Helping Small-Holder Farmers Deal with Climate Change

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Paper prepared for presentation at the "Agriculture in A Changing Climate: The New International Research Frontier" conference conducted by the Crawford Fund for International Agricultural Research, Parliament House, Canberra, Australia, September 3, 2008

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Agriculture is a major activity and land use across the developing world; it is vulnerable to changes in climatic conditions. Climate change affects agricultural systems and production in various ways, for example by changing agro-ecological conditions. Changes in the pattern and amount of precipitation, as well as temperature, can directly affect the suitability of cultivable land for agricultural production, food supplies and food utilisation. Climate change can affect food security, depending on the region and the socio-economic status of the country involved. The poorest and food-insecure regions such as sub-Saharan Africa are expected to be most vulnerable to climate change. Overall, the adversities of climate change will disproportionately affect the small-holder poor who largely depend on agriculture and who have limited resources to cope with or adapt to climate change. More than 85% of the world's land-users are classified as small-holders, with farm sizes of less than 2 ha. The impacts of high temperature, variability in precipitation patterns, and events such as severe and frequent drought and floods will most likely enhance production risks for these farmers, further widening the gap between the rich and the poor. Adverse impacts of climate change on the poor may be reduced through appropriate policies such as investment in infrastructure, adoption of sustainable agricultural and natural resource management practices, and advanced technologies that can generate climate-resilient crop varieties and better-adapted livestock breeds. Examples of some of these advanced technologies are described in this account.

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The context

Agriculture is undoubtedly the single most important sector in the economies of most low-income countries, accounting for one-fourth to one-half of the gross domestic product (GDP) and the bulk of export earnings. About 75% of Africans depend solely on income from agriculture and agribusiness, which, in turn, provides 40% of the GDP of African nations (Machuka 2003). Production is subsistence in nature, with a high dependence on rain. Poverty is higher in most African countries than elsewhere in the developing world, and highest in rural areas. Crop yields are stagnant and production struggles to keep up with population growth by expanding land under agriculture, but the area of land suitable for agriculture is not unlimited. Therefore, accelerated growth in agriculture, with concomitant increases in incomes, is needed to sustain growth, to raise food-purchasing power and to reduce poverty. Poor people's links to the land are critical for sustainable development. The front line of any successful assault on poverty and environmental degradation must therefore have a focus on agriculture and rural development (Kelemu *et al.* 2003).

A major challenge for Africa is to feed its growing population. During the last two decades of the 20th century, the per-capita food production in Africa declined (Machuka 2003) because of dropping agricultural productivity and rapid population growth. Decline in agricultural productivity was associated with several biophysical and socio-economic factors, including an inability to replenish declining soil fertility; use of poor quality seeds and low-yielding crop varieties; recurrent drought; inability and lack of resources to control large yield losses to pests, diseases and weeds; limited access to and participation in local, regional and international markets; lack of, or ineffectual, implementation of supportive policies to boost agricultural production; poor infrastructure; and, particularly today, immense healthcare problems.

Africa's current population is projected to rise to 1700 million by 2050 (Pinstrup-Andersen and Pandya-Lorch 1999). Demand for imported food — mostly cereals and legumes — will increase from 50 to 70 million tons per year. If the current economic situation of Africa does not improve, food-deficit nations are unlikely to have the resources to purchase such a huge quantity of food on a commercial basis.

Agricultural productivity can be increased sustainably in numerous ways, such as using inorganic and organic fertilisers; improving disease, pest and weed control; practising soil and water conservation; and using improved crop varieties developed either conventionally or through biotechnology. Most remarkable is the unsatisfactory performance of agriculture in sub-Saharan Africa, especially when contrasted with parts of Asia and Latin America. There is a clear direct link between crop yields and poverty. For example, in the mid-1980s, cereal yields were comparably low and poverty was comparably high in sub-Saharan Africa and South Asia. Some fifteen years later, yields had increased by more than 50% and poverty had declined by 30% in South Asia. In sub-Saharan Africa, however, yields and poverty were static during the same period, making the issue of food security a major challenge for the continent (World Bank 2008).

