



CHAPTER 7
Agriculture and Rural Sector

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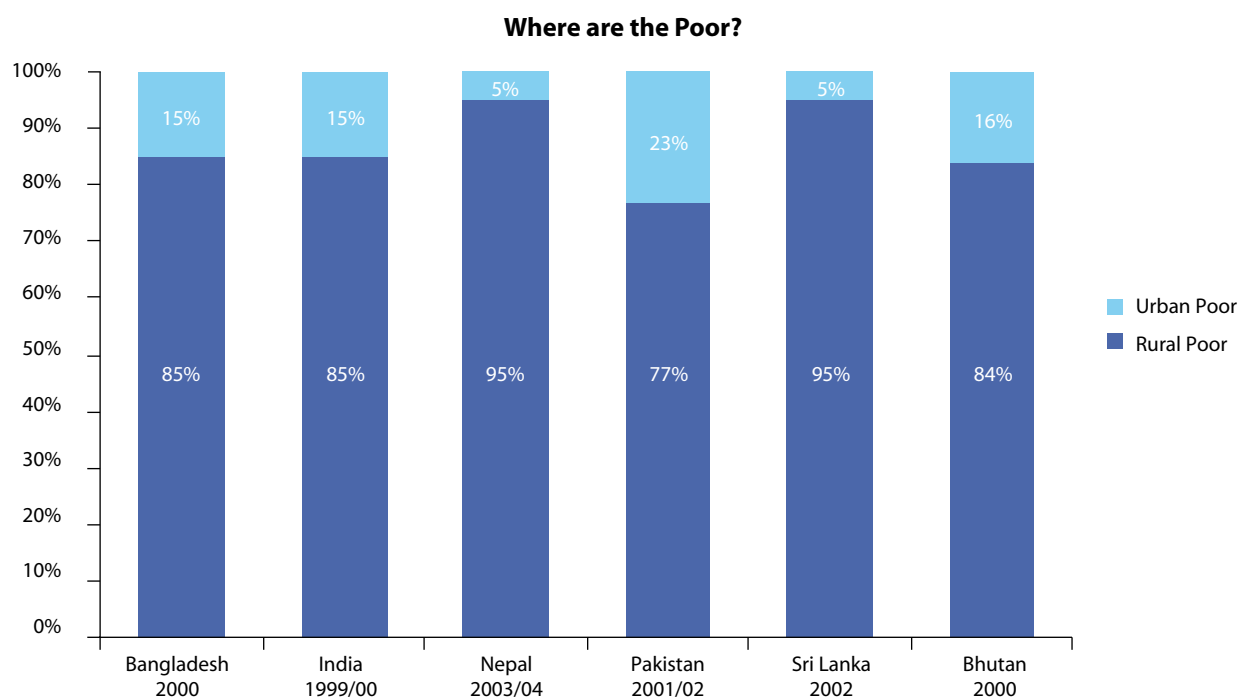
Agriculture is critical to South Asia's development. Rural areas in the region are home to more than 70 percent of its population, and agriculture is the region's principal occupation, employing more than 60 percent of the labor force. More than 75 percent of the region's poor live in rural areas (Figure 7.1) and depend on rainfed agriculture, livestock, and fragile forests for their livelihoods. Agricultural and rural nonfarm growth will be critical to reaching the Millennium Development Goal of halving the number of poor people by 2015. Meeting this challenge calls for growth that stems from agricultural productivity and raises the incomes of small-scale farmers and landless laborers. The Green Revolution of the 1970s and 1980s substantially increased food grain productivity and improved food security and rural wages. Consequently, those dramatic leaps in agricultural production raised farmer incomes, bringing a significant reduction in rural poverty. In India, for example, the rural poverty rate declined from about 53 percent in 1977/1978 to 26 percent in 1999/2000. The challenge is to replicate and sustain these achievements during the future with a more variable and unpredictable climate.

The growth of agricultural productivity has slowed down and the sector now languishes behind the other dynamic growth drivers in the region. Per capita growth in agricultural productivity in South Asia (less than 2 percent) has barely kept pace with population growth; it is also lower than that of East Asia and the Pacific (3.1 percent) and Latin America (2.8 percent). Several problems have emerged that have constrained growth: deteriorating soil fertility and declining quality of inputs such as seeds, fertilizers, and pesticides; reduced water availability; lack of access to credit; suboptimal farming practices; and lack of investment in new technologies. As a result, there is a large gap between actual yields and technologically feasible yields.

