Executive Summary

Overview

Climate change is threatening food production systems and therefore the livelihoods and food security of billions of people who depend on agriculture in the Asia and Pacific region (hereafter, Asia and the Pacific). Agriculture is the sector most vulnerable to climate change due to its high dependence on climate and weather and because people involved in agriculture tend to be poorer compared with urban residents. Consistent warming trends and more frequent and intense extreme weather events have been observed across Asia and the Pacific in recent decades. In line with these trends, climate change scenarios consistently project temperature increases across the region, which will require farmers to adapt to changing conditions. At the same time, agricultural activities release significant amounts of greenhouse gases (GHG) into the atmosphere. Asia and the Pacific accounts for 37% of the world's total emissions from agricultural production, and the People's Republic of China (PRC) alone accounts for more than 18% of the total.

The combination of these characteristics of agriculture—its importance as an economic sector, its vulnerability to climate change, and its contribution to emissions—make building resilience to climate change in Asia and the Pacific an enormous challenge. For the sector to meet the food and income needs of current and future generations, individual farmers, governments, community groups, and the private sector will need to implement comprehensive mitigation and adaptation strategies, which will require targeted investments.

This report presents broad indicators of exposure, sensitivity, and adaptive capacity in the region. A review of the indicators highlights the vulnerability of the agriculture sector as a livelihood source for many, and as a source of food security for all. The review also exposes the large heterogeneity in farming systems across Central, East, Southeast, and South Asia and the Pacific Islands, and highlights the many facets of vulnerability to climate change across the region, including undernourishment, poverty, and slowing productivity growth, all of which will be exacerbated by the effects of climate change.

Climate change is expected to have multifaceted impacts on the countries of Asia and the Pacific. Overall, the region is expected to become warmer, with a large degree of variability, depending on latitude. In general, northern areas will experience greater warming than those at lower latitudes. While the Pacific countries will experience low mean annual changes in rainfall and temperature, rising sea levels are expected to alter significantly not only livelihoods but also livability on some of the smaller islands. Coastal areas in South and Southeast Asia and parts of the PRC will face the triple threat of changing precipitation, temperature, and rising sea levels. Finally, the cooler (northern) subregions of the Asian land mass are expected to get warm, which may lengthen agricultural growing seasons.

The combination of poverty in rural areas and the expected impacts of climate change and its remaining uncertainty will require careful planning for adaptation. Targeted climate change investments and more flexible decision making will be necessary to make the most of scarce budgetary resources, which must also be allocated to crucial social development needs.

Agricultural Profile of Asia and the Pacific

Agriculture is important for all countries of Asia and the Pacific. More than 60% of the economically active population and their dependents—which amounts to 2.2 billion people—rely on agriculture for their livelihoods. While agriculture's contribution to gross domestic product (GDP) is declining throughout the region, large populations are still based in rural areas, depending on agriculture directly or indirectly for employment and income. Poverty remains highest in these rural areas, and the disparity between rural and urban areas is widening. On the other hand, there is a heterogeneous poverty profile and divergent growth paths, with some economies growing at an accelerated rate compared to others. In addition, the importance of agriculture to the overall economy is highly variable among subregions and countries. The degree of political stability and the level of institutional maturity also varies. The profile of the region indicates, at the country level, the importance of ensuring food security in the region, to which is added the challenge of achieving food security in the context of climate change. For many countries in Asia and the Pacific, agriculture is not perceived in terms of its contribution to the growth process through increased GDP share, but mainly in the context of attaining food security.

In the Central Asia subregion, and with the exception of Turkmenistan, the importance of agriculture to GDP has been declining. Similarly, agricultural GDP in East Asia has been declining. Although the sector accounts for only 12% of the PRC's total GDP, nearly 64% of its economically active population is still 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, several East Asian countries—including

the PRC, Japan, and the Republic of Korea—have begun to purchase or lease land for food production in other parts of Asia (Indonesia and the Philippines) as well as in Africa, Eastern Europe, and Latin America.

The importance of agriculture to GDP has been declining in Southeast Asia; however, it still contributes 30% in Cambodia and over 40% in the Lao People's Democratic Republic (Lao PDR). In addition, undernourishment in Southeast Asia has declined since 1995 but still averages 18% of the population, with 26% of the population of Cambodia classified as malnourished. Reducing the food security risk in Southeast Asia, however, has resulted in the large-scale deterioration of the agricultural resource base, e.g., land and water resources.

Unlike Central, East, and Southeast Asia, the importance of agriculture to GDP remains high in South Asia and declined only slightly between 1995 and 2006. As a result, employment in agriculture is also high, with close to 50% or more of the population dedicated to this sector (with the exception of the Maldives). Finally, the proportion of undernourished within the population averages over 20%, making South Asia the least food-secure subregion both in Asia and the Pacific and the world.

