focus F

Adaptation to and mitigation of climate change in agriculture

Climate change will have far-reaching consequences for agriculture that will disproportionately affect the poor. Greater risks of crop failures and livestock deaths are already imposing economic losses and undermining food security and they are likely to get far more severe as global warming continues. Adaptation measures are needed urgently to reduce the adverse impacts of climate change, facilitated by concerted international action and strategic country planning. As a major source of greenhouse gas (GHG) emissions, agriculture also has much untapped potential to reduce emissions through reduced deforestation and changes in land use and agricultural practices. But for this to be achieved, the current global carbon financing mechanism needs to change.

Impact of climate change

The impacts of climate change on agriculture could be devastating in many areas. Many regions already feel these impacts, which will get progressively more severe as mean temperatures rise and the climate becomes more variable (chapter 2).

Scientific evidence about the seriousness of the climate threat to agriculture is now unambiguous, but the exact magnitude is uncertain because of the complex interactions and feedback processes in the ecosystem and the economy. Five main factors will affect agricultural productivity: changes in temperature, precipitation, carbon dioxide (CO_2) fertilization, climate variability, and surface water runoff. Initially, rising atmospheric concentrations of carbon benefit crop growth and could offset yield losses from heat and water stress, but this "carbon fertilization" may be smaller in practice than previously estimated from experimental data.[1]

Under moderate to medium estimates of rising global temperatures (1–3°C), crop-climate models predict a small impact on global agricultural production because negative impacts in tropical and mostly developing countries are offset by gains in temperate and largely industrial countries.[2] In tropical countries even moderate warming (1°C for wheat and maize and 2°C for rice) can reduce yields significantly because many crops are already at the limit of their heat tolerance.

For temperature increases above 3°C, yield losses are expected to occur everywhere and be particularly severe in tropical regions. In parts of Africa, Asia, and Central America yields of wheat and maize could decline by around 20 to 40 percent as temperature rises by 3 to 4°C, even assuming farm-level adjustments to higher average temperatures.[3] With full CO_2 fertilization the losses would be about half as large.[4] Rice yields would also decline, though less than wheat and maize yields.

These are conservative estimates because they do not consider crop and livestock losses arising from more intense droughts and floods, changes in surface water runoff, and threshold effects in the response of crop growth to temperature changes.[5] Agriculture in low-lying areas in some developing countries would also be damaged by flooding and salinization caused by sea level rise and salt water intrusions in groundwater aquifers.[6] Less precipitation would reduce the availability of water for irrigation from surface and groundwater sources in some areas. Access to perennial surface water may be particularly vulnerable in semiarid regions, especially in parts of Africa and in irrigated areas dependent on glacial melt. Between 75 and 250 million people are expected to experience increased water stress in Africa.[7] In all affected regions, the poor will be disproportionately vulnerable to its effects because of their dependence on agriculture and their lower capacity to adapt.

Adapting to climate change

Adapting agricultural systems to climate change is urgent because its impact is already evident and the trends will continue even if emissions of GHG emissions are stabilized at current levels. Adaptation can substantially reduce the adverse economic impact.

Farmers are already adapting. According to recent survey data from 11 African countries, they are planting different varieties of the same crop, changing planting dates, and adapting practices to a shorter growing season.[8] But in some countries more than a third of all households that perceive greater climate variability or higher temperatures report no change in their agricultural practices. Barriers to adaptation vary by country, but for many the main reported barrier is the lack of credit or savings.[9] Farmers in Ethiopia, Kenya, and Senegal also point to the lack of access to water.[10]

In countries with severe resource constraints, farmers will not be able to adapt to climate change without outside help. And the poor will need additional help in adapting, especially where costs are higher.