While there are many impediments to agricultural growth in South Asia, the one that threatens the economy most is the rapidly deteriorating water situation. Many parts of South Asia face growing water scarcity due to increasing water demands driven by high population growth, urbanization, agricultural needs, and industrial growth. This situation poses a particular threat to agriculture, which uses the largest share of the water consumed in South Asia. Recent work in India, for instance, demonstrates that many of the major river basins in the country will face a water deficit in the future

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Figure 7.1 Breakdown of Poverty (Rural/Urban) by Country



Source: World Bank calculations. Data for Afghanistan and Maldives were not available

by 2050 (Garg and Hassan 2007). This increased pressure on water availability, combined with increasing land and soil degradation, makes rational and efficient utilization of water, and related policy options that promote economic and environmental sustainability of water use, essential to long-term food security in South Asia. The problem is further compounded by the nature of small and marginal landholdings, which are characterized by highly unequal ownership of and access to productive assets such as land and water. Moreover, new challenging demands are being placed on the agricultural sector that add pressure to an already strained sector. These include compliance with sanitary and phytosanitary standards; meeting the growth needs of the biofuels industry; and addressing emerging health epidemics linked to the sector (e.g., avian flu). Addressing these challenges is important to reversing the prolonged slowdown in the agricultural sector, which is in turn essential for inclusive growth.

Climate Variability and Change

Climate change poses a particular challenge to the agricultural sector. Of all potential impacts stemming from climate change, those to the agricultural sector stand out as among the most important. Long-term changes in temperatures and precipitation have direct implications on evaporative demands and agricultural yields. It is true that, in some areas, some reduction in yields may be offset by carbon fertilization and increased precipitation (Box 7.1). However, this opportunity is likely to be limited in scope and only applicable to certain species. A large portion of the population in the region is already vulnerable to a range of natural hazards and extreme weather events (e.g., floods or droughts). The changing hydrological characteristics of these extreme events, in relation to the onset, duration, and magnitude of the yearly monsoon season, will affect agricultural production significantly. The combined effects could be

Box 7.1 Carbon Fertilization Effects

The extent to which increased carbon dioxide levels in the atmosphere may actually improve crop yields (“carbon fertilization”) is a subject of current interest. Much of the debate is focused on the different ways plants fix carbon dioxide. C3 crops, which include rice, wheat, soybeans, fine grains, legumes, and most trees, benefit substantially from increased carbon dioxide levels; C4 crops, which include maize, millet, sorghum, and sugarcane, benefit much less.

Recent research based on experiments using the free air concentration enrichment method, which involves pumping carbon dioxide into the open air surrounding crops grown in fields (to simulate more realistic conditions than previous closed-condition studies), suggests that past estimates of the carbon fertilization effect may have been substantially overstated (Long et al. 2005). Elevation of carbon dioxide levels to 550 to 575 parts per million (ppm) resulted in a yield increase of 11 percent for C3 crops and 7 percent for the world’s five major grain crops: maize, rice, sorghum, soybean, and wheat. This was about one-third to one-quarter of the effect modeled in a 2000 assessment for Europe and the United States by Darwin and Kennedy (2000).

devastating for tropical agriculture. In Bangladesh alone, between 1991 and 2000, 93 major natural disasters were recorded, with the agricultural sector suffering the bulk of the losses.⁵¹ Finally, sea-level rise could have important implications for the availability of land for agriculture. Inundation and changes in the sediment balance and salinity profile of coastal areas could affect large areas of fertile arable land across much of the region.

Climate change may stress rural livelihoods beyond agriculture alone. Climate-induced changes to resource flows (e.g., natural resources, water, biomass) can fundamentally affect the viability of the livelihoods of the rural poor. Resilience is typically low in rural areas as the existing asset base is weak (natural, human, physical, financial, social) and services provided by infrastructure and institutions are often insufficient. Thus, the rural poor are chronically vulnerable to climatic conditions beyond direct agriculture production impacts. This is especially true during natural disasters and in existing climate sensitive areas (e.g., drought-prone and flood-affected areas) where the ability to cope with current climate variability is low. The prospect of increasing climate risks underscores the importance of a more integrated and holistic approach to development in the rural areas. For instance, in addition to

traditional agriculture activities, including livestock and fisheries, supporting socioeconomic activities beyond agriculture are needed to promote livelihood diversification.

