

CHAPTER VI

Conclusions and Policy Recommendations

Introduction

This report reviewed the state of knowledge of, and undertaken highly innovative modeling analyses on, the predicted impacts of climate change on agriculture in Asia and to some extent the Pacific Islands together with potential strategies for adapting to and mitigating those impacts. This chapter briefly synthesizes the salient findings of Chapters I–V, discussing the severity of the impacts on agriculture and food security; agriculture’s contribution to greenhouse gas (GHG) emissions, adaptation and mitigation measures; and the various actors that have critical roles in mainstreaming and implementing climate change policies related to agriculture in Asia and the Pacific.

Agriculture’s Role in Asia and the Pacific

Agriculture is important for all of the Asian Development Bank’s developing member countries. More than 60% of the economically active population and their dependents—2.2 billion people—rely on agriculture for their livelihoods, but the weight of the sector’s importance varies significantly by subregion. In Central Asia, agriculture’s contribution to gross domestic product (GDP) has declined rapidly, with the exception of Turkmenistan. Similarly, agricultural GDP in East Asia has been declining and accounts for only 12% of GDP in the People’s Republic of China (PRC). Nevertheless,

nearly 64% of the economically active population in this subregion is employed in agriculture. Food security has been improving rapidly in East Asia overall, but 30% of Mongolia's population remains undernourished. Given significant land scarcity in the subregion, several countries—including the PRC and the Republic of Korea—have started to purchase or lease land for food production in other parts of Asia as well as in Africa, Eastern Europe, and Latin America. Agricultural GDP has also weakened in most countries in Southeast Asia, except in Cambodia and the Lao People's Democratic Republic (Lao PDR), where it still contributes 30% and over 40%, respectively. Undernourishment has been declining significantly in the Southeast Asia subregion to 18%, on average.

Unlike in Central, East, and Southeast Asia, the importance of agriculture to South Asia's GDP remains high, with only a slight decline from 1995 to 2006. As a result, employment in agriculture is also high, with close to 50% or more of the population employed in this sector (with the exception of the Maldives). The proportion of undernourished people averages over 20%, making South Asia the least food secure subregion both in Asia and the Pacific and in the world.

Data for the Pacific Islands on irrigated cropland, undernourishment, and the importance of agriculture in GDP are scarce. Data from Papua New Guinea, however, indicates that the share of agriculture in GDP has been rising, from 32% in 1995 to 42% of GDP in 2005. In addition, the proportion of the population employed in agriculture in the Pacific subregion averages close to 40%.

While agriculture is crucial for the region's food security and is the backbone of employment throughout Asia and the Pacific, farming systems vary significantly, ranging from the relatively dry

wheat-producing areas of Central Asia to the very wet rice-producing lands of Southeast Asia. Similarly, support for agriculture and agricultural technologies varies significantly across the countries.

Even without climate change, competition for land and water resources is high in many Asian and Pacific countries. Climate change will intensify the struggle for these natural resources, exacerbating challenges to their management in the region and increasing the risk of conflict. Central and South Asia are particularly prone to conflicts as a result of water and land scarcity.

Thus, while agriculture's contribution to GDP is declining in all subregions in Asia and the Pacific overall, large populations are still based in rural areas and depend on agriculture either directly or indirectly for employment and income. Poverty remains highest in rural areas, and the disparity between rural and urban incomes is widening. While agriculture's role has been declining in the overall economies of Asia, goals of (close to) food self-sufficiency have increased in importance, not least as a result of the recent food and financial crises. These crises have also reduced trust in open trading systems, prompting several Asian countries to revert to trade-distorting policies, including export restrictions. Establishing mechanisms to ensure that food can move in times of such crises, and reach the poorest populations, will be an important step for regional cooperation on agriculture under climate change.

Climate Change Trends

Overall, Asia and the Pacific is expected to become warmer, with a greater degree of temperature variability depending on latitude. In general, areas of higher latitude will experience greater warming than those of lower latitude. As a result of global

warming, the Himalayan glaciers are receding faster than any other glaciers in the world. While Pacific Island countries will experience the lowest annual mean changes in rainfall and temperature, rising sea levels are expected to significantly alter livelihoods and livability on some of the smaller islands in particular. Coastal areas in South and Southeast Asia will face the triple threat of changing precipitation, changing temperatures, and rising sea levels. Finally, cooler northern subregions of the Asian landmass are expected to warm, which may bring welcome news to farmers in terms of longer growing seasons.

Climate change is predicted to increase runoff in parts of South and East Asia, increasing the risk of floods during the wet season, while Central Asia will face a decrease in mean runoff. Climate change is also likely to affect groundwater resources by altering recharge capacities in some areas, increasing demand for groundwater as a result of reduced surface water availability, and causing water contamination as sea levels rise. Significant impacts are expected in countries highly dependent on groundwater for food production, including the PRC, India, and Pakistan.