The public sector can facilitate adaptation through such measures as crop and livestock insurance, safety nets, and research on and dissemination of flood-, heat-, and drought-resistant crops. New irrigation schemes in dryland farming areas are likely to be particularly effective, especially when combined with complementary reforms and better market access for high-value products.[11] But greater variability of rainfall and surface flows needs to be taken into account in the design of new irrigation schemes and the retrofitting of existing ones. The cost of modifying irrigation schemes, especially when those depend on glacial melt (as in the Andes, Nepal, and parts of China) or regulation of water flow by high-altitude wetlands, could run into millions if not billions of dollars.[12]

Better climate information is another potentially cost-effective way of adapting to climate change.[13] Consider an agrometeorological support program in Mali. Initiated in 1982 in response to the Sahelian drought, timely weather information and technical advice helped farmers better manage climate risk and reduce the economic impact of droughts.[14]

The greater uncertainty from climate change can be best addressed through contingency planning across sectors. Many of the Least Developed Countries are preparing National Adaptation Action Plans to identify immediate priorities to improve preparedness for climate change.[15] Mainstreaming climate change in the broader economic agenda, rather than taking a narrow agricultural perspective, will be crucial in implementing these plans.[16]

The costs of adapting to climate change—estimated at tens of billions of dollars in developing countries—far exceed the resources available, requiring significant transfers from industrial countries. Contributions to existing adaptation funds are $150 to $300 million a year.[17] The recently announced Nairobi Framework for adapting to climate change is a step in the right direction, but it is not expected to provide even a tenth of the required amounts. The international community needs to devise new mechanisms to provide a range of global public goods, including climate information and forecasting, research and development of crops adapted to new weather patterns, and techniques to reduce land degradation. Many of these measures are win-win, such as developing drought- and flood-tolerant varieties, improving climate information, or planning for hydrological variability in new irrigation investments. Because of the long time lag between the development of technologies and information systems and their adoption in the field, investments to support adaptation need to be developed now. Carbon taxes based on the polluter pays principle could be a major source of revenue for this.

Mitigating climate change through agriculture

Livestock and crops emit CO_2, methane, nitrous oxide, and other gases, making agriculture a major source of GHG emissions (figure F.1). According to the emissions inventories that governments submit to the United Nations Framework Convention on Climate Change, agriculture accounts for around 15 percent of global GHG emissions. Adding emissions from deforestation in developing countries (agriculture is the leading cause of deforestation), raises its global contribution to 26 and up to 35 percent of GHG emissions. Around 80 percent of total emissions from agriculture, including deforestation, are from developing countries (figure F.1).[18]

Agriculture contributes about half of the global emissions of two of the most potent noncarbon dioxide greenhouse gases: nitrous oxide and methane. Nitrous oxide emissions from soils (from fertilizer application and manures) and methane from enteric fermentation in livestock production each account for about one-third of agriculture's total noncarbon dioxide emissions and are projected to rise.[19] The rest of noncarbon dioxide emissions are from biomass burning, rice production, and manure management. Agriculture is also a major contributor of reduced carbon sequestration (storage) through land use change (e.g., the loss of soil organic matter in cropland and pastures, and forest conversion to agriculture), although quantitative estimates are uncertain.

Emissions of carbon dioxide from changes in agricultural land use can be reduced by slowing deforestation. And opportunities for this reduction through carbon trading are in principle quite large because of generally low returns from forest conversion to agricultural uses. At one extreme, conversion of forest to traditional pasture in Acre, Brazil, produces a net present value of future earnings of $2 per hectare in land value at a cost of a loss of 145 tons of sequestered carbon, or equivalent to less than $0.01 per ton of CO_2. The corresponding value for forest conversion to intensive cocoa plantations in Cameroon is $3 per ton of CO_2.[20] A price of around $27 per ton of CO_2 in carbon markets (comparable to the May 2007 trading price in the European Climate Exchange for 2008–10 carbon allowances) could deter conversion of 5 million square kilometers of forest by 2050.[21]