Costs of Climate Change in the Agricultural Sector

Measuring the precise economic impacts of climate change on agriculture is difficult because of uncertainty. First, the exact magnitude of impacts is uncertain because the complex biophysical interactions and feedback processes are poorly understood. Second, any assessment of climate impacts on the agricultural sector must be



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⁵¹ Emergency Events Database (EM-DAT: The OFDA/CRED International Disaster Database), <http://www.em-dat.net>.

Box 7.2 Food Price Crisis

The surge in global commodity prices of the past few years has presented a tremendous development challenge to South Asian countries. On a net basis South Asia is estimated to have suffered an income loss equivalent to some 9.6 percent of GDP between January 2003 and April 2008. Although much of the income loss resulted from the hike in petroleum prices, the surge in food prices between January 2007 and April 2008, especially of staple food—wheat and rice—has created a tremendous adverse social impact in South Asia. All countries have witnessed unprecedented surges in food prices, although India was largely able to limit this increase through a combination of timely interventions. Net food importing countries like Afghanistan, Sri Lanka, and Bangladesh have suffered the most from the food price crisis. The adverse effect of the rise in global commodity prices on macroeconomic balances has been substantial. South Asian countries have seen a sharp increase in fiscal deficits and a worsening in the balance of payments. Inflation has been hit badly. For the first time in decades countries have simultaneously experienced double digit inflation rates, exceeding 20 percent in Afghanistan, Pakistan, and Sri Lanka. Economic growth is showing signs of slowdown. The emerging global financial crisis is adding fuel to the fire, with further adverse consequences for macroeconomic balances and growth.

Source: Ahmed 2008.

undertaken against the background of a volatile global food supply and demand system (see Box 7.2 on food price crisis, for example) that is affected by changing socioeconomic conditions, such as population growth, increasing urbanization, changing patterns in consumption and trade, and technology development. These future socioeconomic uncertainties may in fact dominant most impact assessments.

Several approaches to assessing the impacts of climate change on crops are typical. Three common methods are (i) statistical assessments (termed neo-Ricardian models) that examine actual farmers' responses to climate variation; (ii) agronomic crop models that simulate plant growth and biophysical changes to the climate; and (iii) hybrid approaches that combine both elements (Cline 2007) (see Box 7.3).

Box 7.3 Approaches to Measuring Climate Impacts on Yields

The Ricardian approach makes use of cross-sectional data to capture the influence of climatic as well as economic and other factors on land values (or farm income). This technique implicitly captures the adaptation measures that farmers will adopt as the climate changes. Moreover, it is assumed that because farmer adaptations will be reflected in land values, the costs and benefits of adaptation are embedded in those values. This approach is used to generate estimates of farm performance across different climate conditions that can be used to infer the consequences of future climate change.

Alternatively, a crop model (or agronomic) approach can be used whereby models are calibrated from controlled field experiments that are designed to simulate climate events and different management regimes. Typically, these models assume that farmers do not respond to predictably changing conditions, nor do they learn from past experiences. As a result, estimates of the costs of adapting to climate change are often larger than those derived from Ricardian approaches.

The accompanying figure shows the impacts, by 2030, of climate change on yields of five major crops in the South Asia region, as a percentage change compared to current yields (Lobell et al. 2008). For each crop, the dark vertical line represents the middle value out of one hundred different model projections (range shown in yellow). The number in parentheses is an overall global ranking given to each crop based on its importance to food security, calculated by factoring in the number of malnourished people in the region and the percentage of calories they derive from the crop.

