are therefore not able to respond to increased food prices due to their inability to access the farming inputs needed to raise production, unless public and private investment in irrigation becomes a priority.

The past three decades have seen the development and commercialization of innovative irrigation techniques. Many of the new techniques have been designed for relatively large and fairly sophisticated systems, and tend to be adopted by well-resourced farmers. These techniques include automated canal and piped water delivery systems, laser land levelling for surface irrigation applications, automated sprinkle irrigation, microirrigation (including surface and sub-surface drip systems), and sophisticated control systems for managing these technologies. The majority of resource-poor smallholders are not able to afford these types of irrigation technology.

Unless the special irrigation technology needs of smallholders are addressed and the prices of these technologies are substantially reduced, small-holder farmers will continue to be excluded from the benefits such technologies. Irrigation systems must match smallholders' unique characteristics, including small landholdings, low capital availability, low risk tolerance, and a relatively low opportunity cost of family labour.[189] Examples of improved irrigation technologies in the water supply, water conveyance and water application components of irrigation systems suitable for smallholders include:

- ***Low-cost drip irrigation*** for efficient water application. Thanks to precise timing, drip irrigation allows higher uniformity and accuracy in the amount of water applied. Farmers in Asia using drip irrigation reported yield increases of between 50 and 100 per cent and decreases in water use ranging from 40 to 80 per cent compared to their experience with traditional surface irrigation systems. More than 200,000 low-cost drip irrigation systems have been distributed through market channels in India, Nepal and other parts of Asia.
- ***Treadlepumps for water lifting.*** A treadle pump is a simple, low-cost, foot-operated pump that can lift water from depths of up to seven metres with a flow rate ranging from about 30 to 80 litres per minute. The retail cost of a basic pump ranges from $12 to $15, including the wood or bamboo treadles and the support structure. Their design and construction is simple, so local craftsmen can manufacture them using readily available tools and materials and they can be maintained and repaired easily by the users. The foot valve at the bottom of each cylinder is made from rubber that can be replaced using a discarded bicycle tyre inner tube. The two pistons keep water in motion during the up- and down-strokes, resulting in a continuous flow and efficient use of manual energy. These features make such pumps ideal for use by poor smallholder farmers. The treadle pump was the first new irrigation technology to be successfully and widely distributed using a business development approach.
- ***Bagging water for irrigation.*** Low-cost plastic water tanks are used to store runoff water collected during the rainy season from small catchments or water from perennial wells or streams for use in the dry season. They bring the benefits of supplemental irrigation to smallholders who have no other access to irrigation water. Each tank stores 10 cubic metres of water that is completely enclosed to eliminate evaporation losses. The tanks cost roughly $40 each and have a life expectancy of about five years.

6.3.2 Predicting when to irrigate

Small- to moderate-sized farms can benefit from the efficient scheduling of irrigation. Irrigation Decision Support Systems (IDSS) are computerized scheduling programmes and water management systems that aim to improve water-use and distribution efficiencies for optimum crop production.[190] Such systems can help save water, particularly during times of drought. Typically, an IDSS is based on weather station data and crop growth models and is linked to a network information system, including local radio links, well-suited to informing small-holder farmers in developing countries. In Africa, water-saving irrigation scheduling advice is currently transmitted from a computing centre in South Africa, linked by telecommunication networks to farmers in other provinces and countries, including Zimbabwe and Swaziland, with a further service planned for the United Republic of Tanzania.

Decision support systems are driving research towards 'precision agriculture', an approach to farming which uses satellite data to determine soil conditions and plant development, in order to fine-tune the use of technologies such as fertilizer or water use. 'Precision agriculture' can thus provide farmers with information to make better management decisions, reduce costs and increase profit margins.[191]

6.3.3 Available technological solutions

Solutions for farming with limited water that can help offset the impact of water scarcity and the expected negative impacts of climate change and increasing water shortages are outlined in Table 9.

6.4 BIOLOGICAL TECHNOLOGY

If the original planting material happens to be of poor quality, it will result in poor yields and generate losses to the farmer.[192] A great deal of plant breeding has been undertaken with some crops to meet a wide range of quality attributes. For example, commercial fruit and vegetable varieties are available in varying shapes, sizes, colours, productivity levels, pest and disease resistance levels (the primary drivers for breeding). Dry matter and taste attributes as well as ripening times and rates and post-harvest longevity have also influenced the breeding process.[193] This underscores the importance of demand-driven provision of planting material as a critical ingredient for genetic technical change in a cropping system[194].

Table 9. Solutions for water management

Solution	Application
Drip irrigation	The technique involves dripping down water directly to the roots of plants, via a well-defined assembly of pipes, tubings and valves.
Desalination of seawater	Desalination of seawater has emerged as a viable solution that can help utilize this vast resource.
Use of moisture sensor-based irrigation system	The use of moisture sensors to control irrigation in a conventional drip irrigation system. It could be applied to farms in a small area. The devices used could be solar- or wind-powered and can be networked with mobile connectivity.
Recycling wastewater	Channels could be established to recycle used city water that can be used for varied purposes, including freshwater for irrigated farming.
Rainwater storage	In areas where freshwater for irrigation is very scarce, tanks can be set up to store rainwater for productive irrigation.
Regular maintenance of irrigation systems	Regular maintenance is needed to fix leaks around fittings, cracks/ disconnects in the water line due to tractor or vehicle damage, holes in drip tape and broken sprinkler heads.
Use of city water	Public policies and incentives to promote the prudent use of water by households by creating a positive and appropriate price for water usage. Reuse of city water for domestic as well as agricultural purposes. For agriculture, there is no need to purify the water and little management is required for its use.

6.4.1 New Rice for Africa

New Rice for Africa ('NERICA') was developed by the former West Africa Rice Development Association (WARDA), now known as the Africa Rice Center (ARC), to improve the yield of African rice varieties. The NERICA Project was funded by the African Development Bank, the Japanese government, and the United Nations Development Programme. African rice (O. glaberrima Steud.) and Asian rice (O. sativa L.) were crossbred to produce progeny that combine the best traits of both parents. These include high yields from the Asian parent and drought resistance and hardiness from the African parent. The progeny were dubbed New Rice for Africa (NERICA) and the name was trademarked in 2004. NERICA is not a genetically modified variety. Nearly 20 different NERICA varieties have been developed and a number of them are already being commercially cropped in many African countries. The main advantages of NERICA include:

- higher yields (by 50 per cent without fertilizer and by more than 200 per cent with fertilizer);
- earlier maturity (by 30 to 50 days); and
- resistance to local stress (acid soil, improved drought resistance.

The crop responds to the needs of millions of upland and dryland rice farmers of sub-Saharan Africa and therefore has the potential to increase income and alleviate poverty in the region. For example, in Benin where agriculture employs 75 per cent of labour and where 80 per cent of rice farmers are women, some farmers are able to invest the profits of NERICA in diversifying their agriculture with other cash crops such as peanuts, soya and corn. NERICA rice varieties have proven able to boost Benin's rice production in some cases up to fourfold the current output. A new FAO project aims to support the dissemination and cropping of high quality seeds including NERICA varieties to support Benin in achieving the goal of more than doubling rice production to over 300,000 tons by 2011, thereby reversing the country's strong dependency in rice imports and enabling it to become an exporter for sub-regional, regional and even the European market. A number of African countries (Guinea, Nigeria, Côte d'Ivoire and Uganda) now consider NERICA a priority, as do development cooperation agencies.[195]

6.4.2 Developing disease-resistant crops

Increasing disease resistance in crops is another means to increase plant yields, as disease can seriously limit productivity. For example, the pearl millet downy mildew disease caused by the fungus Sclerospora graminicola was responsible for yield reductions estimated at 30 per cent in the Eritrean region of Anseba in 2000.