Vulnerability to Climate Change in Asia and the Pacific

Studies show that several countries in Asia and the Pacific have high levels of vulnerability to climate change. The region is already highly prone to natural disasters: statistics for 1975–2006 show Asia as the most disaster-afflicted region in the world, during which period, Asia accounted for about 89% of people affected by disasters worldwide, 57% of total fatalities, and 44% of total economic damage. Temperatures are expected to increase in all countries in Asia and the Pacific under climate change but precipitation changes vary by

subregion, with increased annual precipitation volumes expected for most Asian countries with the exception of Central Asia where declines in annual volumes are predicted. Moreover, glacier melt and sea-level rise are of particular concern for the countries of Asia and the Pacific.

Nevertheless, vulnerability to climate change depends not only on exposure to climate events, but also on the physical, environmental, socioeconomic, and political factors that influence the sensitivity of countries to a changing climate and how they will be able to cope. The countries most vulnerable to climate change are Afghanistan, Bangladesh, Cambodia, India, Lao PDR, Myanmar, and Nepal. Countries with significant vulnerability include Bhutan, the PRC, Indonesia, Pakistan, Papua New Guinea, Sri Lanka, Thailand, Timor-Leste, Uzbekistan, and Viet Nam. Data for most Pacific Islands are insufficient to construct the same vulnerability indicator. While high levels of vulnerability indicate an urgent need for investments focusing on adaptation, both the capacity of these countries to absorb additional funding and the governance structures and institutions required to support adaptation, need to be carefully assessed.

Climate Change Impacts on Agriculture

Based on the modeling framework used—combining macroeconomic with crop models—the study finds that Asia and the Pacific experiences, under the climate change scenarios examined here, the largest negative impact on rice and wheat yields across all subregions. Biophysical (crop model) results indicate irrigated rice yield declines in 2050 of 14%–20%, depending on scenario, irrigated wheat yield declines of 32%–44%, irrigated maize

yield declines of 2%–5%, and irrigated soybean yield declines of 9%–18%, all compared to a no climate change case. Spreads are somewhat wider for rainfed crops. Rainfed maize yield changes range from -6% to +1%, and rainfed wheat yield changes from -16% to +18%. If carbon fertilization is included, then changes in crop yields are smaller or even turn positive in some cases. However, recent research experiments indicate that carbon fertilization effects have been overestimated and models have yet to be adjusted to account for recent insights.

Analysis that combines biophysical modeling with the IMPACT global agricultural supply, demand, and trade model shows that food prices increase sharply for key crops due to climate change, with adverse consequences for the poor. Rice prices increase 29%–37% by 2050 compared to the no climate change case, wheat prices rise 81%–102%, maize prices rise 58%–97%, and soybean prices increase 14%–49%.

Higher food prices in turn induce autonomous adaptation in the form of demand, supply, and trade responses. As a result, final yield and production price declines are lower than the biophysical shock from climate change, but remain large in much of Asia and the Pacific. Higher food prices also result in a reduction in consumption and increase in malnutrition. For Asia and the Pacific, rice yields decline by 10%–18%, on average, without carbon fertilization, and wheat yields by 35%–48%, while maize yields increase by 4%–13%, and soybean yields increase by 4%–10%. This shows the importance of autonomous adaptation as well as the need for functioning global trading regimes to compensate with net food imports in regions of the world that are particularly hard hit by climate change.

While Asia and the Pacific is particularly hit with lower rice and wheat yields, other regions fare

worse regarding maize yields. As a result, prospects for changing trading patterns are mixed for the region. Net imports to Asia increase in one climate change scenario and decline in two scenarios compared to the no climate change case. There is a clear result for India, however, with increases in net cereal imports under all three scenarios.

In addition, a separate sea-level rise impact analysis showed that under a 1-meter sea-level rise, a total of 7.7 million hectares (ha) of cropland in Asia and the Pacific is submerged, while under a potential 3-meter sea-level rise, the area submerged more than doubles to 16.1 million ha. Rice is by far the most affected crop, at 4.9 million ha and 10.5 million ha, respectively in Asia and the Pacific, accounting for 5% and 11% of global rice cultivated area, respectively. Such area losses could create significant additional upward pressures on world rice prices and downward pressure on consumption, especially for the poor. Also significantly affected, but not brought into the calculation here, would be large negative impacts on aquaculture production for Asia and the Pacific countries with secondary impacts on prices for livestock products.