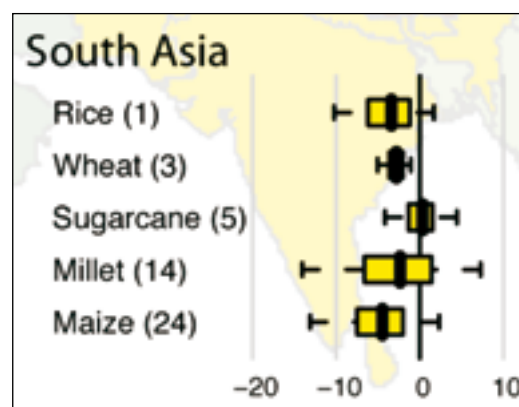


Table 7.1 Estimates of Climate-change-related Impacts on Agricultural Production by 2080 for Selected Countries in the South Asia Region

Country ^a	Farm Area (1,000 ha)	Output per Hectare (US\$) ^a	Output (US\$mil) ^b	% Change (Ricardian)	% Change (crop models)
Afghanistan	7,827	313	2,448	-9.5	-32.1
Bangladesh	8,429	1,355	11,421	-14.3	-25.3
India	170,115	777	132,140	-49.2	-27.0
Nepal	3,294	728	2,399	-0.9	-25.3
Pakistan	22,120	856	18,935	-17.9	-36.6
Sri Lanka	1,916	1,808	3,465	-9.5	-25.3

Source: Cline 2007

Note: Estimates are based on the A2 scenario of the Special Report on Emission Scenarios (SRES) (Nakicenovic and Swart 2000) and a rough average increase in temperature of 3.3°C.

a. Bhutan and Maldives are too small to be resolved with climate data at a 0.5 x 0.5 degree resolution.

b. At 2003 price levels.

There is a strong consensus that climate change is likely to have severe consequences on the agricultural sector and the rural poor in South Asia. Using a range of different approaches, Cline (2007) estimated broad impacts for a number of South Asian countries. The estimates vary substantially, from as little as a 1 percent loss of agricultural revenues in Nepal to a dramatic 49 percent decline in average revenue in India by 2080 (Table 7.1).

These estimated changes do not consider crop losses arising from more intense droughts and

floods; changes in surface water availability; or threshold effects in the response of crop growth to temperature changes. Nor do they take into account that, for agriculture that is being practiced in low-lying coastal areas (e.g., Bangladesh, and the Mahanadi delta in India), there is also potential for damage arising from sea-level rise and increased saltwater intrusion in groundwater aquifers.

More precise estimates are available for select countries in South Asia and are described in the following subsections.

India

Reflecting India's immense geographic diversity, the projected impacts of climate change on crop yields vary by region. In arid locations where crops already suffer heat stress, a small increase in temperatures could lead to a dramatic decline in yields. The same temperature increase in, say, the cooler Himalayas could generate an increase in yields. Accordingly, agronomic models project a wide range of impacts that vary by location and climate scenario.⁵² Table 7.2 and Table 7.3 summarize

⁵² For instance, the yield impacts for rice vary from increases of 22 percent in western India to a reduction of 20 percent in the country's drier central belt.



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Table 7.2 Results of Ricardian Assessments for Selected Crops in India

Temperature Change	% Change (net agricultural revenue per hectare)	Source
2°C	-3 to -6	Sanghi, Mendelsohn, and Dinar 1998
2°C	-7 to -9	Kumar and Parikh 1998
2°C	-8	Kumar and Parikh 2001
3.5°C	-20 to -26	Kumar and Parikh 1998
3.5°C	-3 to -8	Sanghi, Mendelsohn, and Dinar 1998

the results from studies that have measured the resulting economic losses using the statistical (Ricardian) approach and the agronomic crop model approach(es), respectively. The Ricardian models suggest that a temperature increase of 2°C would generate a modest loss of between 3 and 9 percent of current agricultural income (net revenue per hectare). However, for a 3°C rise in temperature, the studies predict a wide range of

losses from 3 to 26 percent of income. The estimates are broad and approximate averages need to be treated with caution. In the case of studies that utilize agronomic models, the results also show considerable variation. A general trend that can be ascertained is that increases in temperature greater than 2°C cause higher reductions in yields, which are further exacerbated if rainfall is not increased or is reduced.