Many of the countries in sub-Saharan Africa are too small to sustain effective agricultural research systems or to have a critical mass of agricultural research scientists. Because of small country size, agricultural research systems in sub-Saharan Africa are fragmented into nearly 400 distinct research agencies, almost four times the number in India and eight times that in the United States (Pardey *et al.* 2006). Funding per scientist is also low. With nearly 50% more scientists than India, and about a third more than the United States, all of sub-Saharan Africa spends only about half of what India spends and less than a quarter of what the United States spends (Pardey *et al.* 2006). It is important to note, though, that only a quarter of Africans classified as scientists have a PhD, compared with all or most scientists in India and the United States. All these factors hinder improvement in agricultural research and development. To prevent future human catastrophes, African countries will have to increase public spending in agriculture, develop and implement strategies for increasing agricultural productivity, and adopt technologies that can help cope with the negative effects of climate change, protect the natural resource base and tackle poverty as a whole.

Climate change and its unique challenge for African food security

Agriculture is vulnerable to the impacts of climate change that include increases in temperature, decreases in rainfall and increased frequency of extreme weather events, such as drought, fire and flooding over much of Africa and parts of Asia (Schmidhuber and Tubiello 2007). More climatic variability and extreme events will pose challenges for farmers, particularly small-holders with little or no capacity to cope with these changes. More than 85% of the world's land-users are classified as small-holders with farm sizes of less than 2 ha (FAO 2005). Improving the performance of agriculture as the basis for economic growth, and reducing poverty and food insecurity in agriculture-dependent developing countries requires a productivity and natural resources management focus on small-holder farming (World Bank 2008).

The climate in Africa is largely tropical in nature, which is classified into three major climatic zones: humid equatorial, dry and humid temperate. Within these zones, however, altitude and other localised variables generate distinct regional climates. Climate change, especially manifested by prolonged drought, is one of the most serious climatic hazards affecting the agricultural sector of the continent. As most of the agricultural activities in the majority of African countries are rain-fed, any adverse changes in the pattern and amount of precipitation would have a devastating effect on the sector in the region, and on the livelihood of most of the population. Variability is expected to increase, including frequent occurrences of extreme events particularly in marginal rainfall areas (Nkomo *et al.* 2006).

Drought is perhaps the most dramatic limiting factor to crop and animal production on a global scale, and the situation is expected to deteriorate in Africa. The current trends in land degradation, desertification and climatic variability have been predicted to intensify. The erratic rainfall across seasons, poor soil-water-holding capacity and poor management of water resources have led to drought occurring frequently. In the last two decades, droughts occurred in 1983–1984, 1991–1992, 1995–1996, 1999–2001 and 2004–2005 in parts of Africa with significant impact on human, animal, vegetation and other resources. The debate on climate change and its impacts on agriculture are, therefore, crucial to the very survival of the African continent and its people. The continent is particularly vulnerable to climate change because it consists of some of the world's poorest nations.

The impacts of climate change on agriculture also have the potential to exacerbate other natural resource management challenges in Africa. Examples of aggravated natural resource management challenges include increased soil erosion, increased incidence of wind and rain events; and increased incidence of certain weeds, pests and diseases. In addition, long-term changes in climate, water supply and soil structure and moisture could make it difficult to continue crop and animal production in certain severely affected regions.

As a continent, Africa has vast natural resources including wildlife, plant and animal genetic diversity. Over generations, Africa has contributed greatly to the world's agriculture as a centre of origin and diversity for some important crops and animals, and by supplying unique sources of resistance to diseases and pests of crops and other organisms of African origin (Kelemu *et al.* 2003). These plant and animal genetic resources are also vulnerable to adverse changes in climate, thus potentially depriving Africa and the rest of the world of this natural wealth.