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

While agriculture is crucial for the region's food security and forms the backbone of much of the employment, farming agro-ecosystems 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 countries. The heterogeneity of farming systems will require targeted interventions to support farmers in adapting to and mitigating the effects of climate change.

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

Finally, the impacts of climate change in Asia and the Pacific will affect food security, not just regionally, but globally. The region accounted for 43% of global crop production in 2000 and is expected to account for one-third of total cereal demand and two-thirds of

total meat demand over the next several decades; it also accounts for significant net cereal exports, particularly in terms of rice.

Climate Change Trends

A warmer and mostly wetter rainy season, and possibly drier dry seasons

Climate change is already evident in a number of ways. Consistent warming trends and more frequent and intense extreme weather events have been observed across Asia and the Pacific in recent decades.

All subregions of Asia and the Pacific are expected to become warmer. While there is less certainty regarding changes in precipitation, Asia and the Pacific are expected generally to get wetter, with the exception of Central Asia. However, rainfall tends to be heavier during wet periods, increasing the risk of floods, while dry seasons will remain dry or get drier. Moreover, the region is expected to experience an increased frequency of extreme weather events.

The PRC and Viet Nam are the two countries most affected by sea-level rise in terms of total crop land area, followed by Bangladesh, India, and Indonesia. This is based on the results of the International Food Policy Research Institute (IFPRI) Spatial Allocation Model that excludes 12 countries in the Pacific due to unavailable data. Moreover, glaciers in the Himalayas and Central Asia are already melting as a result of climate change. This brings about potential short-term benefits from increased water flows, as well as increased risks from flooding. In the long-term, impacts on food production and ecosystem health will be negative, particularly during the dry season. Much less is known regarding future changes in extreme weather events. Our knowledge regarding the impact of pests and diseases is also insufficient. Given our limited understanding of the nature and extent of impact of climate change on the sector, planning appropriate adaptation and mitigation measures will be carried out under a scenario of uncertainty.

Impact on agriculture

Developing countries in Asia and the Pacific are likely to face the highest reductions in agricultural potential in the world due to climate change. As a result, climate change will place an additional burden on efforts to meet long-term development goals in Asia and the Pacific. Slow agricultural productivity growth, declining income growth, and problems of maintaining food security already pose challenges to many countries in the region.

Modeling climate change impacts on agriculture

For Asia and the Pacific, depending on the General Circulation Model (GCM) and scenario used, biophysical crop model results show yield reductions under climate change compared to a no-climate change scenario. By 2050, for irrigated paddy, the expected reduction is in the range of 14%–20%; for irrigated wheat, 32%–44%; irrigated maize, 2%–5%; and irrigated soybean, 9%–18%. Spreads across crops and GCM are somewhat wider for rainfed crops, with positive yield effects under some GCM, especially in more temperate areas. If carbon fertilization is modeled, then changes in crop yields are much smaller or even turn positive. However, recent research experiments indicate that carbon fertilization effects have been overestimated, and models have yet to be adjusted to account for recent insights.

Incorporating spatially distributed area and yield impacts into the International Model for Policy Analysis on Agricultural Commodities and Trade (IMPACT, developed by the IFPRI) accounts for the autonomous adaptation effects from supply and demand response adjustments as a result of changes in food prices. Changes in the volume and direction of international trade in agricultural commodities are another avenue to compensate for the differential impacts of climate change, and are also taken into account in IMPACT.

When biophysical impacts of climate change are integrated into the IMPACT model, food prices increase sharply for key crops with adverse consequences for the poor. Rice prices are projected to be 29%–37% higher in 2050 compared to a no-climate change case, wheat prices to be 81%–102% higher, maize prices to rise 58%–97%, and soybean prices to increase 14%–49%. Higher food prices lead to declines in total demand for cereal and other crops and a reduction in calorie availability across all Asian subregions, by 13%–15%, on average. The subregion hardest hit is Central Asia, with projected declines in calorie availability of 15% to 18%, given their combination of low levels of calories 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 by between 9 and 11 million children, in addition to the 65 million children projected to remain malnourished in 2050 even under current climate conditions. Avoiding such an increase is difficult 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. It found that aggressive investments into agricultural productivity enhancements are the key to reversing climate change impacts on both agriculture and food security—potentially reducing two-thirds of the increase in malnutrition levels arising

from climate change. Further reductions could be achieved by more aggressive investments in complementary sectors, such as education, and health. While the strongest climate change reduction results can be achieved from local productivity increases, further trade liberalization, accelerated investments in agriculture in the rest of the developing world as well as by industrialized countries can also provide some relief for Asia and the Pacific.