What are the implications for food security in Asia and the Pacific? Across the region, calorie availability under climate change drops sharply, by 13%–15% compared to a no climate change scenario. The subregion hardest hit by a decline in calorie availability is Central Asia, with projected reductions from 15% to 18%, given their combination of low levels of calorie intake at the outset and the strong impact from climate change. Childhood malnutrition levels, which are directly linked to calorie availability, are projected to increase dramatically under climate change: between 9 and 11 million children—on top of the 65 million children—are projected to remain

malnourished in 2050 even under current climate conditions. Avoiding such an increase is a tall order, but not impossible. The study implemented several alternative investment scenarios to explore which sectoral investments could help lower future increases in childhood malnutrition for Asia and the Pacific. The analysis found that aggressive, but plausible investments in crop yield and livestock numbers growth will lead to large declines in childhood malnutrition, reducing by two-thirds the increase in malnutrition levels resulting from climate change. However, agricultural productivity increases alone will not be sufficient to counteract the adverse impacts from global climate change in Asia and the Pacific. If large investment increases in agriculture are combined with more aggressive investments in complementary sectors, such as education and health, then childhood malnutrition levels can be brought back to levels projected under normal climate, or even somewhat below. Alternatively, accelerated investments in agriculture in the rest of the developing world and in industrialized countries can also boost nutrition outcomes in Asia and the Pacific, but the strongest push by far comes from local productivity increases, given that those most affected by food insecurity are located in rural Asia.

Adaptation Measures

At the center of agricultural adaptation are innovative responses to climate change, which are already in development but have not been implemented on a wide scale. These responses include changes in agricultural practices for crop and livestock systems. Enhancing the ability of farmers to respond to climate variability and climate change will require significant improvements in developing and disseminating agricultural technologies targeted toward the major biotic

and abiotic stresses generated by climate change, which are still evolving. Improved crop varieties have the potential to be more drought tolerant, make better use of water and nutrients, and require reduced applications of pesticides. However, new technologies, by themselves, are insufficient to address successfully the challenges that climate change poses for agriculture—including increased risks to production and household income.

To protect against the devastating outcomes of agricultural failure due to weather and climate, reduce risk aversion in farmers' production decisions and thus enhance potential adoption of adaptive farming systems, programs and policies should be implemented to improve risk management and crop insurance, including index-based weather insurance.

A stable and supportive policy environment that makes such programs available and profitable is also a critical factor. Such a policy environment requires strengthening of important ongoing development initiatives to support climate change adaptation, which have been implemented in varying degrees throughout the developing world. These initiatives include secure property rights; improved economic incentives and green markets; improved information collection, use, and dissemination; extension services; and enhanced social protection and fiscal resilience. These adaptation areas need to be supported by ongoing local coping and indigenous knowledge, which farmers have employed for many years and in some cases for centuries. It will also be important to take account of the special needs of women in agriculture.

Finally, effective implementation of an agenda for climate change adaptation will require mainstreaming climate change and adaptation into development planning, reforming climate-related

governance and institutions, and undertaking massive new investments.

Given shifts in the volume of rainfall, increased temperatures, and rising sea levels, investments focusing on enhanced water control, management, and efficiency will be crucial in adapting to climate change, particularly in Bangladesh, India, Viet Nam, Nepal, Bhutan, and the Pacific Islands. Knowledge and information sharing among farmers, government implementing agencies, and researchers should be given an enabling environment that supports adaptive management. Crop breeding will be an essential component of adapting to key biotic and abiotic stresses related to climate change, including drought, heat, salinity, pests, and disease. Biotechnology and genetic modification will be an increasingly large component of crop breeding because of the nature of upcoming climate change stresses.

Only one study (by the United Nations Framework Convention on Climate Change [UNFCCC]) provides a quantification of future investment and financial flows required to meet climate change adaptation needs in agriculture, forestry, and fisheries (AFF). According to the study, about \$14 billion in investment and financial flows are estimated to be needed for agriculture, forestry, and fisheries globally during 2000–2030, including \$11 billion for production and processing, most of which is expected to be financed by domestic private sources; and \$3 billion needed for research and development (R&D) and extension, which is expected to be met by public sources. If converted to annual estimates, developing country needs for adaptation research are estimated at a relatively low \$47 million per year and extension needs at \$2 million per year up to 2030. These numbers contradict the results of most National Adaptation Programme of Action (NAPA) that advocate strong investments in agriculture in developing countries. Our analysis

shows that even very aggressive investments into the agriculture sector (including public agricultural research, rural roads, and irrigation in Asia and the Pacific—amounting to \$3.0–\$3.8 billion annually during 2010–2050)—while cutting by two-thirds the projected increase in child malnutrition due to climate change—are insufficient to counteract the adverse impacts of climate change (based on mean changes in temperature and rainfall). Given the significant trade linkages between Asia and the Pacific and the rest of the world, large-scale increases in agricultural investment in the rest of the developing, and also the developed, world will provide an additional boost to adaptation in Asia and the Pacific. A further third of malnutrition levels can be eliminated, if modest investments in key complementary sectors affecting childhood malnutrition are added—estimated at \$1.2 billion per year—particularly investments in female secondary education and safe domestic water supplies. While it is encouraging to see that investments of this magnitude can significantly help reverse the adverse impacts of climate change, the cost of reversing future damage from extreme weather events and rising sea levels are not part of this calculation.