Table 7.3 Results of Agronomic Assessments for Crops in India

Crop	Yield Change (%)	Scenario	Model
<i>Lal et al. 1998: northwest India</i>			
Rice	0	+2°C; doubling CO2	CERES-Rice
	-20	+2°C; doubling CO2; water shortage	
Wheat	0	+3°C; doubling CO2	CERES-Wheat
<i>Lal et al. 1999: Madhya Pradesh</i>			
Soybean	From -4 to 0	+3°C; doubling CO2; -10% daily rainfall	CROPGRO
<i>Saseendran et al. 2000: Kerala</i>			
Rice	-6	+1.5°C	CERES-Rice
	+12	+1.5°C; +2 mm/day rainfall; 460 ppm CO2	
<i>Aggarwal and Mall 2002: parts of northern, eastern, southern, and western India^a</i>			
Rice	From +3.5 to +4.3 (2010) From +13.8 to +22.3 (2070)	Optimistic IPCC scenarios: +0.1°C, 416 ppm CO2; +0.4°C, 755 ppm CO2. Both at current crop management level ^b	CERES-Rice
	From +1.3 to +1.9 (2010) From +3.6 to +9 (2070)	Pessimistic IPCC scenarios: +0.3°C, 397 ppm CO2; +2°C, 605 ppm CO2. Both at current crop management level	
	From +5.1 to +7.4 (2010) From +16.6 to +25.7 (2070)	Optimistic IPCC scenarios	ORYZAIN
	From +2.5 to +4.1 (2010) From +6.1 to +16.8 (2070)	Pessimistic IPCC scenarios	
<i>Kalra et al. 2007: DEFRA study</i>			
Rice	-5 to -8	+1°C; no change in CO2	CERES-Rice
	-10 to -16	+2°C; no change in CO2	
	-21 to -30	+4°C	

Crop	Yield Change (%)	Scenario	Model
Maize	-10 to -30	+1°C to +4°C; 350 ppm CO2	CERES-Maize
Jowar	-7	+1°C	CERES-Sorghum
	-12	+2°C ^c	
World Bank 2006a			
Rice	-9	Max. temp. +2°C; min. temp. +4°C; annual rainy days -5%; 550 ppm CO2	EPIC
Groundnut	+2		
Jowar	+3		
Sunflower	+10		
Maize	+3		
Rice	-8	Max. temp. +2°C; min. temp. +4°C; annual rainy days -5%; 550 ppm CO2; cumulative monsoon rainfall (Jun–Sept) -10%	
Groundnut	0		
Jowar	0		
Sunflower	+9		
Maize	0		

- Margin of error can be as much as 32 percent, depending on the uncertainty in climate-change scenario and other factors. Sensitivity analyses were run for increases in temperature, level of nutrients fed to the crops, and variations in CO2 levels. These showed that, as long as temperature remains unchanged and CO2 levels increase, yields will increase. However, with temperature increases, this CO2 effect is nullified for increases in temperature as low as 0.9°C.
- “Current crop management level” assumes no change in current nutrient application and irrigation.
- Further increases in temperature resulted always in lower yields irrespective of increases in CO2. The beneficial effect of additional CO2 up to 700 ppm was nullified by an increase of only 0.9°C.

Bangladesh

Bangladesh is especially vulnerable to climate change and natural disasters. Cyclones, storm surges, floods, and coastal erosion are frequent occurrences in Bangladesh. It is ranked as one of the most natural-disaster-prone countries on the planet, due to the frequency of extreme climate events and its high population density (World Bank 2005). In most years between 20 to 30 percent of the country’s area is affected by floods. The huge sediment loads carried by three Himalayan rivers, coupled with drainage congestion problems, exacerbate the extent of flooding. Climate change is projected to increase the intensity and frequency of natural disasters and to cause changes in agricultural yields, with potentially severe implications for rural poverty. The majority of assessments predict a decline in rice yields. For instance, Karim et al. (1999) anticipate a 17 percent decline in overall rice production and a decline as high as 60 percent in wheat production, compared to the baseline

situation (1994/1995). Wheat and *aus* varieties of rice showed the highest yield impacts. Crop-modeling results also suggest that the duration of the growing season could decrease by 2 to 12 days, which may delay the *aman* transplantation (which occurs in December and January). Moisture stress during lean times may also further contribute to a reduction in the yields of *boro* rice (March to May).

Floods (more intense or longer than normal) can also significantly affect agricultural production.