Research by CGIAR scientists, in collaboration with national agricultural research systems in Africa, has helped control two major diseases of cassava – bacterial blight and leaf mosaic – through genetic breeding, the incorporation of resistance genes into high-yielding cassava varieties, and an Africa-wide programme of biological control of the cassava mealybug. The late maturing six-tons-per-hectare-varieties have been replaced by varieties that yield 20–30 tons per hectare. Box 7 highlights some crop varieties that have been developed in Brazil, for disease resistance and other attributes, which could prove beneficial to African farming.

6.5 FERTILIZERS, PESTICIDES AND TILLAGE TECHNOLOGIES

Fertilizers (be they organic or inorganic) supply essential elements to the growth of plants. These elements include nutrients such as nitrogen, phosphorus, potassium, and sulphur, as well as trace elements such as iron, zinc, and magnesium. Organic fertilizers are made from materials derived from living organisms, while chemical fertilizers are manufactured from nonliving materials such as rock phosphate. Organic fertilizers must first be broken down by soil microorganisms into simpler, inorganic molecules and ions. In contrast, the nutrients in chemical fertilizers are already in inorganic form and so can be immediately used by the plants. Both organic and inorganic fertilizers have advantages and disadvantages. While inorganic fertilizers are immediately available to plants

Box 7: New crop varieties of crops that could be transferred to Africa[196]

Below are new crop varieties that have been developed in Brazil. These technologies could be transferred to Africa especially through South-South cooperation projects.

- BRS Seridó Cotton, of average size, a perennial, for family-based agriculture in the Semi-arid zone.
- BRS Safira and BRS Ruby-coloured Cotton, reddish-brown colour, annual cycle, more productive (1,900 kg/ha under drought conditions).
- BRS Querência Rice, with a high industrial yield, early-developing, long and fine grains, resistant to environmental stress and reduced need for pesticides.
- Esplanada Carrots that allow mini-carrot production feasible all year round and a higher level of total carotenoids (precursor of Vitamin A).
- BRS Milênio and BRS Urubuquara cowpea beans, 25 per cent more productive than the regional average in the state of Pará, facilitate mechanization process and have better quality and appearance.
- Pitanga 'purple' beans, resistant to rust, bean common mosaic virus (BCMV) and the four types of fungus that cause anthracnose. Productivity of 1,540 kg/ha (dry conditions) to 2,280 kg/ha (irrigated).
- BRS 188 Paraguaçu and BRS 149 Nordestina Castor Bean, for the semi-arid zone, average yield of 1,200 Kg/ha, cycle of over 250 days, 47 per cent average oil level.
- BRS Gema de Ovo (Egg Yolk) and BRS Dourada (Golden) bio-strengthened manioc, with high concentrations of beta-carotene (precursor of Vitamin A), for the production of fine yellow meal (copioba meal), no artificial colourants, quick cooking-time properties, a sweet flavour and fibreless.
- Catingueiro corn, early variety, for the semi-arid zone, can be harvested 95 days after planting. Productivity of approximately 3.5 t/ha, reducing climate risks and stronger harvest chances.
- BRS Violet Grapes, for juice or table wine. High concentration levels of sugars and colour, high productivity, early harvest, good performance to fungal diseases and stems rot and well adapted to hot weather regions.

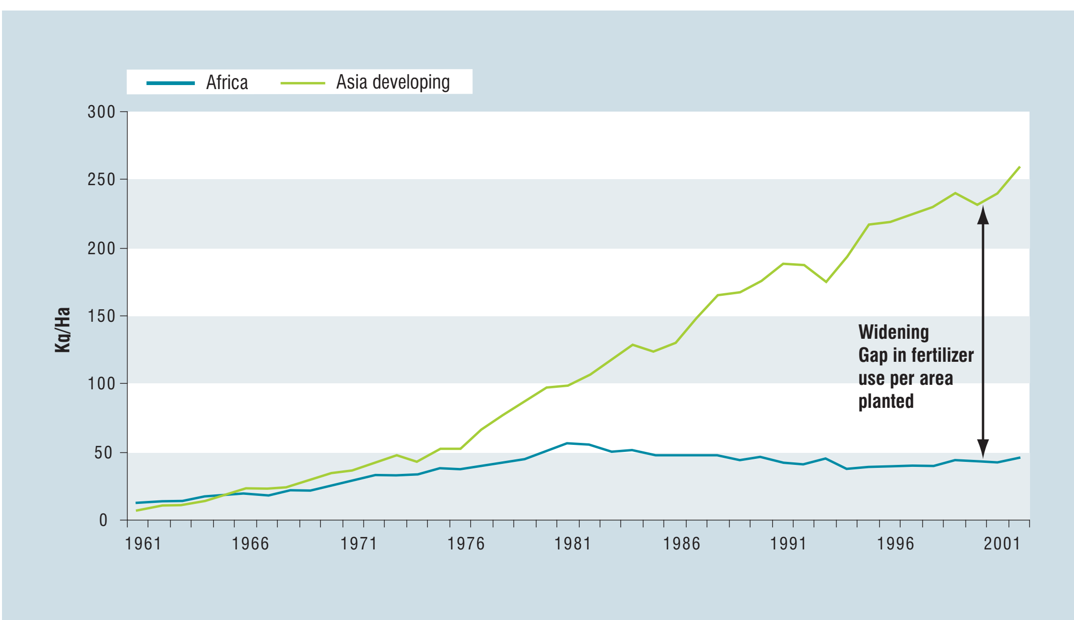
they are subject to leaching, especially with nitrogen. Heavy applications of inorganic fertilizers can also build up toxic concentrations of salts in the soil. On the other hand, as mentioned above, organic fertilizers (such as manure) are not immediately available to the plants. However organic material does more than provide organic nutrients. It also improves the soil structure, and increases its ability to hold both water and nutrients.

Despite its abundance, nitrogen cannot be assimilated by plants directly from the air. Bacteria at the root of certain plants are therefore needed to 'fix' nitrogen (i.e. convert atmospheric nitrogen into compounds such as ammonia), allowing it to then be used by plants. Up to 35 per cent of the total productive capacity of all crops is ascribed to this single input. It is the source of most food protein. Of the total 175 million tons of nitrogen fixed naturally worldwide, 35 million tons are fixed by cropped leguminous plants compared with the 40 million tons fixed industrially.