Synergies between Adaptation and Mitigation

Agricultural activities release significant amounts of GHGs into the atmosphere. Agriculture's share of emissions was 13% in 2000, but if land use change is considered, agriculture contributes upwards of 30% of total emissions. Emissions from this sector are primarily CH₄ and N₂O, making the agriculture sector the largest producer of non-CO₂ emissions (60% of the world total in 2000). In that year, Asian countries accounted for 37% of total world emissions from agricultural production, with the PRC alone accounting for more than 18%. The

contribution of Asia and the Pacific to the world total is increasing.

Emissions from agriculture are expected to continue to rise because of increased demand for agricultural production from growing populations, improved nutrition, and changes in diet preferences favoring meat and dairy products. Yet, farmers have the potential to reduce the quantity of emissions through the efficient management of carbon and nitrogen flows. Mitigation strategies in agriculture can be categorized in three ways: carbon sequestration into soils, on-farm emission reductions, and emission displacements from the transport sectors through biofuel production.

Important low- or no-cost GHG mitigation activities in Asia and the Pacific include low- or no-till and other sequestration methods, as well as CH₄ emission reduction from rice fields. At a price of \$20/tCO₂-eq, benefit streams from mitigation could amount to \$5.5 billion per year. Compared with the total global economic mitigation potential, Asia could mitigate approximately 18% of emissions at these carbon prices.

Biofuels—when produced on marginal lands that do not directly or indirectly lead to deforestation—are a mitigation strategy with high technical feasibility in oil palm producing areas; however, trade-offs with food and land markets would need to be closely monitored. Finally, it should be recognized that biofuels are only one mitigation strategy, and their implementation should be weighed against all available low-cost abatement technologies.

Some conditions need to be met for realizing mitigation potential. The agriculture sector in Asia can play a significant role in GHG mitigation, but incentives to date have not been conducive to investing in mitigation. Significant potential

exists for small farmers to sequester soil carbon if appropriate policy reforms are implemented. If the high transaction costs for small-scale projects can be eliminated, carbon markets could be a significant source of financing. Successful implementation of soil carbon trading would generate significant co-benefits for soil fertility and for long-term agricultural productivity. The outcome of international climate change negotiations will have major effects on the role of agriculture in mitigation. If agriculture is to be included in a post-Kyoto regime, action must be taken now, with a focus on integrating smallholder farmers into carbon markets.

Conclusions and Priority Actions

The results of this study reveal six key messages for Asia and the Pacific:

- 1. Climate change will have negative impacts on agricultural production and food security throughout Asia and the Pacific.** Adverse impacts of climate change on agriculture are of particular concern for the region given the dominant role of agriculture in employment, economic development, and global food security.
- 2. Agricultural adaptation funding is required for all countries in the region. On the margin, assistance should be targeted toward those countries most vulnerable to climate change.** The most vulnerable countries are Afghanistan, Bangladesh, Cambodia, India, Lao PDR, Myanmar, and Nepal. Actual investment programs for these countries need to take into account suitability of governance structures and absorptive capacity. Required public agricultural research, irrigation, and rural road expenditures are estimated to be \$3.0–\$3.8 billion annually during 2010–2050, *above and beyond* projected baseline investments. In addition, these agricultural investments require complementary

investments into education and health, estimated at \$1.2 billion annually up to 2050 for countries in Asia and the Pacific.

- 3. Several important adaptation and mitigation measures should be implemented despite remaining uncertainty regarding climate change impacts.** These include increased investments in agricultural research and rural infrastructure (including irrigation and rural roads as noted in point 2 above), and investment in market and climate information as well as disaster preparedness information systems. Key policy measures to be implemented include those that improve the efficient use of land, water, and ecosystems; those that reduce inefficient subsidies; those that support the development of carbon markets and other ecosystem services; and those that promote open and transparent trade. Remaining uncertainties as to where climate changes will have impacts should be reduced through more spatial analysis and improved information generated by local agencies, users, and scientists.
- 4. The global agricultural trading regime should be opened so that the risks associated with climate change can be shared and thus, resilience increased.** This requires that the Doha Round of Agricultural Trade Negotiations be completed.
- 5. Regional cooperation among governments in Asia and the Pacific needs to be improved to ensure effective implementation of national adaptation and mitigation strategies and implementation of current and future funding mechanisms to address climate change.** Regional cooperation initiatives in Asia, such as Central Asian Countries Initiative for Land Management (CACILM) and the Greater Mekong Subregion (GMS), are important building blocks for climate change adaptation. Moreover, formal regional

organizations in Asia and the Pacific, including the Association of South East Asian Nations (ASEAN) and the South Asian Association for Regional Cooperation (SAARC), should play more prominent roles in technology and knowledge transfer across the region.

- 6. Agricultural adaptation and mitigation strategies must be incorporated into the ongoing international climate change negotiations to ensure the creation of appropriate incentive mechanisms.** These include innovative institutions, technologies, and management systems, as well as the necessary financing mechanisms.