The 1998 flood, for example, caused a 45 percent reduction in agricultural production that year. Moreover, the *aman* production potential of about 2 to 2.3 million hectares could not be realized due to those floods, which lasted 67 days (FAO 1998). As seedlings could not be planted in the flood-affected areas, the resulting estimated shortfall of food-grain production exceeded 3.5 million metric tons. Higher discharge and low drainage capacity, in combination with increased backwater effects, would increase the frequency of such devastating

floods. Calculation of the economic costs of recent extraordinary flood events (1998 and 2004) have shown that much of the total economic losses are attributable to the agricultural sector (almost US\$700 million in 2004 and affecting almost 5 million families or 42 percent of all farm families) (Karim et al. 1999). Sea-level rise would also impact agriculture, but the consequences are poorly understood. Tentative estimates indicate that the loss of food-grain production due to soil salinity intrusion from sea-level rise in the coastal districts could be as much as 40 percent.

Sri Lanka

There is much uncertainty about the likely impacts of climate change in Sri Lanka and assessments are sparse. A recent study by Ajwad et al. (2004) uses the statistical (Ricardian) approach to estimate the impacts of climate change on the smallholder agricultural sector in the country. The effect of predicted climate change depends on the scenario used. With mild warming and a large increase in precipitation, net revenue per hectare is projected to increase by 22 percent. On the other hand, with medium warming and only a small increase in precipitation, losses of 23 percent are projected. These impacts are, however, highly location-specific (Figure 7.2). The wet, high-elevation areas are expected to benefit from climate change, while the hot, dry northwestern and southeastern lowlands will be adversely affected. Changes in precipitation are expected to have more impact than temperature changes, especially during key agricultural production months.

Adaptation in the Agricultural Sector

It is in the context of these potential economic consequences that adaptation measures are needed urgently to reduce the likely adverse impacts stemming from climate change. Many communities in the South Asia region already face extreme climate variability, both annually

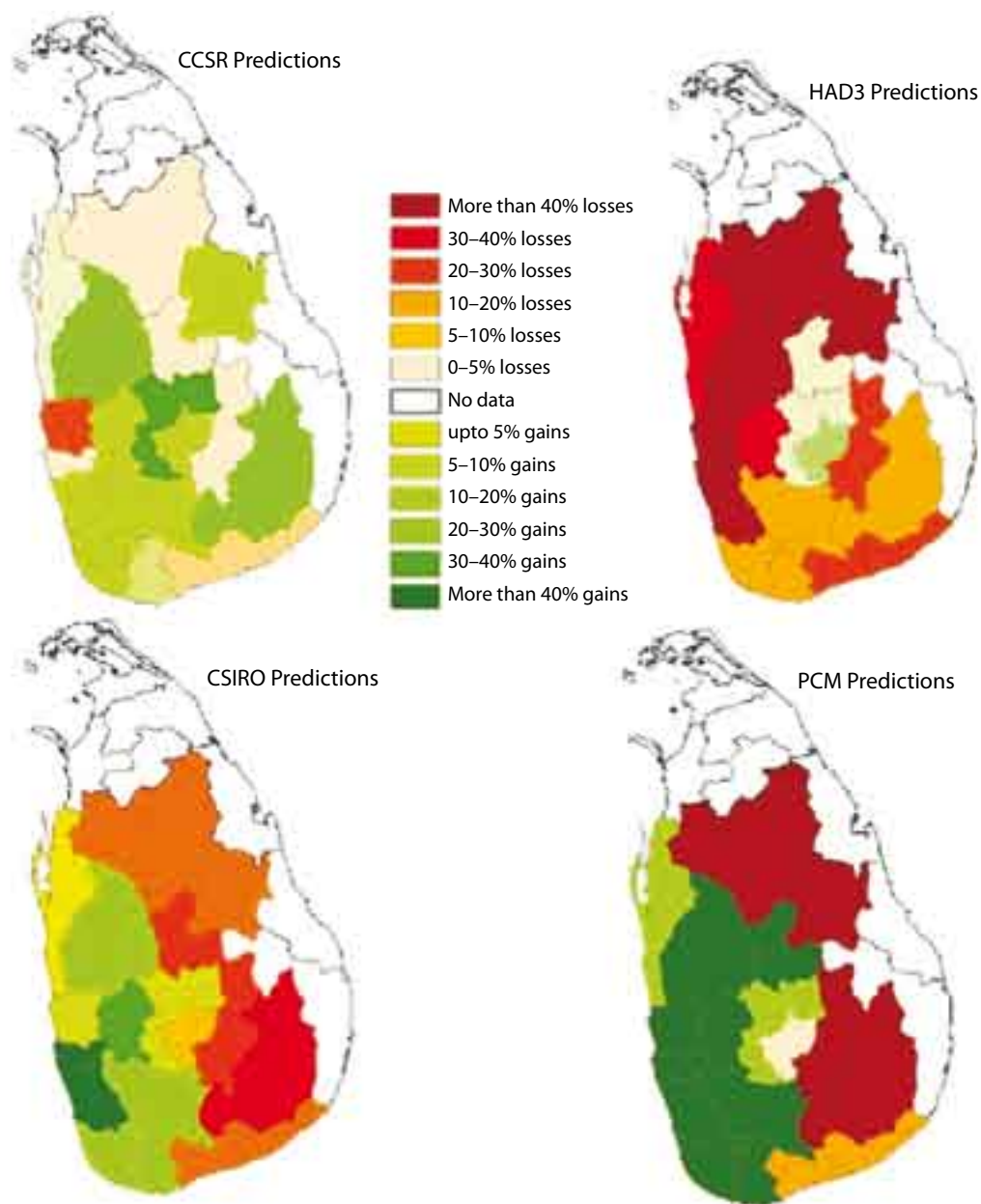
(floods and droughts) and in the longer term (El Niño events, long-term shifts in mean climate parameters). Current agricultural systems are often poorly equipped to deal with climate variability. If agricultural communities can be made more resilient to current climate risks, they will be better prepared to face future climate risks.