Climate change will also affect crops and fisheries in the Pacific Island countries, with potential negative consequences for food security. However, the study suffered from a lack of data and additional research will be needed to obtain more specific results for these countries.

Net trade in meats and cereals in Asia will see strong adjustments due to climate change. Under the no-climate change case, only Central Asia will increase its net cereal exports to 2050, while the other subregions of Asia and the Pacific will rely on increasing net imports of cereals. Net cereal imports are projected to increase in East Asia and South Asia under all climate change scenarios. In Southeast Asia, the impact of climate change on trade varies according to the GCM applied. The final trade results produced by the study are the outcome of a complex interaction between the size of the biophysical impact, the resulting price increases, and the responsiveness of demand and supply to prices in each subregion.

Moreover, a warmer and drier climate and more frequent and intense extreme weather events will reduce the agricultural GDP of all countries in Asia, particularly in South and Southeast Asia. Economic losses in the Pacific Island countries are also likely to be high. Fundamentally, across all Asia and the Pacific subregions, but particularly in South and Southeast Asia, climate change will lead to the reduction of agricultural GDP and worsening trade conditions, which will likely increase poverty.

As a result of uncertain climate predictions and other factors (e.g., CO_2 fertilization effects, socioeconomic pathways, as well as the individual adaptive capacity of countries), projections of the impacts of climate change on agriculture are not as precise as desired and depend heavily on scenario assumptions. Nonetheless, projections show that agriculture systems in many vulnerable subregions in Asia and the Pacific will suffer with climate change, particularly in South Asia. Further research should be done to better assess detailed impacts in Central Asia and the Pacific Islands.

Resilience as the Conceptual Framework

Resilience is used to describe the magnitude of a disturbance that a system can withstand without crossing a threshold into a new structure or dynamic. In human systems, resilience refers to the ability of communities to withstand and recover from stress, such as

environmental change or social, economic, or political upheaval, while for natural systems, it is a measure of how much disturbance (e.g., storms, fire, and pollutants) an ecosystem can handle without shifting into a qualitatively different state. This definition implies that social systems have the additional ability to anticipate and plan according to perceived and real changes. Therefore, the ability of institutions and individuals to avoid potential damage and to take advantage of opportunities will be a critical factor in building resilience to climate change. In addition, building resilience to climate change requires simultaneously building resilience in human systems and in the interlinked ecosystems on which they depend.

The concept of resilience has emerged in response to the need to manage interactions between human systems and ecosystems sustainably. Humans depend on ecosystem services (e.g., water filtration, carbon sequestration, and soil formation) for survival, yet the ability of institutions to manage these natural systems sustainably has not kept pace with the changes occurring within these systems. Socioeconomic institutions have considered ecosystems and the services they provide to be infinite and largely in a steady cycle of regeneration. This attitude has led to the creation of economic instruments and incentives that use ecosystems deterministically, from extraction to consumption. The concept of resilience, however, recognizes that social and environmental systems are interlinked, complex, and adaptive; process dependent—rather than input dependent—and self-organizing rather than predictable. The lens of resilience is useful in analyzing climate change because it is founded on the recognition that human existence within ecological systems is complex, unpredictable, and dynamic, and that institutional measures and responses should be based on this principle.

Agriculture is a form of natural resource management for the production of food, fuel, and fiber. As such, it depends on the resilience of both social and ecological systems. In social systems, resilience varies greatly among households, communities, and regions, depending both on the assets and knowledge farmers can mobilize and the services provided by governments and institutions. On the other hand, the resilience of agriculture-related ecosystems depends largely on slowly changing variables, such as climate, land use, nutrient availability, and the size of the farming system. In addition, agriculture is a source of livelihood for billions of people—particularly poor people—and their income directly contributes to society's resilience. As a result, enacting measures to build agricultural resilience requires an understanding of strategies to reduce vulnerability while at the same time generating income and reducing poverty.

This report introduces a conceptual framework for building resilience in the agriculture sector (Figure 1.1). This framework introduces key concepts related to building resilience and provides entry points for policy and investments. Figure 1.1 outlines factors that influence resilience to climate change—namely, the nature of the biophysical impacts, a

society's sensitivity to those impacts, its capacity to cope and adapt, and the adaptation and mitigation strategies implemented by governing institutions. These components will be used to guide the discussion throughout this report.

Vulnerability to climate change in Asia and the Pacific

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as a function of the character, magnitude, and rate of climate variation to which a system is exposed; its sensitivity; and its adaptive capacity. More succinctly, vulnerability is defined as having three components: exposure, sensitivity, and adaptive capacity.

Exposure has been used in the literature to characterize the biophysical impacts of climate change on agroecological systems. Exposure encompasses the spatial and temporal dimensions of climate variability, such as droughts and heavy rains, the magnitude and duration of weather events, and long-term change in mean climate (temperature and precipitation).