These messages are discussed in more detail in the sections that follow.

Negative Impacts on Agricultural Production and Food Security

Climate change hinders development in all sectors, not only in Asia, but globally. It is negatively affecting agriculture, particularly by intensifying the struggle for land and water resources. Understanding the adverse impacts on agriculture in Asia and the Pacific is important because agriculture plays a crucial role in ensuring inclusive and sustainable development and because agricultural growth contributes to the attainment of the Millennium Development Goals, particularly those on hunger, poverty, environmental sustainability, water access, and to some extent, health.

Agriculture is the principal source of livelihood for more than 60% of the population of the region and the sector most vulnerable to climate change. Therefore, the effects on food production systems will directly affect the primary income source of billions of people in the region, and perturbations in the food supply will have overall implications

for the wider population of net food purchasers. Finally, Asia and the Pacific accounts for half the world's supply of and demand for cereals. Any significant changes in the food systems of this region will have implications for food supply and food prices globally.

Climate change will have significant negative impacts on agricultural production in Asia and the Pacific with all crops affected negatively under the three scenarios examined here. Negative crop impacts are strongest for rice and wheat. Climate change impacts on agriculture will render Asia and the Pacific less food and nutrition secure. Given that climate change is a global phenomenon, trade is an important measure that will provide some relief, but will be insufficient to fill production gaps from adverse future climate change. Home-grown productivity improvements will be the key path to maintaining food production growth and food security under climate change. Such productivity improvements require advances in agricultural research, development, and extension, including advances in crop and livestock breeding, enhanced farm management practices, soil quality improvements, and investments in rural infrastructure, including rural roads and irrigation.

Significant declines in agricultural production will adversely affect agricultural GDP in many Asian countries, and grave climatic conditions will cause heavy economic losses in Pacific Island countries. The decline in production due to climate change is projected to lead to substantial increases in food prices, at levels close to those seen during the 2008 food price crisis. While these predictions have been shown across a number of models, specific effects will differ by subregion. The effects of multiple stresses, such as extreme weather events, pests, and diseases, have not been adequately considered and require additional analysis.

Thus, given agriculture's pivotal role in employment, economic development, and global food security, adverse impacts on agriculture are of particular concern for the countries of Asia and the Pacific.

Assistance Should be Targeted Toward Those Most Vulnerable to Climate Change

In addition to broad-based adaptation investments, within Asia and the Pacific, targeted assistance should be directed toward those countries that are most vulnerable to climate change—that is, those with large exposure to climate change impacts, high sensitivity to the impacts from climate change, and low adaptive capacity. These countries include Afghanistan, Bangladesh, Cambodia, India, Lao PDR, Myanmar, and Nepal—with poor outcomes under all three categories of vulnerability—revealing South and Southeast Asia as the subregions of Asia and the Pacific most vulnerable to climate change.

Countries in South Asia, Southeast Asia, and the Pacific Islands are highly vulnerable to rising sea levels, which will increase the risk of floods. Glaciers in the Himalayas and Central Asia are already melting as a result of global warming. In areas highly dependent on livestock production, such as Mongolia and Inner Mongolia, the PRC, overgrazing increases vulnerability to climate change.

Vulnerability assessments are important to ensure that scarce public and private resources are allocated to those most in need of adapting to climate change. Although various vulnerability assessments generally come to similar conclusions, differences in results do exist because of the use of different data, different factors representing vulnerability, and differing methodologies. Given the low levels of adaptive capacity in the highly vulnerable countries, it will be important to take

governance structures and country absorptive capacities into account during the development of adaptation strategies.

As was shown by Bangladesh's improved resilience to tropical cyclones between 1991 and 1997, adaptation is possible even for the most destitute and vulnerable countries.

Key Adaptation and Mitigation Measures Need to be Undertaken Now

Sound development policies are necessary but not sufficient to effect the necessary agricultural adaptations to climate change. A pro-growth, pro-poor development agenda that supports agricultural sustainability is vital, including more targeted assistance to improve resilience. Adaptation will, however, also require targeted investments in agriculture.

First, because climate change has a negative impact on agricultural production in most developing countries, achieving any food security target will require greater investments in agricultural productivity. Key areas for increased investment include agricultural research, irrigation, rural roads, information technologies, market support, and extension services.

Second, the allocation of investment within and across sectors will need modification to achieve effective adaptation. Investments in agricultural research will need to undergo a relative shift toward traits relevant to climate change adaptation, such as drought and heat tolerance, insect and pest tolerance, and nitrogen use efficiency—all of which can reduce carbon emissions while promoting agricultural productivity. Biotechnology and genetic modification will play an increasingly large role in crop breeding because of the need for wider genetic variation to adapt to climate

change stresses. In irrigation and water resources, investments may be needed to expand large-scale storage to deal with the increased variability of rainfall and runoff. On the other hand, in subregions where changes in precipitation are highly uncertain, investments would better be distributed in a variety of small catchments. Climate change and variability in water supply, together with potential long-term changes in the cost of energy, could also dramatically change the cost-benefit calculus for big dams for storage, irrigation, and hydropower, making these investments more attractive despite the environmental and human relocation issues that such dams raise. The appropriate level and location of future irrigation investments could also change dramatically.