Many different adaptation practices are possible. In some cases, farmers are already adapting by planting resilient crop varieties, changing planting dates, and adapting farming practices to a shorter growing season. In other cases, however, there exist large barriers to adaptation, often related to policy shortcomings and resource constraints. Examples include price controls that promote water-intensive cropping in arid areas; input (e.g., power supply) subsidies that encourage over-abstraction of groundwater; poor irrigation practices; lack of credit or savings; weak extension services; lack of access to improved seeds and inputs; and inadequate agricultural research and technology. Thus, the public sector can facilitate adaptation through improved policy measures such as crop and livestock insurance, social safety nets, research on and dissemination of flood, heat, and drought-resistance crops, including conservation of traditional plant varieties with those characteristics, and in some instances support to new irrigation schemes.

Climate change increases the urgency for implementing measures that are needed to ignite agricultural growth in the region and address rural poverty. In this respect, the region's priorities lie in four core areas:

- a. **Research on and dissemination of climate-resilient agriculture:** New climate-resilient agricultural technologies are increasingly complex, knowledge intensive, and location specific. They require considerable investment in research and sophisticated systems of extension and dissemination. The Bank and its partners can play a key role in encouraging

Figure 7.2 Sri Lanka: Distribution of Climate Impacts on Smallholder Agricultural Net Revenues per Hectare Based on Alternative Climate Scenarios



* Based on aggregating impacts at the household level North and Eastern Provinces excluded

Source: Ajwad et al. 2004 (reproduced with permission)

research and facilitating the adoption of climate-resilient technologies (e.g., drought-, pest-, and saline-resistant crop varieties). Biotechnology will also have an important role to play in developing new, more resilient varieties of crops.

b. Provision of better climate information through improved forecasting and early warning systems. With possible changes in the timing and magnitude of monsoon events, building human and technical capacity and community systems to better

prepare for and respond to the wide range of climate risks (e.g. floods, cyclones, droughts) will be critical to sustaining agricultural growth rates in the region and improving rural livelihoods. Although many different information channels exist for farmers, few of them are sufficiently customized that they are able to improve farmers' productivity and incomes. This will require the strengthening of existing agricultural extension services and other community dissemination means (e.g., information kiosks, community agroclimatic atlases) to provide farmers with improved access to real-time climate information. Improving information dissemination can also help to remove existing barriers to adaptation.

c. Improved water-resource management (further details described in chapter 4):