Agriculture in the developed world is widely expected to be less vulnerable to climate change than agriculture in the developing countries, particularly those in the tropics. The poor developing countries are more vulnerable because of:

- their heavy dependence on agriculture and lack of economic diversification
- low income and high levels of poverty
- farming practices in marginal rainfall areas
- lack of advanced technologies to enhance production to keep up with population growth
- soil degradation
- generally poor infrastructure.

All of these factors collectively lead to low adaptive capacity. The effects of climate change will largely depend on the agricultural sector's ability to adapt through changes in advanced technologies and environmental conditions. Adjustment of agricultural management practices, and access to and adoption of various technologies, can help farmers adapt to climate variability.

Dealing with climate change: advanced technologies

There is no doubt about the impact of climate change on agriculture. Farmers know this better than anybody else. Adverse impacts of climate change on the poor may be reduced through appropriate policies such as investment in infrastructure and education, increased investment in agricultural research and development, implementation of sustainable agricultural and natural resource management practices, and advanced technologies that can generate climate-resilient crop varieties and better-adapted livestock breeds along with conditions for optimal production.

One such advanced technology that can help farmers deal with climate change is agricultural biotechnology. The potential role of agricultural biotechnology, particularly genetically modified crops and animals, in improving the livelihoods of the poor is being debated vigorously. Many biotechnology products are being developed in various countries for different uses. These products include modified plants for food and fiber, animal feed, medical care and bioremediation. I do not wish to imply that agricultural biotechnologies will, singlehandedly, solve Africa's agricultural production constraints and make Africans self-sufficient in food, or completely solve the impacts of climate change. While recognising the potential, genetically modified crop varieties — just like those developed through conventional breeding strategies — must be combined with other appropriate and optimal management practices for satisfactory production.

Data provided by the International Service for the Acquisition of Agri-biotech Applications (ISAAA) show that in 2007 (the twelfth year of commercialisation of genetically modified crops (GMC) or biotech crops), 23 countries adopted biotech crops, planting a total of 114 million ha of land (James 2007). Of these, twelve are developing countries, namely Argentina, Brazil, Chile, China, Colombia, Honduras, India, Mexico, Paraguay, Philippines, South Africa and Uruguay. According to this ISAAA report, during these first 12 years (1996–2007), biotech crops have provided substantial economic and environmental benefits to farmers in both developed and developing countries.

The accumulated area under biotech crops from 1996 to 2007 was 690 million ha, with the 67-fold increase between 1996 and 2007 making this the most rapidly adopted crop technology in recent history (James 2007). Furthermore, of the global total of 12 million farmers who adopted biotech crops in 2007, about 11 million were small-holders (most were growers of Bt cotton for insect resistance). South Africa is the only African country which commercialised biotech cotton, maize and soybeans, often grown by subsistence women farmers.

To make an impact in Africa, biotechnology research must be pro-resource-poor farmers and pro-women and children, target crops that African farmers traditionally know how to grow, and address agronomic traits of significant importance to their needs (Kelemu *et al.* 2003). Food shortages in Africa are often strongly associated with environmental calamities. The major abiotic stress factors affecting food production in sub-Saharan Africa are low soil fertility, drought, salinity, soil acidity and heat stress.

Scientists around the world are working on various strategies to develop drought-tolerant and other climate-resilient crops. Although challenging, drought resistance can be improved through conventional breeding, using existing genetic diversity. Modern tools, involving molecular markers, genetic engineering and comprehensive gene expression profiling, provide opportunities for directing the continued breeding of genotypes that provide stable grain yield under widely varied environmental conditions (Bruce *et al.* 2002).