During the 1960s and 1970s, the use of inorganic fertilizers was spurred by government subsidies in most developing countries. With the elimination of subsidies, fertilizer use dropped sharply. For example, in Senegal, fertilizer use increased from 13,000 to 96,000 tons between 1970 and 1976, and then dropped to 1,500 tons in the 1990s. Food-producing farmers are often the most severely affected by such cuts due to their low income, compared to export crop farmers. The latter use an average of 30 kg of chemical fertilizer per hectare, compared to 5 kg by the former.[197]

Small-holder farmers in sub-Saharan Africa use only a tenth of the global average inorganic fertilizer use. The annual total input of fertilizers in Africa is only 21 kg (nutrients) per ha of harvested land, compared to 100 kg/ha for South Asia, 135 kg/ha for East and Southeast Asia, 73 kg/ha for Latin America and 206 kg/ha for the industrial countries. The widening gap between Africa and Asia's fertilizer use is illustrated in Figure 18. The low level of fertilizer use in Africa is due to the fact that fertilizers are much more costly in Africa than the average world market price and fertilizers are not readily available to farmers in remote areas due to inadequate infrastructure, or to farmers being simply too poor to afford them.

Figure 18: Fertilizer consumption (kg/hectare of cereals)[198]



Source: Faostat elaborated by ATDF

According to Borlaug, the key to unlocking the potential of agriculture in Africa and restoring the health of the continent's soils is a practice known as 'integrated soil fertility management' (ISFM).[199] This practice combines the use of organic and inorganic nutrients with mineral nutrients to increase crop yields. It is an integrated approach to agricultural intensification that fosters both technical and institutional change. The approach focuses on the timing and placing of inputs to maximize nutrient-use efficiency. The ISFM approach must be tailored both to the characteristics of the site and the constraints faced by the farmer. It also demands an emphasis on context-specific, adaptive responses that require partnership between researchers, farmers and extension workers.

6.5.1 Zero tillage

Zero tillage breaks with the traditional technique of ploughing the soil and consists of simply planting a new crop over the dead leaves and vegetation left after harvesting the previous crop. The use of zero tillage (sometimes called direct seeding or conservation agriculture) offers significant benefits for developing countries' agriculture as it can help avoid soil loss from erosion. Zero tillage is being used on over 25 million hectares of farmland in Brazil and other Mercosur countries have reached significant achievements in yields using this technique. Expectations are that 85 per cent of the soybean cropped in the region will be produced under zero tillage. India and Pakistan are benefiting from the Brazilian and Mercosur experiences after adapting it to tropical and subtropical conditions.

6.5.2 Beneficial biological organisms

Soil microorganisms can help plants to absorb nutrients. The utility of these microorganisms can be enhanced by selecting the most efficient, culturing them and adding them to soils directly or through seeds. The cultured microorganisms packed in carrier material (such as peat or lignite powder) for easy application in the field are called bio-fertilizers.

Although Green Revolution crops achieve their maximum yields with high chemical fertilizer inputs, it is still profitable to grow them without any nitrogen fertilizer – an attractive option for poor farmers who cannot afford such inputs. Green Revolution crops grown under these conditions (and outyielding traditional varieties that use no nitrogen fertilizer) must be receiving nutrients from non-chemical sources in the soil. Biofertilizers could help reinforce these natural nutrient sources. For example, Azolla prinnata (a water fern) has a symbiotic association with the blue-green algae (BGA) Anabaena, and can fix atmospheric nitrogen. Ploughed into the soil between rice harvests, it can increase the crop yield by over 50 per cent and its effect, which lasts for two years, is equivalent to the use of 60 kg of nitrogen fertilizer per hectare. BGA can fix up to 77 kg of nitrogen per hectare in a cropping season under non-symbiotic conditions. In symbiosis with Azolla, the amount fixed can reach 425 kg of nitrogen per hectare in 100 days.[200]

It is important to encourage farmers to rely more extensively on organic or bio-fertilizer (which is much less costly), mixed cropping (which helps preserve soil fertility). In some cases this may require government intervention to better regulate fertilizer markets to ensure supply, quality and affordable prices. Elimination or reduction of chemical fertilizer dependency with the use of biofertilizers would drastically reduce production costs at the farm level. Chemical fertilizers account for some 60 per cent of the energy costs of wheat production in India.[201]

6.6 BIOTECHNOLOGY

6.6.1 Tissue culture and micropropagation

The plant tissue culture technique has already been mastered in many developing countries and is the most commonly applied form of biotechnology in Africa. The technique requires a sterile workplace, a nursery/greenhouse, and trained manpower. It is an important technology for the production of disease-free, high-quality planting material and the rapid production of many uniform plants. Plant cells, tissues, or organs are cultivated on specially formulated nutrient media under the right conditions to regenerate an entire plant from a single cell. The downside is that tissue culture is labour-intensive, time-consuming, and can be costly. Plants that have been grown in tissue culture and are important to developing countries include oil palm, coffee, pine, banana, date, eggplant, jojoba, pineapple, rubber tree, cassava, yam, sweet potato and tomato.[202]

The single most important factor that contributed to greater labour use per hectare in Green Revolution areas was the practice of multiple cropping facilitated by early-maturing varieties of cereals. The application of micropropagation techniques to potato could similarly help improve cropping intensity. Since potatoes take only 40-90 days to grow in the climates of most developing countries (compared to 150 days in temperate climates), they can easily be incorporated into the cropping patterns currently practised for cereals such as wheat, rice and corn.

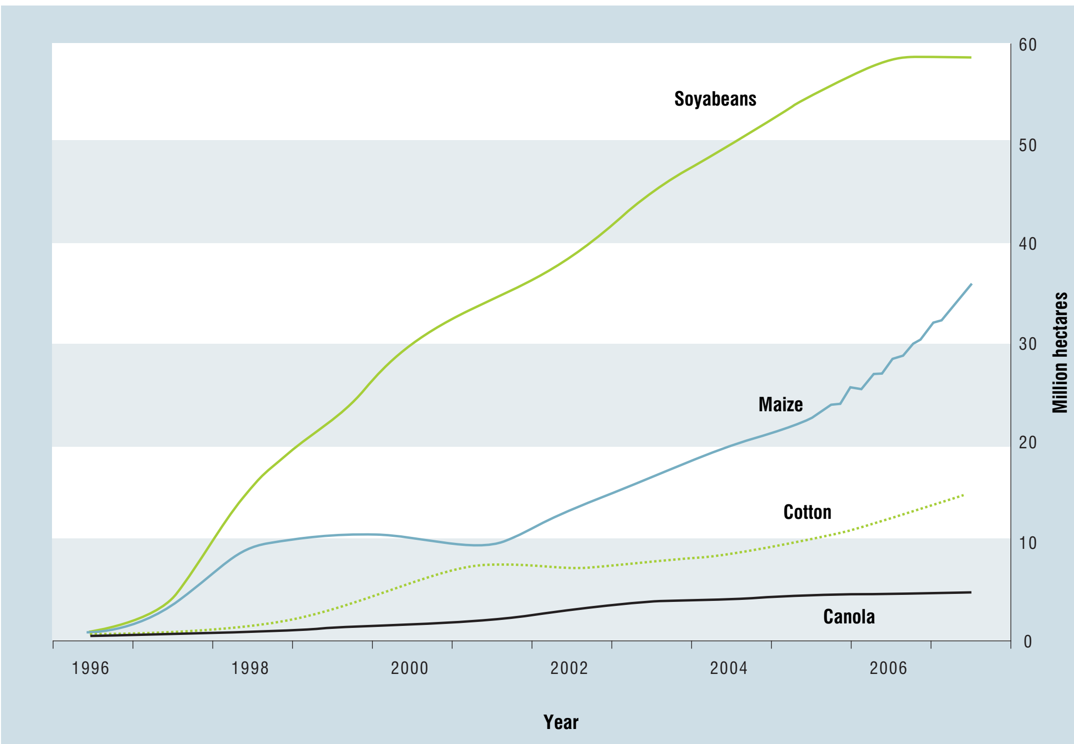
Thirty developing countries already have the capacity to micropropagate potatoes. The crop is a major source of food for poor families in Africa, and some Asian countries such as India, Sri Lanka and the Philippines. Indeed, micropropagation techniques have made potatoes the second-biggest crop (by weight) after rice in Vietnam, and have quadrupled their production in China over the past thirty years.[203]