Other promising approaches are changes in agricultural land management (conservation tillage, agroforestry, and rehabilitation of degraded crop and pasture land), overall improvement of nutrition and genetics of ruminant livestock, storage and capture technologies for manure, and conversions of emissions into biogas. Many of these approaches have win-win outcomes in higher productivity, better management of natural resources, or the production of valuable by-products, such as bioenergy. Others require substantial investment at the global level, such as the development of low-emission rice varieties and livestock breeds. And it is not yet clear that they would be more cost-effective than alternatives to reduce GHG emissions by increasing efficiency in transport and power sectors.[22]

The public-good nature of research in this area warrants international support for innovative cost-effective solutions to reduce emissions from livestock and rice paddy fields, for example, by breeding low-emissions plant varieties and animal breeds and by using advanced biotechnologies. Agriculture might also reduce climate change through greater production of bioenergy for transport and power. Much depends on the total GHG emissions through the entire production cycle from the cultivation of feedstock crops to final use—which can negate much of the carbon sequestration from producing biofuels (see focus B).

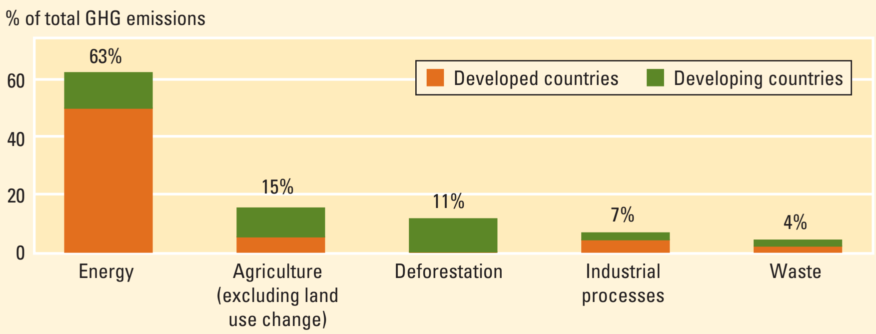
Carbon financing can support mitigation

The emerging market for trading carbon emissions offers new possibilities for agriculture to benefit from land uses that sequester carbon. The main obstacle to realizing broader benefits from the main mechanism for these payments—the Clean Development Mechanism (CDM) of the Kyoto Protocol—is its limited coverage of afforestation and reforestation (chapter 11). No incentives were included in the protocol for developing countries to preserve forests, despite the fact that deforestation contributes close to a fifth of global GHG emissions, largely through agricultural encroachment.

Negotiations for the period after 2012 should correct this major flaw. They could also explore credits for sequestration of carbon in soils (for example, through conservation tillage), for "green" biofuels, and for agroforestry in agricultural landscapes. Incentives are also needed for investment in science and technology for low-emission technologies, such as cattle breeds that emit less methane. Remote satellite sensing to monitor results on the ground is a promising new approach.[23]

For mitigation, a future climate treaty will need a better incentive structure to encourage full participation and compliance. For adaptation, because of an unfavorable distribution of benefits, the international community faces major challenges in obtaining the cooperation and financing of industrial countries, which do not see the direct benefits from contributing. But the manifestation of climate change is increasing the urgency and the will at the global level to tackle both adaptation and mitigation (chapter 11).

Figure F.1 Agriculture and the associated deforestation are major sources of GHG emissions



Source: WDR 2008 team based on data from the United Nations Framework Convention on Climate Change, www.unfccc.int.
Note: These are the latest available data for developing countries as a group, and consistent comparisons using UNFCCC data are possible only for 1994 data. There is a large range of uncertainty about gross emissions from land use change (mainly from deforestation). The best estimate of the contribution of emissions from land use change to total emissions is 20 percent (with a range from 10 to 30 percent) of total global emissions during the 1990s (Watson and others 2000). The UNFCCC estimate of total emissions from deforestation based on emissions inventories as reported by developing countries (11.4 percent) is a low-range estimate.