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# Agricultural biotechnology for climate change mitigation and adaptation

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## *Can biotechnology help respond to and deal with climate change and other agricultural development issues?*

Climate implications for agriculture are clear, direct, and significant. Likewise agriculture has important implications for global greenhouse gas (GHG) emissions. Fossil fuel for farm inputs and equipment, animal agriculture, land clearing and preparation are significant contributors to GHG emissions. The Intergovernmental Panel on Climate Change (IPCC) has reported that farming is responsible for over a quarter of total global greenhouse gas emissions. By contrast, the share of farming in global gross domestic product (GDP) is about four percent, indicating that agriculture is highly GHG intensive. Important interlinkages between agriculture and climate have broadened the policy agenda for both. The climate change agenda includes farming as simultaneously vulnerable to climate change, a worrying source of GHG emissions, and – through adjustment in production practices – a potentially potent source of mitigation.

What role can innovative agricultural practices and technologies play in GHG mitigation and adaptation to climate change? What policy and institutional changes would encourage the innovation and diffusion of these practices and technologies to developing countries? We address these questions in a research paper and subsequent article published in science journal Food Policy in 2012 on which this article is based.

**Climate effects on agriculture production**

Forecasting climate change is imperfect, complex, important, and often controversial. While disputes remain, the consensus foresees accelerating increases in average annual temperatures and changes in precipitation, coupled with increasingly erratic intra-annual weather patterns. Forecasters agree that many developing country climates will become less suitable for current agricultural practices because places that are now warm and humid will be disadvantaged relative to places that are now cooler. While the precise nature of these changes is uncertain, it is clear that these climate changes will alter global patterns of comparative agricultural advantage through changes in relative productivity and prices.

Some agricultural production in temperate North America, Europe, and Asia may benefit from higher mean temperatures and longer growing seasons, while agriculture in much of the rest of the world will likely suffer declines in productivity. This research is ever-evolving, and some recent work suggests that grain yields in temperate zones may be more vulnerable than previously thought, but the basic patterns are worth noting. Higher temperatures in already-hot regions will likely reduce crop yields and effectively shorten the growing season by introducing longer periods of excessive heat.

In 2010, the best available estimates combining agronomic and economic modelling forecasts suggested that the aggregate impact of these effects will reduce global agricultural production by six percent by 2080 relative to expected production in the absence of climate change. Of course, regional disparities around this global average impact are substantial. Without increased innovation India and Africa are projected to see reductions of agricultural output by 30 percent or more relative to no climate change.

With expected hotter temperatures and changing precipitation patterns, controlling water supplies and improving irrigation access and efficiency will become increasingly important. Climate change will burden currently irrigated areas, and may even outstrip current irrigation capacity due to general water shortages, but farmers with no access to irrigation are clearly most vulnerable to precipitation volatility. Across the Middle East, Northern and Southern Africa and Central Asia, water availability for farms is projected to decline with climate change and population growth in the next several decades. In particular, African farmers are in desperate need of techniques, technologies, and investments that improve water management efficiency and access to irrigation, or find ways to improve incomes with less secure and more variable water availability.

Developing countries are especially vulnerable to climate change because they depend heavily on agriculture, tend to be relatively warm already, lack infrastructure to respond well to increased variability, and lack capital to invest in innovative adaptations. Moreover, within already poor regions, the largest effects will be on the very poor who tend to earn their livelihoods from farming. Climate, however, is only one of many things that are changing in poor countries and for poor people. If income growth and economic development continue the number of farms and the farm population in developing countries is expected to decline markedly by 2080. With climate change this familiar agricultural transition will likely happen much faster. Moreover, some marginal areas in Africa and India may abandon agriculture altogether not because of increased labour productivity off the farm, but because of declining farmland productivity and rising production uncertainty. While a falling employment share in agriculture may help reduce a population's direct vulnerability to climate change, the political tensions and urban pressures associated with such a speedy transformation could be particularly problematic.