6.6.2 The potential of GM crops and their adoption

Genetically modified (GM) crops are often held up as the solution to yield deficits as well as offering other benefits such as improved appearance, taste and nutritional quality, drought tolerance, and insect and disease resistance. The most common trait being introduced into GM crops is herbicide tolerance; this trait is now found in about 80 per cent of all GM crops planted worldwide.

Sorghum is the second food crop from the grass family after rice to have its genome fully sequenced. Combining the new knowledge on the sorghum genome sequence with expertise on molecular-marker assisted crop selection and breeding could result in the development of improved sorghum varieties and hybrids with improved drought tolerance or disease resistance. Up until now, the biotechnology option has focused on just a few crops: soya beans and maize (primarily used for animal feed), cotton and canola (oilseed rape). Soya beans' share of the total GM crop area is the highest and was growing most rapidly until recently, when the shares of GM maize and GM cotton areas also expanded (as seen in Figure 19).

Figure 19: Area cultivated globally by GM crop, 1996–2007[204]



Source: ISAAA, (2008)

6.7 COMBATING CROP DISEASES

Bananas and plantains, which feed about 100 million people in sub-Saharan Africa, are threatened by pests and diseases that are cutting yields across the continent, in some cases by 50 per cent or more. Bananas are particularly susceptible to significant pest and disease build-ups because they grow directly from 'mother plants' and not from seeds. Farmers may not be aware of infected cuttings from banana plants when they replant, sell or exchange them with fellow growers, thus unwittingly spreading disease. For example, in Uganda, which harvests 10 million tons of East African highland cooking bananas a year (making it the world's second-largest banana producer after India), was hit by bacterial wilt (*Xanthomonas campestris pv. campestris*) in 2001. This has now spread to Rwanda, the United Republic of Tanzania, Kenya, and Congo, and is suspected to have reached Burundi. Bacterial wilt causes banana leaves of infected plants to turn yellow and drip a yellowish fluid. The bananas ripen prematurely and rot away.

The main diseases affecting cassava in Africa are cassava mosaic disease, cassava bacterial blight, cassava anthracnose disease, and root rot. The major pests are the cassava green mite, the cassava mealybug, and the variegated grasshopper. These combined with poor farming systems cause yield losses that may be as high as 50 per cent. IITA found that a new disease affecting the cassava crop – the Cassava Brown Streak Virus – has spread from the United Republic of Tanzania to Kenya, Rwanda, Burundi, Democratic Republic of Congo, and Uganda, supported by a whitefly vector (bemisia tabaci) which is predominant in East Africa and could negatively affect food security in the region. Of the 172 million tons of cassava produced globally in 2000, Africa accounted for 54 per cent,, with Nigeria the world's largest producer. Research to understand the virus and to develop resistant varieties is underway in Uganda.

One of the most devastating diseases in rice is blight, caused by bacteria common throughout Asia and Africa. The bacteria, *Xanthomonas oryzae pv. Oryzae*, spreads rapidly from rice plant to rice plant and from field to field in water droplets. Infected leaves develop lesions, yellow and wilt in a matter of days. In severely infected fields, bacterial blight can wipe out half of a farmer's rice crop. The farmer's predicament is that all rice plants are vulnerable to some diseases more than others. Breeders have exploited disease-resistance genes in rice for nearly a century, redistributing this genetic wealth from hardy species to agriculturally useful varieties.[205]

As trade and commerce of agricultural products increases so does the risk of new diseases entering a country. Furthermore, existing pathogens can always adapt, or new pathogens can be introduced. Many developing countries are having to make choices about how best to allocate limited resources to the many potential uses in the broad field of sanitary and phytosanitary (SPS) control. SPS standards and monitoring is an important issue in the global trade of high-value perishable products. Such standards enable the effective management of risks associated with the spread of plant and animal pests and diseases and the incidence of microbial pathogens or contaminants in food. The development of SPS control mechanisms in developing countries is still in its infancy.

6.7.1 Herbicides and pesticides

The inability to control weeds is an important factor in stifling crop growth and yields. In sub-Saharan Africa, millions of labour hours are wasted, especially by women, who are often subjected to this backbreaking work. Weeding for Green Revolution crops was also the most labour-intensive of all agricultural operations. Even with a prodigious amount of labour, African farmers still lose 25 to 100 per cent of their crop yields to competition from weeds.[206]

Proponents of organic farming are encouraging the use of natural, non-toxic and environmentally friendly forms of pest control. Unfortunately, very few herbicide alternatives have been developed, and fewer still match the productivity and economic advantages of chemical herbicides, thereby resulting in a competitive disadvantage for organic farmers. Nonetheless, organic produce can yield higher incomes as organic food often commands a price premium. This is however only true in developed countries where a critical mass of consumers can afford such premiums. These premiums are not to be had in Africa.

In addition, manual weeding provides a major source of agricultural employment and cash income for hired labour, including women from the poorest households. Increased use of herbicides could therefore have negative socio-economic impacts for these labourers and their families.

In the United States, advances in sophisticated Global Positioning Systems allow farmers to apply specifically designed plans for spraying herbicides and pesticides. Additionally, weed detectors equipped with infrared light identify specific plants by the different rates of light they reflect and then send signals to a pump to spray a preset amount of herbicide onto the weed, reducing the amount spent on herbicides.[207]

6.8 POST-HARVEST TECHNOLOGIES

6.8.1 Reducing post-harvest losses and enhancing shelf life

Studies show post-harvest losses of cereals in developing countries are between 10 and 20 per cent, with even higher losses (up to 100 per cent) for fruit and vegetables. These sizeable losses could offset any significant investment made in raising productivity. Crop losses could be reduced and the world food supply increased by between 10 and 30 per cent through the application of readily available technologies and input management using minimal additional resources. Efforts to improve Africa's traditional post-harvest technologies have had mixed results. Modifications to one post-harvest activity may have serious effects on other operations, thus affecting the equilibrium of the system. For example, while new high-yielding varieties increase production, they may create new problems in terms of handling and storage of larger volumes of grain. Mechanical threshing leads farmers to store grain rather than unthreshed ears, making them potentially more susceptible to insect attack. Traditionally, farmers used various types of natural insecticides of either vegetable or mineral origin to preserve their grain from insect attack. Certain advanced products, if not properly used, can have serious negative consequences on the health of farmers or consumers.

