DEC

Climate Change Research by Development Economics

Impacts and Adaptation Strategies for African Agriculture

Research at the World Bank on climate change and agriculture has gained momentum in recent years, recognizing both the important role agriculture plays in the economies and the livelihoods of the poor in developing countries, as well as the vulnerability of the agricultural sector to climate change. Major research efforts have been focusing on the agricultural sectors of India, Africa, Latin America, and China.

Much of this research has been carried out by the Development Economics Research Group (DECRG) (see *Box*). This article focuses on recent research dealing with the impact of climate change on African agriculture.

A Focus on Africa

Even without climate change, African agriculture faces serious challenges—land degradation, high rainfall variability, lack of storage infrastructure, inadequate irrigation systems, and a relatively stagnant contribution to economic growth. In addition, many rural areas in Africa also must deal with rural-to-urban migration, political instability, persistent poverty, and a high disease burden. Agriculture and agro-ecological systems are the most vulnerable sectors in Africa because the climates of many African countries are already hot and variable. Climate warming is expected to further reduce crop productivity. Additional constraints include low technological progress and a lack of access to information on how to cope with climate change.

Research addressing the potential impact of climate change on the agriculture sector in 11 African countries suggests that much of the continent will be hit hard by climate change under various scenarios. Large re-

Recent Resarch on Climate Change in The World Bank's Development Research Group

Within the Bank, the research work program in the Development Economics Research Group covers issues of impact incidence; adaptation in agriculture; incentive systems to reduce pollution and greenhouse gas emissions; investment in clean energy mechanisms; mitigation, adaptation, and growth; water resources; transportation; and hydropower. Important recent studies include the following:

- Adaptation in developing countries
- Barriers to expanding access to cleaner electricity in Africa
- Carbon-related issues and research
- Climate change and agriculture
- Climate change and economic growth
- Climate sustainability of hydropower-based energy generation treaties
- Country stakes in climate change negotiations
- Economic and policy aspects of bio-energy/biofuel production and use
- Economics of energy consumption and pollution emission in large cities
- Government policies, monetary incentives, effects on adoption of energy-efficient technologies
- Impact of and adaptation to climate change in agriculture in Africa and South America
- Impact of and adaptation to climate change in agro-ecological zones in Africa
- Impact of sea level rise on developing countries
- Measures to increase energy efficiency in transportation systems in India
- Reducing vulnerability—adaptation to climate variability and change
- Role of flexible mechanisms in reducing greenhouse gases
- Role of markets in directing investments under the Kyoto Protocol

gions of marginal agriculture in Africa may be forced out of production by 2100, while others may thrive. Some countries are more vulnerable than others, so it is important to focus help where it is needed most. In several scenarios, many African farmers gain, whereas others lose.

The study, funded through the Impact of and Adaptation to Climate Change in Africa project, was supported by the Global Environment Facility, the World Bank, the Office for Global Programs of the U.S. National Oceanic and Atmospheric Administration, the Center for Environmental Economics and Policy in Africa, and others. Many of the results have been published in a number of World Bank reports, which are listed under selected references at the end of this article. DECRG has played an important role in this research effort.

The study was intended to provide empirical evidence on the role that climate plays in agriculture in Africa today, how that might change with global warming, and what role adaptation could play. The following countries were included in the study: Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Niger, Senegal, South Africa, Zambia, and Zimbabwe. (The project website is at http://www.ceepa.co.za/Climate_Change/index.html).

The research effort integrated socioeconomic household surveys, climatic and soil data across key agro-climatic zones and farming systems (cross-sectional modeling), and river-basin hydrological modeling. Cross-sectional models allowed quantitative estimates of the economic impact of climate change in sampled locations in each country. For these models, baseline data for climate, agricultural production, and water flow were collected for each sampled district in each country.