Two examples of applications of crop improvement for dealing with production constraints and climate variability in Africa are described below:

- **Water-efficient maize for Africa (WEMA):** This is a five-year project, funded by the Bill and Melinda Gates Foundation and the Howard G. Buffett Foundation, to develop new African drought-tolerant maize varieties, incorporating the best technology available internationally and regionally (http://www.aatf-africa.org/projects.php). Maize is an important staple crop in Africa and it is severely affected by frequently occurring drought, putting at risk more than 300 million Africans who depend on this crop as their main food source. The African Agricultural Technology Foundation (AATF), located in Nairobi, Kenya, leads the WEMA project. The project involves conventional plant breeding, molecular markers and genetic engineering, and brings in public and private sectors as partners. Partner institutions include the International Maize and Wheat Improvement Centre (CIMMYT), the private agricultural company Monsanto, and the agricultural research systems in eastern and southern Africa. Partner African countries are Kenya, Mozambique, South Africa, Tanzania and Uganda, and the benefits and safety of the products of this project will be assessed according the regulatory policies and requirements of these countries.

  In this research partnership arrangement, AATF will provide leadership and experience in public–private partnership and project management as well as technology stewardship. CIMMYT, as a centre with a global mandate for maize improvement, will provide high-yielding maize varieties that are adapted to African conditions, and expertise in conventional breeding and testing for drought tolerance. Monsanto will provide proprietary germplasm, advanced breeding tools and expertise, and drought-tolerance transgenes developed in collaboration with BASF. The national agricultural research systems, farmers' groups, and seed companies participating in the project will contribute their expertise in field testing, seed multiplication and distribution. The project will involve local institutions, both public and private, and in the process expand their capacity and experience in crop breeding, biotechnology and biosafety. In the long term, the project is expected to make drought-tolerant maize varieties available royalty-free to small-holder farmers in Sub-Saharan Africa.

- **Cowpea productivity improvement — guarding against insect pests:** Cowpea (*Vigna unguiculata* L.Walp.) is a food grain legume in the dry savannas of Africa consumed by nearly 200 million Africans. The project is designed to tackle one of the major production constraints, a pod borer insect, *Maruca vitrata*, through genetic engineering, and to enable small-holder farmers in Sub-Saharan Africa to have access to farmer-preferred, elite cowpea varieties with resistance to insect pests. Partner institutions or initiatives in this project include AATF; the Network for the Genetic Improvement of Cowpea for Africa (NGICA); the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia; the International Institute of Tropical Agriculture (IITA), Nigeria; Monsanto Company, USA; The Kirkhouse Trust, United Kingdom; Institut de l'Environnement et de Recherches Agricoles (INERA), Burkina Faso; the Institute of Agricultural Research Zaria (IAR), Nigeria, and other national agricultural research systems in target countries of west Africa. The development and adoption of transgenic cowpea varieties that are resistant to the insect pest are expected to increase yields, and minimise pesticide use and its effects on human health and the environment.

Enhancing the capacity of Africa to develop its own solution

Technologies and gene constructs are often introduced to Africa from elsewhere through partnerships, as shown in the two major projects described above. In many instances, African scientists travel to institutions in the developed world to acquire skills in a number of biotechnology areas. To enhance Africa's capacity to develop its own solutions through science and technology, an initiative named Biosciences for east and central Africa (BecA) has been created (http://www.africabiosciences.org/network.php?network1=hub).

BecA aims to employ modern biotechnology to improve agriculture in eastern and central Africa. It also seeks to strengthen the capacity of scientists in that region to conduct bioscience research and to significantly contribute to improved products that can enhance livelihoods of farmers in the region (Kelemu 2008). BecA provides a focal point for the African scientific community to support the activities of national, regional and international agencies as they address agriculture-related problems of importance for alleviating poverty and promoting development.