Some of Africa's staple crops, such as cassava, are bulky, perishable and cannot be traded without significant processing or value-added. This results in some striking disparities. For instance Nigeria is the world's largest cassava producer but accounts for zero per cent of global exports while Thailand, which accounts for only 10 per cent of global production, commands 80 per cent of the global trade in the crop. The same can be said of Uganda, which is the second-largest producer of bananas after India but ranks 75th in terms of exports.[208] Developing post-harvest technologies and innovation therefore provides considerable opportunities for food security, trade and economic growth.

6.8.2 Adding value for perishable products

Well over five million people, most of them among the poorest people in Africa, depend on the cultivation of tropical root and tuber crops such as cassava, sweet potato, yam and cocoyam. These crops are also perishable. Processing cassava and other root and tuber crops is necessary to increase their shelf life, which could contribute considerably to transforming local economies. Overcoming the perishability of the crops, enhancing their nutritional value and adding additional economic value locally through agricultural processing is one important way to increasing food security in Africa.

Agro-industries in many developing countries play a minimal role in economic development. Less than 20 per cent of agricultural output undergoes industrial processing, compared with 80 per cent or more in developed countries. Appropriate technologies for processing cereals, legumes, roots and tubers into flours that serve as indigenous convenience foods in the rural areas of many developing countries are necessary to upgrade traditional food technologies, enabling them to enhance the shelf life and acceptability to consumer of indigenous foods, as well as to develop value-added products with export potential. An FAO compendium of traditional food processing technologies in Africa aims to support the establishment of small-scale, low-capital input installations for food preservation in rural and peri-urban areas.

Technologies for processing roots and tubers could expand these crops' roles as sources of both food and income. A wide range of existing food processing technologies could be made accessible to, and adapted by farming communities, by promoting research to identify, develop and promote diffusion of relevant technologies to reduce post-harvest food loss, with an initial emphasis on crops. It might be useful to focus on conducting an inventory of current technologies and practices for reducing post-harvest food loss.

6.8.3 Post-harvest technologies

The main post-harvest technologies can be classified into primary and secondary processing technologies. The primary processing of agricultural produce involves cleaning, grading, packaging, drying, pre-cooling, storage, etc. It is often poorly developed in rural areas compared to secondary processing industries such as flour mills, sugar mills and oil mills. The key low-cost technologies with the potential to raise income and generate employment opportunities in rural areas include:

- Seed/grain drying, aeration and storage technology;
- Rice drying technology for obtaining higher head rice yield;
- Efficient processing technology for pulses;
- Rice par-boiling technology;
- Modified atmosphere and pre-cooling technology;
- Cool stores for potatoes; and
- Cleaning, grading, and packing technology.

The development and adoption of technologies to reduce post-harvest losses will help generate income and employment opportunities for rural farmers. The greatest potential lies in primary processing technologies. Developing countries need to establish educational institutions with the responsibility to train people in the field of post-harvest engineering and management and to develop and adopt post-harvest technologies suitable to local conditions.

6.8.4 Development and dissemination of post-harvest technologies

Post-harvest losses reflect underinvestment in the value chain and innovation. It is best for all stakeholders involved in the value chain to understand the causes of such losses before deciding on measures to reduce them. All participants in the food system must have reliable access to appropriate post-harvest techniques and technologies to improve quality, throughput, labour and time efficiencies, and, at the same time, add value and enhance the competitiveness of fresh and processed produce and their by-products.

This could be achieved in part by developing and disseminating post-harvest technologies to improve food security and strengthen the competitiveness of small and medium size enterprises (SMEs) by reducing post-harvest losses and improving the marketability of smallholder produce. For subsistence farmers, the uptake of innovative post-harvest technologies and techniques can be enhanced by training the end-users in the application and improvement of these tools. A technology needs assessment should help identify the tools and policies to foster adoption of post-harvest technologies that enable smallholders to reduce post-harvest wastage and by-product contamination of air and water, and allow commercial farmers to capitalize on opportunities to access new and existing markets while improving competitiveness and adhering to food quality and safety standards. This would strengthen the long-term sustainability of remote communities by improving rural enterprises.

The preferred technologies for rural storage are those that use locally available construction materials and involve building designs that reflect social and cultural traditions but also harness scientific research and development in agricultural engineering that fosters optimum utilization of available human, financial and physical resources. In most developing countries this means promoting applied rather than basic research, with a strong emphasis on direct farmer participation.

6.8.5 Methodologies to choose technologies

The modernization of agriculture must not be understood merely as the acquisition of high technologies at high prices: a package that may not address the real development needs of African farmers. The technologies suitable to Africa's farming systems can be selected on the basis of two approaches: the ecological approach and the agro-ecological zone approach.

The ecological approach, illustrated in Figure 20, is centrally concerned with identifying constraints and opportunities for system-specific improvement. It distinguishes the critical factors that determine, limit or reduce crop growth and yields. These factors include the genetic potential of the plant, the availability of water and nutrients, and the occurrence of weeds, pests, and diseases in agricultural-production systems. This approach allows for more comprehensive identification and prioritization of the agro-ecological constraints to yield growth and helps reduce post-harvest losses, while helping to identify and map existing technological opportunities for improvement.

For example, research using the production ecological approach in the 1970s revealed that agricultural

Box 8: Types of farming system in Africa[210]

Farming systems in Africa can be divided into two major groups: traditional subsistence and improved farming systems.

In traditional subsistence farming, the farmer's objective is to grow enough food for on-farm consumption only. In Africa, there are still two types of subsistence farming: shifting subsistence farming and intensive subsistence farming. In a shifting cultivation system, a farmer clears a piece of land from bush fallow using traditional methods of slash-and-burn, and then cultivates it. When the soils are exhausted after three to five years, the farmer abandons the plot and moves to another piece of land. The abandoned plot is left to bush fallow for two to three years.

However, when there is high population pressure on the land, the individual farmer has no alternative land to move to. The farmer is forced to cultivate permanently in one location, using the intensive subsistence farming system.

Some types of improved farming systems also exist in Africa. Examples include: (a) improved farming systems under irrigation (such as the Gezira irrigation scheme in Sudan; (b) improved intensive farming systems by smallholders as in the Uboma district in Imo State, East Nigeria; and (c) improved (commercial) farming on large estates such as the settlers in Zimbabwe. In all theses aspects of improved farming systems, there are some improved methods especially for maintaining soil fertility and land productivity. Under improved commercial farming, the objective is to specialize in producing food, non-food crops and animal products for sale while maximizing profits.[211]

production in the Sahelian region was limited by drought and by poor soil fertility. This pointed to the need to invest in, and develop, drought- and pest-resistant crops and to enhance soil fertility.