Third, adaptation will require a shift away from business-as-usual development policy because greater variability in weather and production outcomes will require greater attention to risk-sharing and risk-reducing investments. Such investments include financial market innovations, climate-based crop insurance, and broad-based social safety nets to both protect against the negative impacts of increased risk and induce farmers to make decisions that are not unduly risk-averse. International agricultural trade is an important mechanism for sharing climate change risk, so open trading regimes should be supported. Appropriate agricultural advisory services, hydrometeorological infrastructure, functioning financial markets, and effective institutions are necessary to minimize the risks to farmers as they make decisions about agricultural production. Also directly related to managing risk is the need to upgrade the efficiency and sophistication of infrastructure and other investments, including modernizing instead of rehabilitating irrigation, and investing in paved, not dirt, roads. More sophisticated agricultural practices, such as integrated pest management, are also needed,

requiring improved human capacity in agricultural management. Strengthening the role of women in household and agricultural production, as well as their rights to and control of assets, would further improve the effectiveness of risk management.

Fourth, investments will need to be targeted at subregions where the benefits are magnified because of climate change, and they should be reduced in areas where climate change impacts are so severe that production is no longer feasible. Sea-level rise will increase salt concentrations in coastal farming areas, which may require retooling of production systems, for example. Instead of producing crops, farmers may be better off pursuing alternative livelihoods, such as raising livestock, as practiced in the southwestern coastal areas of Bangladesh during flood season.

Fifth, climate change will exacerbate the negative implications of bad policies, thereby further increasing food, energy, and water prices. Subsidies for water, energy, and fertilizers should therefore be reduced, with the savings invested in adaptation activities that boost farm incomes and productivity. These subsidies have not only distorted production decisions, but also encouraged carbon emissions beyond economically appropriate levels. As the real prices of natural resources rise, market-based approaches to managing environmental services in response to climate change (such as through water pricing, payments for environmental services, and carbon trading) will become increasingly important. Improved definition and protection of land and water property rights will be necessary to effectively implement market-based approaches to climate change policy.

Sixth, the valuation of carbon through carbon trade and other forms of agricultural ecosystem services will increase the value of sustainable farming practices, thereby improving the likelihood

that farmers will adopt such practices as minimum tillage; integrated soil fertility management; and integrated pest, disease, and weed management.

Implementation of these adaptation and mitigation measures can only be realized through increased agricultural investments. A strong need exists to revisit national investment priorities and opportunities among the countries of Asia and the Pacific. Developing countries have chronically underinvested in science, technology, and innovation; and growth in public investments in research stagnated in developing countries after the 1980s. Investments in biotechnology and biosafety, especially by the public sector, may be insufficient to address pressing needs in both areas. In spite of the limitations, the public sector in many developing countries has invested in agricultural biotechnology research, yet few of its technologies have reached the commercialization stage. Many developing countries, particularly those in Southeast Asia, need to develop the minimal infrastructure and scientific capacity to master and implement risk assessments and biosafety regulations.

Investments in biotechnology, including genetically modified (GM) crops, could provide a transformational approach to addressing the trade-offs between energy efficiency and agricultural productivity. Biotechnology could profoundly affect future demand for freshwater and investment requirements in irrigation and other water sectors. GM crops have the potential to address major water-related stresses under both rainfed and irrigated farming and possibly to offer solutions to important water-quality problems. Breeding crop varieties with high water-use efficiency—a good indicator of the crop's ability to withstand environmental stresses, particularly drought and salinity—is thus, one policy option. Biotechnology's role as a possible substitute for large-scale water

investments must be considered in future planning for irrigation, water supply, and sanitation investments.

Increased and diversified investments are needed in plant breeding, livestock improvement, and other interventions at the biological and molecular levels to enhance agricultural productivity in ways that ultimately contribute to poverty reduction, agricultural development, and economy-wide growth throughout the region. Such a program requires heavy investment in advanced scientific expertise and equipment, as well as a political and social commitment to long-term funding of agricultural science and technology at levels significantly greater than current funding. Furthermore, it requires new investments to create organizations that are more dynamic, responsive, and competitive than the public organizations that currently make up the bulk of national agricultural research and extension systems in Asia.

Major investments in water infrastructure are also needed. Dams have proven to be an effective means of protecting agricultural systems and human settlements from water variability, and a higher demand for dams is expected to result from increasing water variability and energy demand. Big dams are known, however, to cause considerable environmental and social impacts. Furthermore, investment is needed in engineering techniques to reduce environmental impacts, management techniques to optimize their use, planning tools to reduce social impacts, and tools to improve design and operational techniques. Investments should also be made to scale up underground storage techniques. Finally, more investments should be made in research on the viability of inter-basin transfer schemes, which can be politically challenging and risky in light of future uncertainty about water availability.