**Agricultural technologies, including GM crops**

The core challenge of climate change adaptation and mitigation in agriculture is to produce (i) more food, (ii) more efficiently, (iii) under more volatile production conditions, and (iv) with net reductions in GHG emissions from food production and marketing. Agricultural technologies will play a central role in enabling producers to meet these core challenges. However, while most technologies have climate implications, some of them are of particular relevance to developing country agriculture and climate change.

Several new varieties and traits offer farmers not only increased productivity, but also greater flexibility in adapting to climate change, including traits that confer tolerance to drought and heat, tolerance to salinity – for example, due to rising sea levels in coastal areas – and early maturation in order to shorten the growing season and reduce farmers' exposure to risk of extreme weather events. Climate change will also lead to new pest and disease pressures. The nuances of temperature changes –higher low temperatures and fewer freezes – could shorten dormant periods, speeding up pest and disease growth, and changing the dynamics of these populations and their resistance. Crops, varieties, and traits that are resistant to pests and diseases will improve producers' ability to adapt to climate change. These varieties reduce carbon emissions by decreasing demand for pesticides and the number of in-field applications. These promising new traits and varieties, many still in development, can emerge from traditional breeding techniques that leverage existing varieties that are well suited to the vagaries of local production environments, but also importantly from more advanced biotechnology techniques such as market assisted selection and genetic modification.

While agricultural biotechnology remains controversial, these techniques provide an especially promising set of tools that have produced dramatic improvements in yield and reductions in production costs and input use intensity. Examples of new crops that have benefited agriculture and reduced emissions include genetically modified crops with pest resistance and herbicide tolerance. Some question whether these benefits are real, but the fact that farmers worldwide have never adopted an agricultural technology as quickly as they have genetically modified (GM) crops suggests otherwise. In 2012, GM crops were grown on roughly 12 percent of the world's arable land with a total reduction due to both the direct and indirect emission effects of GM crops of over 26.7 billion kg of carbon dioxide ($CO_2$), or the equivalent of removing nearly 12 million cars from circulation. [Ref 1]

While new traits, varieties and crops will play an important role in climate change mitigation and adaptation, the range of relevant practice and technologies is much broader than this, including water management, production practices, post-harvest technologies, information and forecasting, and insurance. As discussed in in our earlier survey, however, understanding the policy and innovation issues raised by this broader set of agricultural practices and related technologies is important since responding to climate change genuinely demands an “all hands on deck” approach.

**Challenges**

Creating the necessary agricultural technologies and harnessing them to enable developing countries to adapt their agricultural systems to a changing climate will require innovations in policy and institutions at multiple levels. Impediments to the development, diffusion, and use of relevant technologies can surface in several places, from the inception and innovation stages, to the transfer of technologies and the access to agricultural innovations by vulnerable smallholders in developing countries.

Potential constraints to innovation involve both the private and public sectors in both developing and developed countries. While the Consultative Group for International Agricultural Research (CGIAR) has been invaluable to developing countries as a source of agricultural innovation for nearly 40 years, many countries have a long history of large, direct government intervention in both input and output markets in agriculture that have stifled the formation of vibrant private firms and accompanying incentives to innovate.

The process of transferring agricultural innovations across agro-ecological and climatic zones is often subject to agronomic constraints. Agricultural biotechnology has relaxed some of these but it also raises a new set of potential impediments in the form of biotechnology regulations. Although intellectual property (IP) can also constrain technology transfer, it is almost never the most important barrier. Where IP seems to pose a problem, recent institutional and legal innovations provide a point of departure for effective remedies, including humanitarian use licensing, patent pools, and public-private partnership. Often, the most binding constraints occur at the adoption stage, with several factors potentially impeding poor farmers’ access to and use of new technologies. These include static, poorly functioning or poorly integrated input or output markets; weak local institutions and infrastructure; inadequate or ineffective extension systems; as well as missing credit and insurance markets.