Vulnerability to climate change depends not only on exposure to climate events, but also on physical, environmental, socioeconomic, and political factors that influence how sensitive countries will be to a changing climate, as well as their ability to cope and to adapt. For adaptation and mitigation measures to be successful, an assessment of poor communities' current vulnerabilities, needs, and coping abilities is needed, including influential factors such as gender equality.

Sensitivity is defined by the IPCC as "*the degree to which a system is affected, either adversely or beneficially, by climate variability or change*" and refers to the ability of an agroecological system to withstand impacts without overt efforts to adapt. Sensitivity is a complex concept because the responsiveness of a system can be influenced by both intrinsic characteristics and degrees of external manipulation. For example, unprotected low-lying coastal areas may be more sensitive to rising sea levels and storm surges than those that have sea walls. Similarly, water-stressed areas that have no irrigation infrastructure will be more sensitive to drought compared to those that do have such systems in place. In Asia and the Pacific, many countries are sensitive to climate change and extreme weather events because of high water stress, high rates of land degradation, and the high dependency of their economies on agriculture.

Low-income and other vulnerable populations will feel the effects of climate change and increases in the incidence of natural disasters most strongly. For instance, climate change is likely to increase the vulnerability of poor farmers who already struggle with land degradation in Asia and the Pacific. In areas highly dependent on livestock production, such as Mongolia and Inner Mongolia, the PRC, overgrazing increases vulnerability to climate change.

Rural women from developing countries will be among the most affected groups in the world given their dependence on subsistence crops, their limited access to resources, and their lack of decision- making power. Adaptation strategies should acknowledge the greater vulnerability of women to climate change.

Health impacts in developing countries are expected to be mostly negative. The ultimate impacts of climate change will be highly dependent on the capacity of countries to limit disease transmission and treat infections. Climate change might increase the global burden of disease as more frequent and severe floods and droughts, as well as changes in mean temperatures and rainfall are likely to increase the number of people at risk.

A combination of indicator values representing exposure (change in temperature and precipitation), sensitivity (share of labor in agriculture), and adaptive capacity (poverty) identifies Afghanistan, Bangladesh, Cambodia, India, Lao PDR, Myanmar, and Nepal as the countries most vulnerable to climate change in Asia and the Pacific. Countries with significant vulnerability—poor outcomes in two out of the above three components—include Bhutan, the PRC, Indonesia, Pakistan, Papua New Guinea, Sri Lanka, Thailand, Timor-Leste, Uzbekistan, and Viet Nam. As in Africa, those countries least responsible for climate change are likely to suffer most from its adverse impacts as a result of their location and low adaptive capacities. On the positive side, however—as has been shown by improvements in Bangladesh's ability to withstand tropical cyclones—adaptation is possible even for the most destitute and vulnerable countries.

The Role of Adaptation

Important ongoing development initiatives need to be strengthened to reduce vulnerability to climate change, including developing agricultural markets, reducing distortions and subsidies in agricultural policies, continuing trade liberalization policies, enhancing social protection and microfinance, preparing for disasters and, critically, mainstreaming climate change in agricultural policies. However, neither these development policies, nor autonomous or reactive adaptation, will be enough for countries of Asia and the Pacific to adapt to climate change.

Instead, adaptation will require improvements that take existing development policies above and beyond their current capacity. Innovative policies include: (i) changing investment allocation within and across sectors, (ii) increasing the focus on risk-sharing and risk-reducing investments, (iii) improving spatial targeting of investments, (iv) eliminating existing detrimental policies that will exacerbate climate change impacts, and (v) reducing greenhouse gas (GHG) emissions from agriculture and increasing the value of sustainable farming practices through the valuation of carbon and other forms of agricultural ecosystem services such as water purification and biodiversity.

Key components of new and innovative adaptation measures to climate change include (i) changes in agricultural practices to improve soil fertility and enhance carbon sequestration; (ii) changes in agricultural water management for more efficient water use; (iii) agricultural diversification toward enhanced climate resilience; (iv) agricultural science and technology development, agricultural advisory services, and information systems; and (v) risk management and crop insurance.

Changing investment allocation within and across sectors

Developing countries have chronically underinvested in science, technology, and innovation. However, crop breeding—using biotechnology and genetic modification—will be an essential component of adapting to key biotic and abiotic stresses related to climate change, including drought, heat, salinity, pests, and disease. These should be combined with tapping of traditional knowledge on crop varieties and adaptation.

Policies that favor private sector 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. A growing number of food companies are successfully adopting various sustainable pathways as new marketing strategies. This includes growing crops organically, offsetting GHG, sourcing fair-trade, and promoting biodiversity. These companies' experiences should be documented and lessons should be extracted on how the public sector can facilitate scaling up these initiatives.