Pulling observations from across the continent permitted region-wide analyses with extrapolations to any location in Africa, assuming comparable country settings. Two types of analyses were conducted: (1) an estimate of marginal impact using only the cross-sectional coefficients, and (2) an analysis involving predicted climate scenarios, which provided more comprehensive estimates of impact. Within these two approaches, the first assumed a uniform change across the country, and the second involved specific climate scenarios from global circulation models (GCMs), accounting for within-country variability. Three different GCM scenarios by 2100 explored the consequences of a range of climate changes considered plausible by climate scientists.

Study Results

Results predict a number of significant impacts in Africa, including heightened impacts on streamflow after 2050, differing marginal impacts of temperature and precipitation on net farm revenues, stronger positive/negative impacts on rainfed farms, and differing effects on large and small livestock farms.

Heightened impacts on streamflow after 2050. The range of possible Africa-wide climate change impacts on streamflow (by countries) increases significantly between 2050 and 2100.

Implications of crop choice. There is an optimal precipitation and temperature range for each crop within which production value is maximized. Farmers can reduce crop and livestock sensitivity to climate variables through the choice of species and by introducing new technologies and management practices. Better-equipped farmers can adapt to and survive change in climatic conditions more easily with increased levels of technology, which can help widen the temperature range for crop growth and make water supplies less dependent on short-term fluctuations in precipitation

Differing marginal impact of temperature and precipitation on net farm revenues. For rainfed farms, evaluated at their mean temperature, net revenues fall by an average of $27/°C. In contrast, the marginal effect of temperature on irrigated farms, evaluated at their mean temperature, is a positive $35/°C. Assuming a given availability of water and present level of soil quality, warmer temperatures increase the net revenues of irrigated farms because the mean temperature in regions with irrigated farms in the countries included in the study is relatively cool and because irrigation buffers net revenues from temperature effects such as evapotranspiration.

In uniform climate change impact scenarios for Africa (2.5° and 5°C temperature increase and 7 and 14 percent precipitation decrease by 2100), values per hectare and the total Africa impact suggest a big loss for rain-

Net revenue impacts from uniform climate scenarios

Impacts			Warming increase of 2.5°C	Warming increase of 5°C	Precipitation decrease of 7%	Precipitation decrease of 14%
Rainfed						
ΔNet ($ per ha)		revenue	–72.2 (–16%)	–120.4 (–30%)	–14.1 (–6%)	–28.3 (–11%)
ΔTotal (billions $)	net	revenue	–22.6	–37.7	–4.4	–8.9
Irrigated						
ΔNet ($ per ha)		revenue	110.3 (9%)	258.8 (23%)	–15.9 (–1.4%)	–31.5 (–2.7%)
ΔTotal (billions $)	net	revenue	1.4	3.4	–0.21	–0.41
Total (Africa)						
ΔNet ($ per ha)		revenue	–49.2 (–11.3%)	–95.7 (–21.9%)	–18.3 (–4.2%)	–37.2 (–8,5%)
ΔTotal (billions $)	net	revenue	–16.0	–31.2	–5.96	–12.1

Note: Values in parenthesis represent percentage changes from present climate.
Source: Kurukulasuriya and Mendelsohn 2007.

fed agriculture if temperature increases (see *Table* on page 59). However, assuming sufficient water availability, irrigated agriculture is likely to gain from rising temperatures.

Stronger positive/negative impacts on rainfed farms. Net revenues from crops will rise in a mild wet scenario by as much as $90 billion across Africa, while a very hot scenario could lead to losses of $48 billion by 2100.

Despite these aggregate impacts, irrigated farms are predicted to generally benefit because they are less climate-sensitive and located in relatively cool places. Rainfed farms are likely to be affected the most, whether in terms of benefits or losses.

Differing effects on large and small livestock farms. The results suggest that net revenues for small livestock farms increase with warming by 25 to 58 percent. The net revenues of large livestock owners, however, are expected to fall, except in a very dry scenario.