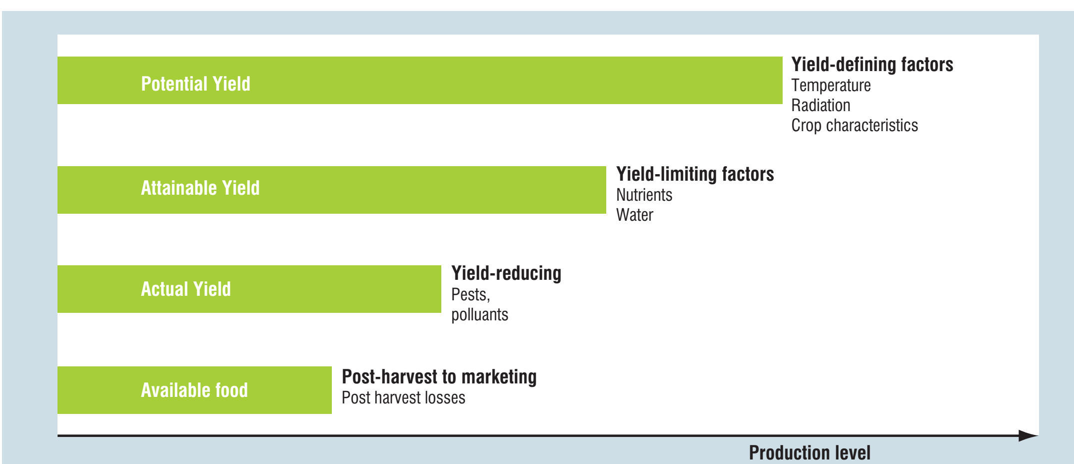
The ecological zone approach is based on the specific ecological zone where farming takes place, and aims to increase the choices and options available to farmers and enhance their ability to adapt to challenges such as erratic rainfall and climate change.

In this regard, each ecological zone dictates a range of possible farming systems. This could be a mixture of traditional and modern production systems. Technologies can be chosen according to their adaptability to the type of agro-ecological zone. Box 8 summarizes the main types of farming system seen in Africa.

The technologies reviewed in this report tend to be those that are suitable to drylands and areas of uncertain rainfall, since these lands account for 90 per cent of agricultural production in developing countries. Drylands are particularly important in Africa as they are home to over 500 million people in an area of some 3400 million hectares, covering the Sudan savannah, the Sahelian savannah, the Mediterranean and the deserts (see Table 10). These drylands are characterized by light, erratic rainfall of less than 500 mm/yr.

It is important to realize that each technological component undergoes three phases before it can be commercialized or absorbed by end-users. First, there is the technology generation and development phase, carried out through basic research on research stations and agriculture institutions. This is followed by

Figure 20: Ecological approach to realizing potential yield[209]



Source: IAC, (2004)

an on-farm adaptive research phase, concentrating on evaluation and testing. Finally, there is the commercialization or dissemination phase. These three phases are discussed in the earlier section on technology transfer.

Table 10. Africa's agro-ecological zones[212]

Eco. Zone	Rainfall mm/yr.	Vegetation	Crops
1	2000+	Tropical rainforest	Palm oil, cocoa, cassava
2	1500–2000	Rainforest with grassland	Palm oil, cocoa, cassava
3	1000–1500	Tropical grassland savannah	West Africa: cassava, yams, sweet potatoes, maize and beans East Africa: cassava, banana, coffee, sweet potatoes, maize and beans
4	500–1000	Sudan savannah	North: sorghum, millet, cowpea South: sorghum, millet, beans
5	250–500	Sahelian savannah	Millet, sorghum
6	500–1000	Temperate/ Mediterranean evergreen	Wheat, chickpeas, olives
7	< 850	Desert	Jojoba, date palms, citrus

The FAO Knowledge Forum-Best Practices guide for Conservation Farming is a good example of the way modern scientific understanding is able to modify traditional farming systems to achieve improvements in both yield and ecological sustainability. Achieving an ecological balance that encourages biodiversity and eliminates pollution will require a strong grasp of all categories of technology, in an effort to make well-informed, holistic decisions on which technologies to acquire.

The requisite knowledge, products and methods for stimulating a massive hike in smallholder productivity is well established; it must not be assumed that only the very latest high-tech GMO technology can assure success. When considering the technology transfer requirements for a developing country, it is essential to think about more than just high-technology solutions and explore medium- and low-tech solutions that may be better suited to deliver substantial improvements in yield. Indeed an immense list of solutions is already available, so the initial challenge is to isolate the very best opportunities and to provide individual dissemination paths for each of the 'solutions'. Box 9 gives some examples of high-, medium- and low-tech solutions. The optimal mixture of solutions might include a combination of both high-tech and more traditional inputs, tools and techniques, driven by a strategy focused on achieving maximum positive impact within the prevailing constraints.

Box 9: Examples of technology solutions[213]

Below are three descriptions and examples of technologies that could be more widely explored.

'High-tech' solutions are typically characterized by big-budget commercial or university research discoveries or inventions. Although GMO seed technology (or DNA-informed 'smart breeding' of non-GMO crops) is the most obvious example, an array of other types of technology is also available, particularly from the chemical and bio-chemical research stable. Given their technical complexity and regulatory aspects, modern pesticides and herbicides might also be included in this category. The physical science arena also has much to offer, particularly Information and Communication Technologies (ICT) capable of providing major benefits in training and education, improved distribution, accelerated market development and social/business networking.

'Medium-tech' solutions are generally more mature technologies which form the backbone of conventional (post-Green Revolution) agriculture. This might include improved (non-GMO) seed varieties using conventional plant breeding/hybridization, the use of fertilizers, the efficient use of machinery, small- to medium-scale integrated water resource projects, etc.

Natural fixation of nitrogen: an example of medium technology

This technique has a massive environmental and economic impact and has been widely used in a number of countries in the world. Soybeans in Brazil are inoculated with highly active bacteria (Bradyrizhobium) that fixate nitrogen from the air into the soil. The technology reduces the impact of the large-scale use of fertilizers on soil and groundwater. Moreover, it contributes to the mitigation of climate change, since it contributes to reducing to zero the use of nitrogen on over 13 million hectares in Brazil. Last but not least, the techniques results in a total saving of $3.0 billion per year.

'Low-tech' solutions are defined as simpler tools and techniques that may include modern best practice guidelines, or improved tools or devices that may have existed prior to the Green Revolution. Examples include agro-well construction, improved water harvesting and drip irrigation, intelligent planting schemes, integrated pest control, the use of animals and organic fertilizer, strategies for reducing post-harvest losses, etc.

Biological control of soybean caterpillar: an example of low technology

The caterpillar of soybean crops causes important reductions in productivity and control is affected mainly with pesticides that, if misused, can damage the environment, biodiversity and human health. In the 1970s researchers at Embrapa, the Brazilian Agricultural Research Corporation discovered a virus that acts as a natural enemy of the caterpillar and could be used as part of a very simple technique to biologically control the infestation. Researchers macerated virus-killed larvae and diluted the resulting mass in water for spraying in the fields. The technique was successfully implemented and is now used on 2 million hectares of soybean crops in Brazil. As a result, since the beginning of the 1980s the use of over 16 million litres of pesticides has been avoided, saving nearly $350 million. The technique can be easily employed by small, medium and large farmers. Embrapa has initiated projects with Kenya and the United Republic of Tanzania and other countries in sub-Saharan Africa to deliver the technology. Their implementation remains to be seen.

6.9 SUMMARY

A wide range of production and post-harvest technologies are currently available for a wider range of crops than during those which were the subject of the Green Revolution. There is also a better (but still incomplete) understanding of the context and factors that determine technology adoption, diffusion and impact. As research is moving towards ‘precision agriculture’, efforts to build an enabling environment need to incorporate an understanding of contextual factors, and should incorporate efforts to utilize farmers’ innovative capacity.