In much of Asia, growth of public investments in research slowed after the 1980s. Investments in biotechnology and biosafety regulatory systems have been insufficient to address pressing needs in both areas, especially when focused on resolving national constraints. Many countries in Asia and the Pacific need to develop the infrastructure and scientific capacity to implement risk assessments and biosafety regulations to enable effective development and adoption of biotechnology.

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 regions where changes in precipitation are highly uncertain, investments might be better 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 dams raise. The appropriate level and location of future irrigation investments could also change dramatically.

Increasing the focus on risk-sharing and risk-reducing investments

Greater variability in weather and production outcomes will require enhanced attention to risk-sharing and risk-reducing investments. Such investments include financial market innovations, weather-based crop insurance, and broad-based social safety nets, which both protect against the negative impacts of increased risk and induce farmers to make decisions that are not excessively 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, hydro-meteorological infrastructure, functioning financial markets, and effective institutions are necessary to minimize the risks to farmers as they make decisions about agricultural production. Institutional innovations—such as various forms of contract farming—will facilitate participation of smallholders in export markets.

Also directly related to managing risk is the need to upgrade the efficiency and sophistication of infrastructure and other investments, including modernizing instead of just rehabilitating irrigation and investing in paved, not dirt, roads. More sophisticated agricultural practices, such as integrated pest management, are also needed, requiring improvement in 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 improve the effectiveness of risk management.

An existing mechanism to reduce risk and improve disaster preparedness is the Indian Ocean Tsunami Warning and Mitigation System, which is funded by the United Nations Economic and Social Commission for Asia and the Pacific. The fund aims to strengthen tsunami early warning capabilities by building institutional, technical, and system-wide capacity in the countries of the region. The fund will be administered by governments, which will identify their own priorities and design and implement projects. At the end of 2008, the fund had approved 11 projects in the region with a budget of $9.2 million. Although currently operating at a relatively small scale, this initiative shows the potential for regional cooperation.

Improved spatial targeting of investments

Broad-based investment in adaptation is needed, but funds should also be targeted on the margin to those areas most vulnerable to climate change—that is, areas with the largest climate change signal and highest sensitivity to climate change, particularly those depending on rainfed agriculture or in low-lying delta areas. Sea-level rise will increase the

concentration of salt in farm areas, which may require retooling of production systems. In some areas, for example, instead of producing crops, farmers may need to pursue alternative livelihoods, such as raising livestock or practicing aquaculture, as is already being done in the southwestern coastal areas of Bangladesh during flooding season. More and better spatial analysis is needed to reduce uncertainty about where climate change will have impacts.

Eliminating existing detrimental policies that will exacerbate climate change impacts

Climate change increases the costs of subsidy policies because climate change will contribute to increased food, energy, and water prices. Perverse subsidies for water, energy, and fertilizer should be reduced, with the savings invested in adaptation activities that boost farm income. 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 for managing environmental services in response to climate change (such as through water pricing, payment for environmental services (PES), and carbon trading) will become increasingly important. Improved definition and protection of land and water property rights will be necessary to implement effectively market-based approaches to climate change policy, including PES.

One way to improve upon previous PES approaches is to involve local communities, allowing them to negotiate to determine the terms of the payments. For example, downstream users in a watershed may try to negotiate with upstream users to protect the water from pollution and sedimentation. The downstream users may offer a payment or reward in exchange for implementing agreed-upon management practices. When the initiative comes from local people who are direct stakeholders, it may make sustainability easier to achieve, because the downstream users will have an interest in continuing to monitor compliance. Such negotiation and collective agreements are more likely within relatively small and cohesive communities than between wider communities and where the ability to ensure that all resource users benefit, is greater. The fact that few such examples exist in practice may be less dependent on local leadership and other idiosyncratic factors and more related to absence of local control over resources.

Increasing the value of sustainable farming practices through the valuation of carbon

Carbon needs to be recognized as a global externality, with carbon valued through carbon trade to increase the value of sustainable farming practices. This situation improves the likelihood that farmers will adopt long-term sustainable farming practices such as minimum tillage; integrated soil fertility management; and integrated pest, disease, and weed management.

Property rights

A lack of property rights makes farmers reluctant to invest in measures to conserve land, as they cannot secure future rights. Insecure land tenure reduces incentives to improve practices to cope with environmental degradation, which intensifies the adverse impacts of climate change and variability on crop production. Unsustainable land practices increase land degradation, which can further contribute to climate change. Increasing the profitability of land, such as through the potential for income from carbon markets and biofuels, may actually worsen the position of famers with insecure property rights, as the land may be expropriated by landlords seeking to increase their share of new income streams.