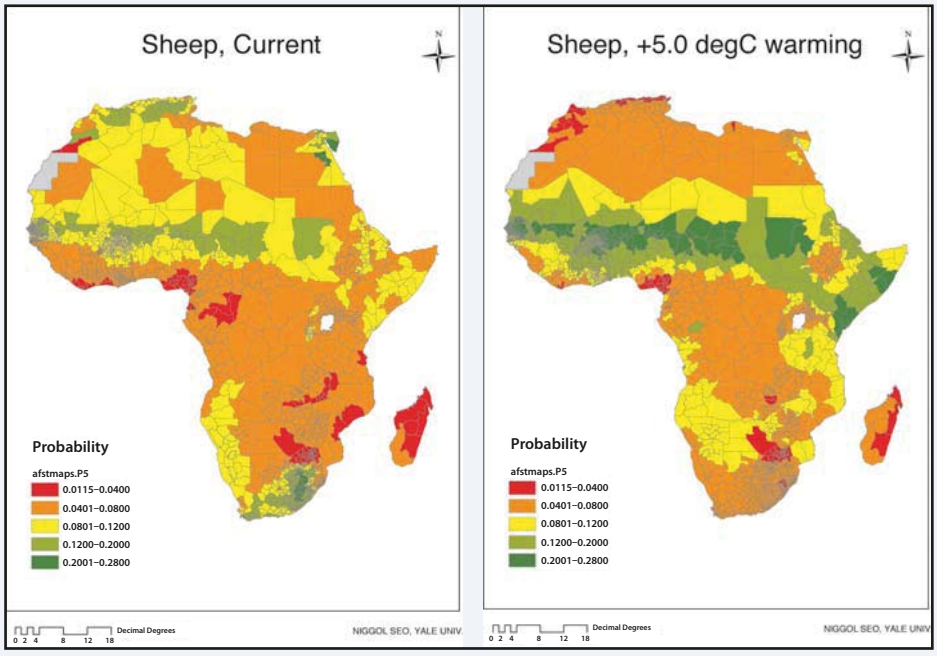
In general, small farms can more easily substitute animals that are heat-tolerant, whereas large farms are more dependent on species, such as cattle, that are less heat-tolerant. Wetter scenarios imply a shift from grasslands to forests, an increase in harmful disease vectors, and a shift from livestock to crops.

Overall, the livestock sector in Africa loses from climate change, because most animals are raised on large farms. While livestock earnings for small farmers increase with warming, these gains are generally smaller than the losses they face from crops. Still, the analysis suggests that under certain future climate change scenarios livestock may become more attractive than crops in many regions in Africa.

Possible Adaptation Strategies

The study highlights the importance of equipping millions of agriculture-dependent and water-deprived Africans in the most vulnerable countries with the information, technologies, and supporting institutions they need to adapt to further climate deterioration.

Change in the probability of choosing sheep in Africa with a uniform temperature increase of 5˚C



Source: Seo and Mendelsohn 2007.