Adequate water provision presents the most serious challenge to agriculture. Water is becoming increasingly scarce as rising demand from agriculture and industry encounters the diminishing potential for the expansion of water supply. Climate change is projected to increase water scarcity through much of the region. In this context, policies

that improve water management and encourage prudent water use will help build more climate-resilient agricultural systems. In addition, irrigation systems in the region are often poorly maintained and rapidly deteriorating, thus accelerating water losses. A priority of the Bank could be to improve irrigation systems, create water storage systems, and increase access to water in dryland farming areas and areas vulnerable to recurrent droughts. In flood-prone areas, the priority is to facilitate improvements to drainage systems and flood protection works. Lastly, at the community level, introducing methods to conserve soil and water (e.g., lining canals, dry seeding of rice, furrow irrigation, zero tillage) will help to improve the productivity of increasingly scarce land and water resources.

d. Improvements in risk management: Due to the high degree of uncertainty about the future climate, new innovative financial mechanisms are required to protect the agricultural assets upon which so many depend. Strengthening current agricultural and weather insurance mechanisms will be critical. Along similar lines, mapping vulnerable areas and developing and implementing region-specific contingency plans, based on vulnerability and risk assessments, will help to better prepare communities for the challenges that lie ahead. With the advent of extreme climate events, having proper safety nets in place will be important for the protection of those who are most vulnerable.

Many of these measures may be effective at reducing climate risks, especially when combined with complementary reforms and better market access for high-value products. Finally, mainstreaming climate-change and climate-risk issues into the broader economic agenda, rather than taking a narrow agricultural view, will also be critical.



Michael Foley/World Bank

Adaptation and Mitigation Links

Agriculture is also a major source of greenhouse gas emissions.

Crops and livestock are large contributors to GHG emissions, primarily of methane and nitrous oxide. In India, for instance, of a total of 1,469 teragrams (Tg) of CO₂-equivalent greenhouse gases emitted in 2000, almost 13 percent came from livestock-related activities (including both CH₄ and N₂O contributions; these two gases represented 30 percent of total greenhouse gas emissions)⁵³ (Table 7.4). CH₄ emissions dominate in comparison to those of N₂O. With almost 300 million cattle and buffalo in the country,⁵⁴ livestock contributions to Indian emissions are significant; the negative balance of such emissions is also considerable, due to the generally low productivity and efficiency of

livestock farming in the country (and throughout much of the region).

Agriculture has much untapped potential to reduce such emissions through changes in land use and agricultural practices, and by reducing deforestation. The most promising area for reduction in methane emissions is in the livestock sector. Improving the diet of livestock can both improve their overall productivity (methane production currently results in a 5 to 15 percent loss of energy) and reduce methane emissions. Swamy and Bhattacharya (2006) find that feed conversion efficiency can be improved through (i) replacement of roughages with concentrates and a change in composition of concentrations; (ii) modification in feeding (e.g., alkali/ammonia treatment of low digestibility straws); and (iii) supplementation with molasses or urea nutrient blocks. If livestock manure is kept under aerobic conditions by turning regularly, methane emissions can also be reduced by as much as 30 to 40 percent.

Table 7.4 Contributors to Indian CO₂-equivalent Greenhouse Gas Emissions in 2000

Source categories	Main Emissions	% Share
Coal-based electricity	CO ₂	29.9
Steel industry	CO ₂	8.8
Cement industry	CO ₂	5.1
Livestock related	CH ₄ , N ₂ O	12.6
Paddy cultivation	CH ₄	6.6
Biomass consumption	CH ₄ , N ₂ O	5.2
Synthetic fertilizer use	N ₂ O	4.1
Transport sector	CO ₂	9.5
Waste disposal	CH ₄	3.8
Other sources	CO ₂ , CH ₄ , N ₂ O	14.4

Source: Garg and Shukla 2002

Emissions of carbon dioxide can be further reduced by slowing deforestation; through changes in agricultural land management such as conservation tillage, agroforestry, and rehabilitation of degraded crop and pasture land; utilizing storage and capture technologies for manure; and conversion of emissions into biogas. Opportunities through carbon trading are in principle quite large and offer new possibilities for agriculture to benefit from land uses that sequester carbon.

⁵³ In 2000, methane emissions were 18.6 Tg; NO₂ emissions were 0.308 Tg. Amounts are converted into equivalent CO₂ by multiplying by the global warming potentials of 21 and 310, respectively. That is, methane and NO₂ have a greater potential to warm compared to an equivalent mass of CO₂. Other contributors to methane and NO₂ emissions include rice paddy cultivation, municipal solid waste, and biomass burning.

⁵⁴ Based on livestock census data (1997).