Meeting the challenges of climate change adaptation in agriculture requires long-term investment by farmers. Secure property rights are needed for these investments (such as integrated soil fertility management, tree planting, and water harvesting) to provide people with the incentive and authority to make the investments. Improved definition and protection of land and water property rights is therefore an essential component in effective and equitable adaptation and market-based approaches to climate change policy.

Secure property rights do not necessarily need to be individual or titled land; secure collective or customary tenure can also be options. In cases where pressure on land is growing, however, customary tenure may no longer be secure. These cases call for innovative approaches to guaranteeing land tenure, which may involve alternatives to titling. These alternatives could range from recognizing customary rights to land, to identifying agents to represent customary interests, to formalizing groups and granting them collective rights over resources. Again, special attention needs to be given to the rights of women.

Implementing climate change adaptation investments and policies

Climate change adaptation investments have been extremely slow in developed countries and will be difficult to implement in developing countries, including those in Asia and the Pacific, given competing short-term budgetary needs and a lack of capacity in key ministries to assess adaptation requirements. To mainstream climate change adaptation, countries will need to undertake multifaceted risk assessments that incorporate not only climate risk, but also existing vulnerabilities such as low levels of development, poor governance, political instability and expected future trends such as population growth, rapid urbanization, and increasing land and water scarcity. Qualitative and quantitative scenarios will need to be developed at the country level and potentially at the subnational and regional levels. Combined with detailed economic analysis of adaptation options, these multifaceted risk assessments and scenarios should serve as the basis for developing comprehensive and robust adaptation plans. The National Adaptation Programmes of Action (NAPAs), with the financial support of the United Nations Framework Convention

on Climate Change, could be key mechanisms for mainstreaming climate change into development planning, but progress on NAPAs has been slow.

Climate change can also become the stimulus for implementing difficult but necessary changes to the status quo. Rising prices of carbon, food, fuel, and environmental resources due to climate change could stimulate significant policy and investment opportunities. The IMPACT model is used to estimate the required adaptation investments in agricultural research, irrigation, and rural roads in Asia and the Pacific under alternative climate change scenarios. Adaptation investment costs are defined in this paper as the amount needed to reduce the level of child malnutrition projected in 2050 under a climate change scenario to the levels that would prevail in a no-climate change scenario. The study estimates that, to offset the negative impacts of climate change in Asia, additional spending in the agriculture sector of $168–$201 billion is needed over the period 2010–2050. This figure is above the amounts that are projected to be spent on agriculture under baseline assumptions of $350–$388 billion total or $4.9–$5.8 billion per year, and translates into an additional $4.2–$5 billion per year. Agriculture sector expenditures would need to increase by two-thirds to 2050. The bulk of this additional spending (over 60%) should be dedicated to enhancing investments in agricultural research and development, which has been steadily decreasing over time, both in Asia and the rest of the world. Attention must also be paid to maintaining adequate access to roads in rural areas as they expand to sustain the integration of rural agricultural markets with national and world market forces. The role of irrigation, especially in light of the coming environmental stresses posed by climate change, is also important.

Governance of adaptation implementation

Effectively planning and implementing climate change adaptation for agriculture requires the engagement of a core ministry, such as the Ministry of Finance or Planning, alongside the Ministry of Agriculture, to ensure strong government support. The core capacities of these entities will need to be strengthened in the areas of climate forecasting and scenario planning. Adaptive and flexible management will be essential. The broadening nature and increasing severity of potential climate impacts in a given area and the unavoidable uncertainties associated with predicting these impacts require innovative approaches to management and development that go beyond centralized prediction and control practices. Moreover, effective cooperation among governments in Asia and the Pacific is necessary to ensure sound implementation of adaptation and mitigation strategies in their respective countries, as well as to explore financial means to address climate change.

Better risk-sharing policies, likely provided by both the government and markets, such as weather-based crop insurance, need to be tested and implemented. An appropriate balance between public sector efforts and incentives, such as capacity building, the creation of risk insurance, and private investment, needs to be struck so that the burden can shift away from poor producers.

Experience with collective action in other types of natural resource management suggests that systems that are developed in a top-down manner and which do not engage local people in designing them are unlikely to create viable institutions that operate at the local level in the long run. This experience serves as a warning against focusing only on national-level negotiations and systems for climate change mitigation or adaptation, because they are unlikely to create effective institutions to execute the programs, especially among smallholders.

Markets also play a coordination function, ranging from global to local. The question of when market (rather than state or collective action) institutions work best depends not so much on scale but on issues of transaction costs and attitudes toward markets. Market-based approaches for managing environmental services in response to climate change (such as water pricing, PES, and carbon trading) will be increasingly important. Successful experience—such as the case of organic agriculture development, which has been the most rapidly growing sector in agricultural trade and is uniquely pro-poor—should be further investigated to extract lessons.