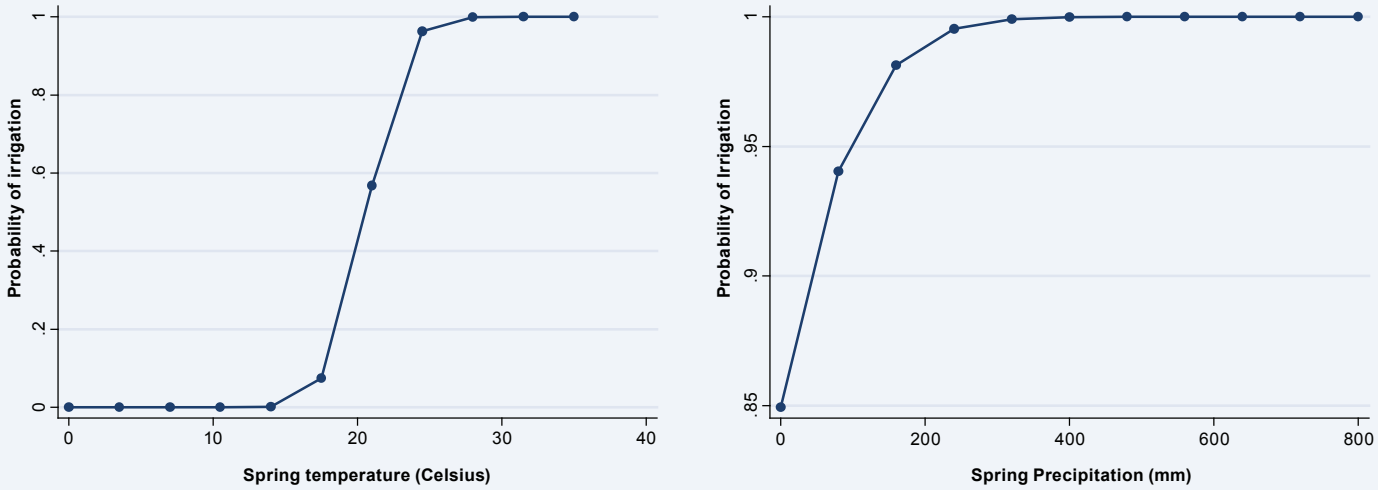
The results strongly suggest that adaptation policies to climate change must take into account crop selection, improved livestock management, and promoting irrigation where surface water is available.

Crop selection. There is an important role for agronomic research in developing new varieties more suited for higher temperatures. Although income from agriculture in Africa will still suffer losses, these will be much smaller if farmers are not confined to their current set of options.

Importance of improved livestock management. The model results predict that managing livestock in Africa is likely to be relatively more profitable than crops under certain future climate conditions. This, on the other hand, could lead to overstocking of rangeland and increased land degradation, which has not been addressed in the research so far. Furthermore, the species mix of livestock chosen is likely to be slightly different than today. Farmers just south of the Sahara are predicted to switch species, diversify their portfolio, and move from cattle toward sheep. Small farmers may be able to adapt without much change in expected net income, but large sheep farmers in South Africa may have to abandon sheep, as the area suitable for sheep farming will shrink as climate changes (see *Figure,* at left). These changes are predicted to reduce the net incomes of large farms considerably.

Promoting irrigation where surface water is available. Irrigation is an effective adaptation strategy against reduction in rainfall. However, for many regions, there is no available surface or groundwater and a lack of storage infrastructure, so warming scenarios with reduced rainfall are particularly deleterious. Furthermore, policy makers have to address the fact that many farmers in Africa have limited experience and hence capacity to deal with irrigation. Conducive policies include marketing policies and access to markets. Policy makers also should consider

Probability of Adopting Irrigation Based on Temperature and Precipitation



Source: Kurululasuria and Mendelsohn 2007.

making resources available to allow the transition from rainfed to irrigated agriculture.

Future Work

Several of the results obtained in this study were based on assumptions that warrant further exploration. Some are based on analytical tools that can be improved.

For example, studying the relationship between climate change and surface and groundwater hydrology is a necessary condition for a more precise understanding of the possible role of irrigation in adapting to climate change (see *Figure*, above). While the study in Africa used a certain approach to assess the available runoff, there is certainly room for improvement in the methodology.

An analysis of the impact of climate change on the quality of soil—and therefore on the ability of farmers to adapt—is needed for a more precise analysis of adaptation options. One approach is to predict how present agro-ecological zones may shift as climate changes, mainly due to changes in soil quality. With additional information on water availability and soil quality, the set of options farmers face would change, which in turn would alter government interventions.

Any adaptation process necessitates experimentation and know-how. With a new cause that can be much better justified by economic cost/benefit figures, the role of public investment in research and extension may be reinvigorated. Future work in this direction would be extremely useful and would inform policy makers.

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For more information on the DECRG work program and the individual studies, see http://go.worldbank.org/K3KFKLUBH0.

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