Policies that favor private investment in crop improvements targeted to climate change in the developed and developing world are critical. These policies include (i) decreasing the bureaucratic hurdles to business formation, (ii) developing infrastructure that enables the production and distribution of improved seeds and other agricultural inputs, (iii) developing appropriate regulatory and biosafety protocols for the introduction of transgenic cultivars, and (iv) reforming intellectual property rights that could encourage private investment in crop improvement.

Meeting the challenges of climate change adaptation in agriculture also requires long-term investment by farmers. Long-term investment (in areas such as integrated soil fertility management, tree planting, and water harvesting), in turn, requires secure property rights to provide people with the incentive and authority to make such investments. By changing the profitability of land, such as through the potential for income from carbon markets and biofuels, climate change may worsen the position of those farmers with insecure property rights, leading to expulsion from their land as landlords seek to increase their share of the new income streams. Improvement in land rights is, therefore, an essential component in effective and equitable adaptation.

International agricultural trade is an important mechanism for sharing climate change risk. A more open global trading regime would increase resilience to the impacts of climate change.

Climate change can become the stimulus for implementing difficult but necessary changes. Managing climate change as an international public good creates opportunities for new markets and pricing policies that can help meet longer-term sustainability goals through the valuation of

resources. Rising prices of carbon, food, fuel, and environmental resources due to climate change could stimulate significant policy and investment opportunities. Instead of seeing climate change as a tax on growth, countries can benefit by implementing low-cost, resource-conserving technologies in the agriculture sector. They can exploit synergies between building ecosystem resilience and agricultural productivity through a focus on agricultural productivity enhancement, and new agricultural financing mechanisms such as carbon markets.

Agriculture can help mitigate GHG emissions in Asia and the Pacific with appropriate incentive mechanisms and innovative institutions, technologies, and management systems. Incorporation of agricultural adaptation and mitigation in the ongoing international climate change negotiations must happen now in order to open opportunities to finance sustainable growth under climate change. Mitigation strategies that support adaptation should be favored.

A broad set of technical skills will be needed to plan for and respond to a wide range of unpredictable contingencies, and the backbone of these efforts will be improved knowledge, coordination, collaboration, information exchange, and institutional responsiveness. Building resilience—especially among the poor—will require enhancing the adaptive capacity of individuals and institutions to deal with uncertainties in their local settings through the testing and scaling up of effective pilot projects.

While many adaptation and mitigation investments can be implemented now, others require additional information to reduce uncertainty about where climate change will manifest impacts. Disagreements among modeling studies with

regard to the future impacts of climate change on agricultural capacity and crop yields are, in part, a result of different assumptions. Another major limitation is the lack of an integrated assessment incorporating all key climate variables. Many climate variables have feedback effects among themselves, which are left out of already complex modeling exercises. Furthermore, almost all climate change modeling efforts leave out several key factors. Extreme weather events and other stressors—such as increased climate variability, rising sea levels, and land degradation—are often partially or entirely ignored. In agriculture, pest and disease aspects and their feedback effects are seldom taken into account. A further limitation is that the quality and extent of research varies by country. For example, much information is available on the PRC, but little, if any is available, on Central Asia and the Pacific Island states.

International Trade is an Important Mechanism for Sharing Climate Change Risk

A more open global trading regime would increase resilience to the impacts of climate change. Rule-based, fair, and free international trade is particularly critical in times of crisis, as the export ban problems following the food price crisis of 2007–2008 underline. A sound global trading system is especially crucial in the context of climate change. As shown in Chapter II, the impacts of climate change on agricultural growth and production will likely make many Asian developing countries increasingly reliant on food imports. To increase confidence in international agricultural trade, the World Trade Organization Doha Round should be completed. Organisation for Economic Co-operation and Development countries should reduce or eliminate trade restrictions that limit a developing country's export access to markets, and buffering mechanisms should be established

to better address volatility in world markets. Alternative or complementary approaches to market stabilization for cereals include a joint pooling of fixed portions of national stocks into an international grain reserve and/or a financial facility, provided by the International Monetary Fund, for imports by countries during food emergencies.

Regional Cooperation among Governments in Asia and the Pacific Needs to be Improved

Cooperation among governments in Asia and the Pacific is necessary to ensure effective implementation of adaptation and mitigation strategies in their respective countries, as well as to explore the financial means for addressing climate change. Funding modalities related to climate change, such as the Clean Development Mechanism and other carbon funds, payments for environmental services, or other mechanisms to mitigate GHGs, must be implemented by Asian development planners and policy makers, and such funds must be accessible to vulnerable people. Climate action plans need to be integrated into Poverty Reduction Strategy Papers or other national development plans. Without this integration, climate adaptation plans may simply add another layer of planning rather than aid the mainstreaming process. Actors at all levels are called to action in the effort to adapt to climate change.