**Policy principles and priorities**

Several policy principles and priorities could facilitate climate change mitigation and adaptation in poor countries by improving the innovation and diffusion of important agricultural technologies. We have advocated for the following six policy principles. In the first instance the best policy and institutional responses will enhance information flows, incentives, and flexibility. Secondly policies and institutions that promote economic development and reduce poverty will often improve agricultural adaptation and may also pave the way for more effective climate change mitigation through agriculture. Third, business as usual among the world’s poor is not sufficient.

Fourth, existing technology options must be made more available and accessible, without overlooking complementary capacity and investments. Fifth, adaptation and mitigation in agriculture will require local responses, but effective policy responses must also reflect global impacts and inter-linkages. Finally, trade will play a critical role in both mitigation and adaptation, and will itself be shaped by climate change.

Climate change will affect the global pattern of comparative advantage and attempts to block the force of global markets would be costly and counterproductive. Shifts of regional comparative advantage and movement of people out of agriculture defines world history. Wealthy nations such as Norway or Japan can support a few million globally non-competitive farmers, but such an approach cannot be successful for hundreds of millions of small farmers in poor countries. Thus, when considering both adaptation and migration, global agricultural responses must be at the centre of the analysis.

These six principles lead to several specific investments and policy priorities. It will be important to invest in public agricultural research and development (R&D) in developed countries, as these are the major global engine of agricultural productivity and in turn lowering food prices for the poor, according to the World Bank. Simultaneously, new crop and trait combinations will be required to meet demands for global food security, while at the same time coping with or even mitigating climate change. Policymakers must fund and improve public agricultural research capacity in poor countries, especially those facing severe climate change. Multilateral and bilateral investments must target countries where these reforms and long-term commitments are feasible. However, the important role for the public sector R&D does not preclude a vital role for profit-driven private sector R&D in developing countries, and each part of the whole has a distinct role to play. Policy should appreciate, leverage, and create complementarities between agricultural R&D in rich and poor countries and between that emerging from public and private sectors.

Agriculture biotechnology use and trade regulations must also be sufficiently flexible that they do not discourage the transfer or adoption of locally important innovations. Policy options related to this flexibility may relate to the protection of intellectual property (IP), including continued work to negotiate appropriate humanitarian use exemptions and preferential treatment.

While governments may be able to help make privately-owned technologies more widely available and accessible by modifying IP rules and taking advantage of the flexibilities provided by international deals such as the WTO's Trade-related aspects of Intellectual Property Rights (TRIPs) Agreement, public-private partnerships, and other institutional arrangements may be even more effective in some cases. However, although support for agricultural biotechnology as an important option in the coming decades of challenging adaptation in agriculture is growing, but GM food remains a deeply divisive topic among some groups of producers and consumers around the world.

Policies and institutions that encourage the development of competitive and responsive input and output markets in agriculture should take on added urgency in the face of climate change. Appropriate responses to new climate conditions or even seasonal weather forecasts require the ability to make efficient production and adjustments in response to these changing conditions. The single best gauge of efficiency when making these adjustments is provided by price signals in functional markets. Market rigidities from government price policies, parastatal restrictions, and dominant buyers – which may be local co-operatives – all limit the ability of farmers and others to adapt and adjust.

**Towards sustainable development**

Agriculture has a crucial and unique relationship with climate as well as a crucial and unique role in economic development. It is our primary source of food and important raw materials, has significant potential for mitigation of global GHG emissions, and is particularly sensitive to climate change. Innovations in agriculture have always been important and will be even more vital in the context of climate change. Thoughtful policy responses that encourage the development and diffusion of appropriate agricultural technologies will be crucial to enabling an effective technological response. These policy and institutional responses are particularly critical as they can provide a pathway for steady progress towards climate mitigation and adaptation. Whereas short-term climate variability demands, and deservedly gets our attention, adapting to longer-term changes requires vision and discipline. A careful balance of institutional change and wise investment is required to deal with both the demands of climate change and the opportunities for the poor to continue improving their lives.

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[Ref 1] Barfoot P, Brookes G (2014), Key global environmental impacts of genetically modified (GM) crop use 1996-2012, in GM Crops and Food: Biotechnology in Agriculture and the Food Chain 2014 5, Issue 2: 149-160.

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