BecA is co-financed by a substantial grant from the Government of Canada through the Canadian International Development Agency (CIDA), and by the International Livestock Research Institute (ILRI). BecA consists of a Hub with a state-of-the-art shared biosciences facility located on the campus of ILRI, Nairobi, Kenya, that provides a research platform, research-related services and capacity-building opportunities; a BecA Secretariat, also located at ILRI Nairobi, and a network of five regional nodes (University of Buea, Cameroon; Ethiopian Institute of Agricultural Research (EIAR), Ethiopia; Sokoine University of Agriculture (SUA), Tanzania; The Ugandan National Agricultural Research Organization (NARO), Uganda; and Kigali Institute of Science and Technology (KIST), Rwanda), and other laboratories distributed throughout eastern and central Africa for conducting research on priority issues affecting Africa's development. The BecA Network (BecANet) covers east and central African countries: Burundi, Cameroon, Central Africa Republic, Congo Brazzaville, Democratic Republic of Congo, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Kenya, Madagascar, Rwanda, Sao Tome and Principe, Somalia, Sudan, Tanzania and Uganda.

An overall program of construction is currently ongoing that includes upgrading the electrical infrastructure and water treatment systems for the ILRI–Nairobi campus, refurbishing existing laboratories and existing offices to required standards, procuring modern laboratory equipment and furniture, and constructing modern greenhouses and offices. These activities are being carefully phased by areas so that on-going and new research and training programs continue with minimal disruption to all site users and visitors. Construction and renovation are expected to be completed by March 2009. Once completed, the BecA Hub will have, among many other things, seven modern laboratories working on crop, livestock and microbial biotechnologies.

The need to ensure availability at the Hub of a critical mass of scientists and technical support staff covering the broad area of biosciences relevant for agriculture and its interfaces with human health and the environment was well recognised at inception of the BecA concept. Capacity in plant, microbial and animal biotechnology is developing at the Hub through various partnerships, ensuring that scientific advances and new technologies are readily available to the African scientific community. To provide expertise in crop sciences and related fields, ILRI has invited other CGIAR centres and non-CGIAR research organisations to locate some of their crop research projects relevant to the region at the BecA Hub. Building this human resource is crucial to the success, viability, sustainability and credibility of the entire BecA initiative. Expertise and knowledge of the livestock sciences is readily available to BecA participants — at the BecA hub, nodes and elsewhere in the BecA network countries — through ILRI and its partners in livestock research.

The challenges for this initiative include:

- to continually strengthen and expand core competencies and scientific capability, and pro-actively make these available to scientists at universities and research institutions across Africa
- to mobilise a critical mass of researchers and resources around key problems to deliver science-based solutions to some of the development issues facing African agriculture and its intersections with human health and the environment
- to make it a financially sustainable and affordable endeavor.

Conclusion

Comprehensive and progressive policies addressing a range of issues are needed to develop and implement effective ways of coping with climate change. Agricultural growth and poverty reduction depend on investments in rural infrastructure, markets and agricultural research and development. Studies show that those types of investments generally provide high returns. Average rates of return on investment in agricultural research and development, for example, have been documented in the range of 35% for sub-Saharan Africa to 50% in Asia in several studies. Results from China, India and Uganda also reveal that the highest returns in terms of both growth and poverty reduction are from investments in agricultural research, rural roads and education.

Current levels of agricultural spending in sub-Saharan Africa are inadequate for sustained growth. Increasing agricultural spending to 10% of national budgets brought success in Asia, and a similar increased spending in Africa may contribute to sustainable growth and poverty reduction. All in all, tackling poverty will help enhance the capacity of small-holders to cope with the effects of climate change.

There are many reasons to be optimistic about the future of Africa and its development: the average GDP growth in the last decade stands at 5.4% for sub-Saharan Africa; better economic policies are being developed and implemented in several African countries; Africa’s diaspora is providing new skills and enthusiasm; conflicts are receding; internet use and access is increasing at a healthy rate; and infrastructure in general is improving. There are many local success stories and new opportunities on which to build. The conditions are conducive for further investments that will result in changes that are fast enough and adequate enough for a growing population in urgent need.

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