Adaptation to climate change, typically treated as a stand-alone activity, should be integrated into development projects, plans, policies, and strategies. Development policy issues must inform the work of the climate change community, and development and climate change perspectives should be integrated into

approaches that recognize how persistent poverty and environmental needs exacerbate the adverse consequences of climate change. Climate change will alter the set of appropriate investments and policies over time, both in type and in spatial location. Effective adaptation, therefore, requires not only that policy makers judiciously select measures within their policy context and strategic development framework, but also that they explicitly target the impacts of climate change, particularly on the poor.

Development policies and plans at all levels need to consider the impacts of climate change on the agriculture sector. National and regional policy makers must integrate the effects of climate change and the outcomes of assessments and scenarios into their national agricultural plans and policies. Moreover, mainstreaming should aim to limit development policies and plans that inadvertently encourage, rather than minimize, vulnerability to the impacts of climate change.

Achieving these goals will require, first, the engagement of a core ministry—such as the Ministry of Finance or the Ministry of Planning, alongside the Ministry of Agriculture—to ensure strong government support. Second, the core capacities of developing country governments will need to be further developed. Such capacity building is required in a number of areas including climate forecasting and scenario planning, and general development topics such as governance, accountability, and empowerment of local communities. Third, adaptive and flexible management will be essential to address the broadening nature and increasing severity of potential climate impacts in a given area and the unavoidable uncertainties associated with predicting these impacts.

New mechanisms to support adaptation, including the Least Developed Country Fund, the Special Climate Change Fund, and the Adaptation Fund, provide the opportunity to mainstream adaptation into local and regional development activities.

Short-term regional adaptation initiatives could include transboundary or regional adaptation evaluation exercises and investment assessments. Medium-term regional adaptation initiatives could include the development of agricultural climate information systems, regional disaster and emergency relief funds, and larger scale infrastructure development. Regional initiatives should be supported by climate change interest groups staffed by experts from the region's ministries of agriculture and finance.

In addition, the private sector—particularly the insurance and reinsurance industries—needs to engage more in adaptation activities in developing countries, building on the risk-transfer products they have already begun to develop, such as microinsurance, weather and crop insurance, and disaster-related bonds.

Agriculture Needs to Form Part of International Climate Change Negotiations

Agriculture can help mitigate GHG emissions in Asia and the Pacific with appropriate incentive mechanisms and innovative institutions, technologies, and management systems. Incorporation of agricultural adaptation and mitigation in the ongoing international climate change negotiations must happen now in order to open opportunities for financing of sustainable growth under climate change. Mitigation strategies that support adaptation should be favored.

Because agriculture is still the main source of livelihood for more than half of the people in the region, benefit streams for Asia from mitigation strategies have the potential to contribute to poverty reduction, food security, and the resilience of agroecological systems. Small farmers have significant potential to sequester soil carbon if appropriate policy reforms are implemented. Successful implementation of soil carbon trading would generate significant co-benefits for soil fertility and long-term agricultural productivity. If the high transaction costs for small-scale projects can be eliminated, carbon markets could be a significant source of financing. The benefit stream from mitigation of 276.79 Mt CO₂-eq a year at a carbon price of \$20/t CO₂-eq in agriculture could amount to \$5.5 billion annually for Asia, accounting for 18% of total global mitigation potential.

The use of high-yielding crop varieties, a shift to rice–wheat production systems, and alternating dry–wet irrigation are technologies that combine mitigation and adaptation objectives by reducing emissions, conserving water, and reducing land requirements and fossil fuel use. Other mitigation strategies that have substantial synergistic effects with adaptation and food security for rural communities in Asia and the Pacific include the restoration of degraded soils and efficient water use in crop cultivation. All of these strategies help conserve soil and water resources while enhancing ecosystem functioning, including water use efficiency and crop resilience to pests, diseases, and extreme weather events. GHG emissions from agriculture can be further mitigated through nutrient, water, and tillage management; through improved crop varieties (particularly rice, the main staple in Asia); and through the use of crop residues for renewable energy and carbon sequestration.

Improved pasture management to control livestock overgrazing will help decelerate desertification.

Although there are viable mitigation technologies in the agriculture sector, key constraints need to be overcome. First, the rules of access—which still do not credit developing countries for reducing emissions by avoiding deforestation or improving soil carbon sequestration—must change. Second, the operational rules—with their high transaction costs for developing countries, and small farmers and foresters, in particular—must be streamlined.

Policies focused on mitigating GHG emissions, if carefully designed, can help create a new development strategy that encourages the creation of more valuable pro-poor investments by increasing the profitability of environmentally sustainable practices. To achieve this goal, it will be necessary to streamline the measurement and enforcement of offsets, financial flows, and carbon credits for investors. It is important to enhance global financial facilities and governance to simplify rules and increase funding flows for climate change mitigation in developing countries.