The importance of financing adaptation

The outcome of negotiations on a new international architecture for climate change policy will have profound implications for development financing for adaptation in Asian agriculture. Therefore, stakeholders need to emphasize the importance of adaptation and the synergies with mitigation in the agriculture sector in their recommendations and negotiations.

Specifically in Asia and the Pacific, the Asian Development Bank (ADB) is supporting the creation of regional funding modalities. The main mechanism in the region available for both adaptation and mitigation is the Climate Change Fund, with an initial contribution of $40 million. Two other smaller funding sources have been created—the Water Financing Partnership Facility (WFPF) and the Poverty and Environment Fund (PEF). The WFPF has secured donor commitments totaling $26 million, while the PEF has a more modest $3.6 million budget.

In addition, the private sector—the insurance and reinsurance industries in particular—has started to engage in adaptation activities in developing countries. The most advanced initiatives have been developed by two global reinsurance companies, Munich Re and Swiss Re. These initiatives focus on developing new risk-transfer products such as microinsurance, weather and crop insurance, and other mechanisms such as risk pooling and disaster-related bonds. A set of pilot programs is currently underway in various developing countries, and implementing partners are assessing their efficacy and the overall business case for engagement.

Important Synergies between Adaptation and Mitigation

Asia and the Pacific is a key emitter of agricultural GHG through fertilizers and soils (nitrous oxide or N_2O), as well as livestock and rice production (methane or CH_4). Emissions in Asian agriculture are expected to increase due to the growth in food production required to feed a larger, wealthier population.

Contributing to emission reductions

The global technical mitigation potential of all strategies in the agriculture sector is 5,500–6,000 megatons of carbon dioxide equivalent per year (Mt CO_2-eq/yr) by 2030. Of this estimate, carbon sequestration accounts for nearly 90% of the potential, and CH_4 mitigation and soil N_2O emission reductions account for 9% and 2%, respectively. Across the subregions of Asia, up to 50% of these emissions (approximately 1,100–3,000 Mt CO_2-eq/yr) can be mitigated by 2030 for all GHGs, much of which can be achieved through the implementation of zero- and low-cost technologies that enhance soil carbon sequestration. Key low- or no-cost GHG mitigation activities in Asia and the Pacific include low- or no-till and other sequestration methods, as well as reducing CH_4 emissions from rice fields. The PRC and India could each reduce CH_4 emissions from rice fields by 26% over the baseline scenario at low cost (that is, less than $15 per ton of CO_2-eq) by 2020. Using high-yielding crop varieties, shifting to rice and/or wheat production systems, and alternating dry/wet irrigation, are strategies that both mitigate emissions and build resilience by conserving water, reducing land requirements, and reducing fossil-fuel use.

Asia could potentially reduce emissions by 276.79 Mt CO_2-eq/yr at a carbon price of $20 per ton of CO_2-eq, which represents approximately 18% of the total global economic potential (including soil carbon sequestration). At this price, the benefit stream from agricultural mitigation in Asia could amount to more than $5.5 billion a year.

The role of biofuels

The use of high-yielding feedstock crops grown on existing cropland or degraded lands for biofuel production has the potential to offer carbon savings compared with the use of conventional fossil fuels. The potential of biofuels to reduce carbon emissions, however, is highly dependent on the nature of the production process. The current generation of crop-based biofuels has had a low or even negative effect on carbon mitigation when land use change for biofuel production is taken into account. Ensuring that biofuel production does not create negative tradeoffs with food and land markets, land use change, biodiversity, and environmental degradation, will require careful policy design, as well as subsequent monitoring.

From the farmer's point of view, biofuels are a cash crop that would generate higher incomes. Yet, while biofuel producers will likely benefit from the creation of new markets for their crops, the competition between food and fuel markets and the subsequent impact on food prices may outweigh the benefits of income generation under current biofuel technologies. Projections show that the prices of all feedstock commodities—cassava, maize, oil seeds, sugar, and wheat—will increase if biofuel expansion continues without significant breakthroughs in technology. For example, in a high biofuel scenario, depending on the rate of expansion, the price of oil seeds increases by 20%–40% by 2050 compared to the baseline scenario. While these projections assume baseline productivity growth, they are an important illustration of the tradeoffs that crop-based biofuels will likely present with food security—even in the absence of climate change.