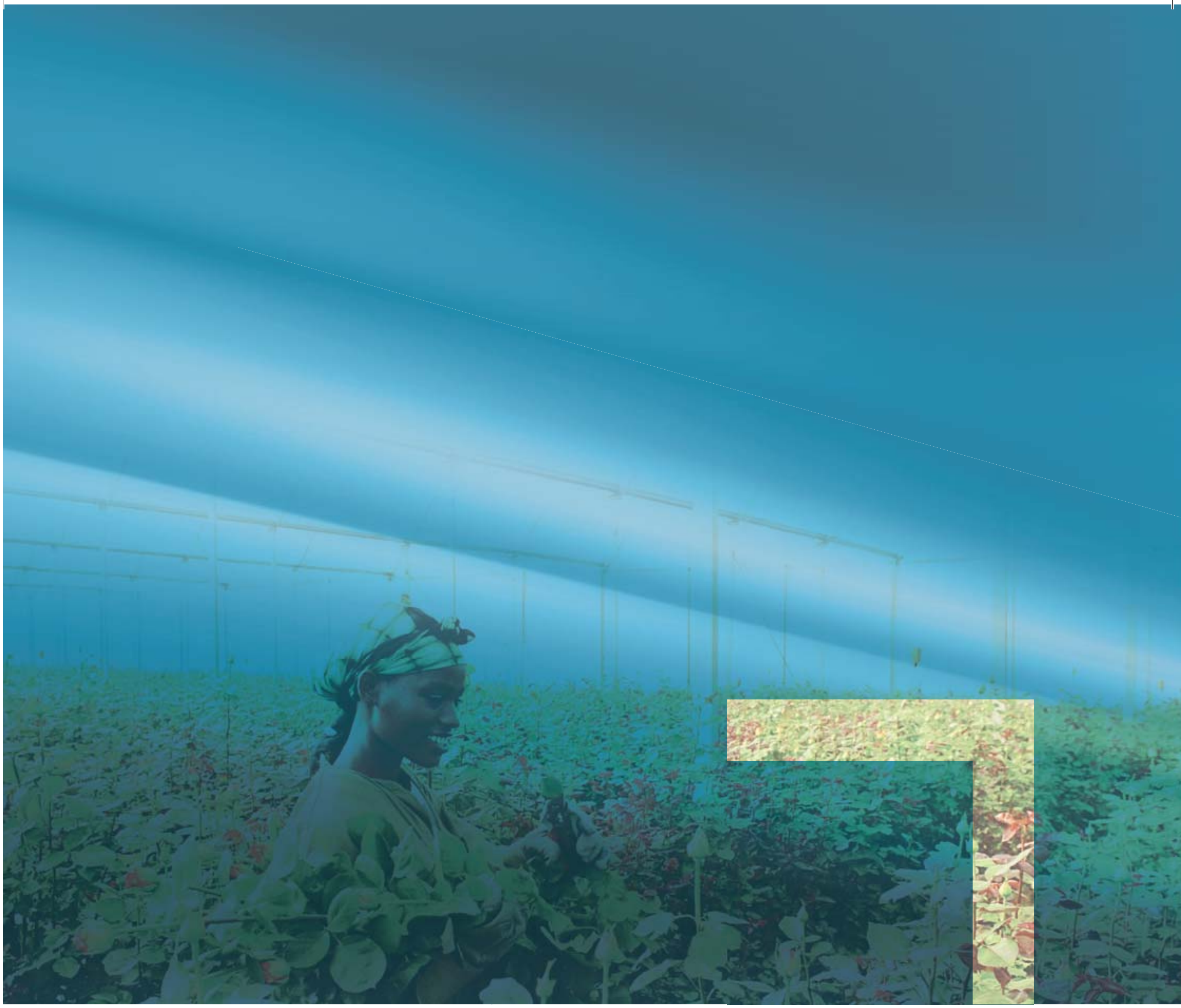
Local agro-ecological conditions play a vital role in shaping the overall technology acquisition strategy, which in turn requires close relationships with local grassroots initiatives coordinated by extension services, NGOs and private enterprise at the district level. Issues of sustainability (particularly in terms of water and energy use) are a major consideration in the choice of technologies, and must take centre-stage when discussing all aspects of technology adoption.

The urgent need for improvement underlines the importance of adopting and diffusing existing technologies as a matter of priority, and ensuring that public and private partnerships work toward the development, dissemination and adoption of technologies. Opportunities to reduce crop losses can be realized when farmers, processors and traders have access to reliable information and appropriate techniques and technologies to improve quality, throughput, labour and time efficiencies.

Technology needs assessments should identify gaps in technology, infrastructure or information in order to better facilitate the deployment and use of technologies that reduce post-harvest losses of smallholder rural produce.

In the future, climate change will render the need for new agricultural technologies more important for strongly affected parts of Africa. There is a need for: (a) increased agricultural R&D that is relevant to African agro-ecological conditions; (b) much stronger innovation capabilities among African institutions and smallholder farmers; (c) promotion of new techniques and technologies; and (d) training end-users in their application and improvement.

This chapter has outlined the main types of technologies used in agriculture and provided guidelines on how agricultural technologies could be selected that will be most useful for smallholder African farmers. These technologies all exist and can be transferred to smallholder farmers through technology transfer.



7 RECOMMENDATIONS

This final chapter recaps the main issues and solutions discussed in the report and proposes a set of fourteen priority recommendations for policy-makers in Africa (and other regions, including developed countries) for action to support agricultural research and development in Africa, with a view to raising productivity, improving human wellbeing and strengthening food security. Most of the recommendations are for national-level interventions though there is also a strong need for coordination between countries in sub-Saharan Africa and beyond.

With these recommendations, the report corroborates the opinion that when looking for solutions for agriculture development and food security, there is no one monolithic group with the same needs, challenges, and skill sets. As such solutions will need to avoid the 'one-size-fits-all' prescriptions that according to UNCTAD have been so damaging to development in recent years. A single overarching message to solve the food security problem should be distrusted. The solutions lie in hundreds of fronts and will be slow and technocratic rather than quick and spectacular.[214] Actors or agents operating in the agriculture innovation system include individuals such as farmers, enterprise owners, and engineers/scientists; and organizations including enterprises universities and firms, R&D departments, financial institutions such as development banks, and intermediary organisations such as seed banks and providers of extension services, such as marketing boards, cooperatives among others. The knowledge base of African agricultural systems of innovation is more dispersed than what we know wfrom our experiences of studying agricultural innovation systems from industrialized and other developing countries, and the organisations that play the critical role in applying existing knowledge or generating new knowledge through learning activities are in the public sector. The private sector is conspicuous largely by its absence, rather than for its proven ability for product development as is the case in the industrialized countries. The market for agricultural products is severely fragmented in African countries and this stunts advance that require demand and supply side coordination. The absence of linkages between the key actors not only prevents the ability of the agricultural system to use available knowledge to innovate and respond to local demand, but it also stymies its ability to be resilient in the face of external shocks, such as that posed by the global food crisis

(a) Place smallholder farmers at the centre of policy

Policies must be oriented towards ensuring that agricultural research, development and extension services meet the real needs of small-scale farmers who represent the majority of farmers in most developing countries. Policies must also seek to strengthen the competitiveness of small-holder farmers thus avoiding a rural exodus that would put pressure on the cities and lead to more food imports, thereby perpetuating the negative trade balance in agriculture and turning yet more African countries into net food importers. In addition, the intricacies of the labour and production processes and the socio-economic determinants of the status of female labour have to be understood, and imperfections in the rural factor markets removed through a combination of policy measures, structural changes and bold institutional reforms, if modern technologies and innovations are to be adopted by smallholder farmers.

(b) Strengthen policymaking capacities

Given the key role that policy-makers play in creating an enabling environment for agricultural innovation, it is essential that these stakeholders are adequately informed and prepared for the task. Promoting the sharing of policy-makers' experiences and relevant knowledge flows at the national and international level is a good place to start. There also needs to be a strong level of political will and international support, as well as some degree of experimentation in designing public policies, to find what works best.

(c) Target agricultural investment

Because financial resources are severely stretched in most African countries, policy-makers need to target investments carefully, putting resources into areas that are most likely to have a large impact on increasing physical and scientific infrastructure, linkages and greater investment into extension services that could lead to improving national food security. Nevertheless, there is also a need for African countries to increase their overall investment in agricultural development. Greater international support is crucial.

(d) Reinforce agricultural innovation systems by focusing on the enabling environment

Consciously creating an enabling environment for agricultural innovation is an imperative for African countries in order to promote sustainable agricultural development. Key aspects of an enabling environment that policy-makers would need to address include: (a) the role of private markets to produce optimum levels of public goods, including agricultural research; (b) the Wexternalities of technology use that call for regulatory frameworks, such as biosafety; (c) the role of external rules and norms, such as intellectual property protection on the development of local capabilities; and (d) the market weaknesses in African countries that lead to high transaction costs in establishing user-producer networks. These require public investment in research, regulation and institutional capacity development to foster growth.

(e) Take into account local agro-ecological conditions

African agriculture is tremendously diverse, and any single, Africa-wide strategy for agricultural transformation (e.g., based on an Asian-style Green Revolution) is unlikely to be successful. Technologies should be tailored to different agro-ecological zones and include appropriate and effective mixes both of low-, medium- and high-tech solutions as well as traditional knowledge and modern science. Within African's six broad agro-ecological zones, further disaggregation is necessary, based on local socio-political and agro-ecological conditions. Developing appropriate disaggregation and specific strategies for each zone is a key challenge for National Agricultural Research System (NARS). There is a need to strengthen NARS (typically the weak link in the research system in Africa), as international and regional research systems are unlikely to carry out the disaggregated research needed to tailor innovations to local areas. Specific attention must be given to rainfed agriculture as it is, and will continue to be, the dominant system in Africa for several decades to come. Ecological synergies including drought-tolerant cultivars should be exploited to take full advantage of the new breeding methods.

(f) Explore the potential of global networks and value chains

Supporting smallholder farmers in joining sub-regional, regional or global networks and value chains will help provide them with access to international markets and to inputs, finance and technology. It may well be useful to start with a value chain analysis to identify the opportunities for improvement. As mentioned earlier in the report, efforts to support links to value chains can be supported by the following activities: (a) actively increasing market efficiencies and access, especially to the markets for high value-added agricultural exports, including processed agricultural exports; (b) putting in place marketing information systems; and (c) designing and implementing trade facilitation programmes. However, the real challenge that remains is one of matching such supply led approaches by demand-led ones. Strong productivity and (real) income growth which is key for industrialization of countries,[215] however, derives mainly from the ability to achieve scale economies in production, specialization and technological learning on the supply side; and on the demand side, the ability to respond to demand.[216] Precisely because of this, such approaches need to be complemented by the building of productive capacities in African agriculture systems.

(g) Link national, regional and international agriculture research to innovation

One important lesson learnt from the evolution of the Green Revolution technology in Asia is that International Agricultural Research Centres (IARCs) should cooperate in developing improved crop varieties. Research collaboration between IARC and NARS has to be strengthened and intensified. The success of collaborative activities depends much on the existence of national capabilities and institutional infrastructure for testing, adapting and disseminating technology prototypes shared among participating countries. Sub-regional cooperation can help address capability and financing shortages as well as scarcity of scientific laboratory equipment. African countries need to engage in greater partnership nationally, regionally and internationally that focuses on the needs of their agricultural systems.

(h) Revitalize funding and strategies for research and development

There is an immediate need to reverse the declining trend in funding for agricultural research and development (R&D). The priority here is to revitalize the domestic and internationally-supported agricultural R&D activities by substantially increasing the investment in agricultural R&D as percentage of GDP and to decrease donor dependency. A greater share of the overall ODA funds should be allocated to agricultural investments to augment enhanced, but limited, national resources available for this purpose in order to enhance the capabilities of African National Agricultural Research Systems (NARS) to undertake adaptive research.

(i) Promote Linkages Within and Outside of the Agriculture Innovation System

Four kinds of linkages are critical to enable this transition: linkages between scientists and practitioners, including farmers within the agricultural innovation system; horizontal linkages between farmers and extension services, linkages between farmers and global networks and value chains and linkages between farming and non-farming systems. The specific policies needed at the national level will depend on existing capabilities and human and financial resources, the political, social and institutional contexts and agro-ecological conditions.

(j) Engage in capacity building

Capacity-building policies and programmes for science and technology should be assessed to ensure that they work in support of public policy objectives as an integral part of national and regional policies. There is a need for an agreement among African countries on a common underlying vision for capacity building to provide sustainable capacity support for specific needs of the agriculture sector at various levels. At a national level, assessing local technological competence to overcome weaknesses would serve a valuable function to assess capacity needs. It is also necessary to mainstream science and technology policy by, for example: (a) strengthening linkages and understanding between the scientific and policy-making communities; (b) enhancing capacities needed to articulate and assess policy choices and options related to science and technology; (c) focusing capacity-building strategies towards long-term education programmes through universities and strategically selected on-farm activities; and (d) developing a critical mass of experts at all levels through organized long-term training, both formal and informal.

(k) International cooperation on technology transfer and technology sharing

African governments must take the lead in cooperating to advance technology transfer within the region. There are already numerous examples of how South-South cooperation and triangular cooperation have helped ensure the right technological tools are made available to African farmers. South-South cooperation also offers an important catalyst for addressing issues of productivity at bilateral, regional and interregional levels among developing countries and building food security. Such cooperation can include exchange of best practices, technologies and technicians on agricultural production. It can be undertaken within the framework of sub-regional or regional organizations of developing countries through dedicated agriculture and food sector development programmes and trade programmes

(l) Multilateral rule-making and policy space

Policies over the past 30 years that led to the withdrawal of governments from agricultural markets, the dismantling of marketing boards and deregulation of markets for agricultural inputs and outputs (in many cases accompanied by a shift in resources from food production for the domestic market to export crops) have not been successful in creating dynamic agricultural systems and strong productive capacities by smallholder farmers in Africa. Multilateral, national and regional technology policies must be an important element when crafting trade rules in the WTO and other multilateral fora. Intellectual property issues are generally less pertinent to smallholders than larger commercial farmers, but the issues that may arise for them merit investigation. Adequate policy space especially in relation to international rule-making is necessary to address and implement some critical policies in these areas.

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