Countries in Asia and the Pacific are stepping-up investments in biofuel production capacity. Indonesia, Malaysia, and the Philippines have national blending targets for biofuels, while countries like India and Thailand are making significant investments in conversion technologies and expanding the production of key feedstocks. The most widely produced feedstock crop is oil palm for biodiesel in Southeast Asia. Oil palm production on degraded lands would provide net carbon savings, but the crop is currently considered a cause of deforestation in the region, and oil palm cultivation on deforested land is currently up to 10 times more profitable to landowners than preserving the land for carbon credits in the voluntary market. Thus, developing formal carbon markets to pay for environmental services, such as avoided deforestation, may be critical mitigation policies in the region. Rather than subsidizing less efficient biofuels, governments should invest in developing the next generation of cellulosic biofuels or in improving the efficiency of sugarcane-based ethanol, which is currently the most efficient crop-based biofuel. In addition, the broader treatment of biomass energy sources, such as biogas and fuelwood alternatives that provide GHG savings and low-cost energy, should be promoted.

Agricultural mitigation could provide benefit streams to smallholder farmers

There is significant potential 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 important co-benefits for soil fertility and long-term agricultural productivity.

As with adaptation, the outcome of international climate change negotiations will have major effects on the role of agriculture in mitigation. Actions toward including agriculture in a post-Kyoto regime should be taken now, with a focus on integrating smallholder farmers in carbon markets. Soil carbon sequestration has the highest technical potential

for mitigation in the agriculture sector, but carbon sequestration projects are not included in the Clean Development Mechanism (CDM). However, there are feasibility issues in selling agricultural soil carbon within a market-based credit-trading program related to current carbon markets rules, as well as to transaction costs when working with smallholder farmers. To ensure that emerging carbon markets benefit developing countries, rules for carbon trading—whether for CDM or a more flexible successor mechanism—should encourage the participation of small farmers and protect them against major livelihood risks, while at the same time meeting investor needs and rigorously ensuring carbon goals. New rules can support these goals by promoting measures to reduce transaction costs, establishing international capacity-building and advisory services, and investing in advanced measurement and monitoring.

Synergies between adaptation and mitigation strategies need to be actively pursued

Synergies between adaptation and mitigation strategies exist, but many have yet to be exploited. Many changes in agricultural and water management practices, as well as crop productivity improvements, contribute to adaptation while also fulfilling mitigation objectives. Examples include zero- or low-till land management practices, soil and water conservation techniques, and alternative wetting and drying for rice production. These practices can help build ecosystem resilience and generate income, helping to ensure food security in the region. Given that benefit streams from global carbon markets are not generally available to mitigation in agriculture, synergies between adaptation and mitigation are undervalued. It will therefore be important to incorporate agriculture, forestry, and other land uses into carbon markets through global commitments, and to strengthen and simplify monitoring rules.

Adoption by farmers of any mitigation technology depends on their assessment of its effects on their well-being. It is important to distinguish between two types of mitigation strategies. The first is financially attractive but involves upfront investments or significant technical capacity unavailable to farmers. Policies and programs to improve access to credit and provide technology and management training will accelerate adoption of these desirable mitigation strategies, as farmers see it in their long-term interest to do so.

The second type would result in an economic loss, either because of reduced income or increased risk. Adoption by farmers will require some form of payment for these services. Essentially, society will need to pay farmers to provide the mitigation service, e.g., PES. To be most effective, PES programs identify, and pay for, only those services with the greatest mitigation benefit per unit of payment. Choice of payment mechanism can have a substantial effect on adoption of a mitigation technology and costs.

Conclusions and Priority Actions

- Climate change poses a major challenge for agriculture at the global level and in Asia and the Pacific. Given the role of agriculture in employment, economic development, and global food security, adverse impacts on agriculture are of particular concern. Decreased agricultural production in most of the region owing to climate change will result in higher food prices and decreased food consumption, especially among the poor, leading to an increased number of people at risk of hunger. Areas that are already lagging behind in achieving important human well-being outcomes will likely suffer the most.

- Sound development policies are necessary but not sufficient to adapt agriculture to climate change in Asia and the Pacific as well as elsewhere. A pro-growth, pro-poor development agenda that supports agricultural sustainability and includes better targeting to climate change impacts will improve resilience and climate change adaptation. Because climate change has a negative impact on agricultural production in most developing countries, achieving any given 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. Public–private partnerships will play an important role in achieving advances in these areas. Even so, there is still uncertainty about where climate changes will have impacts. This uncertainty can be reduced through more spatial analysis and improved information.

- 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 financial means for addressing climate change. Regional cooperation, even when not initially designed to deal with climate change, can provide essential building blocks for climate change adaptation. ADB-sponsored regional programs have important roles to play. The Central Asian Countries Initiative for Land Management (CACILM) project supports regional cooperation on sustainable land management, including transboundary issues, which will generate greater knowledge-sharing and impacts than individual country initiatives could accomplish. The Greater Mekong Subregion (GMS) Core Environment Program assesses risks and vulnerabilities of the GMS countries from climate change within the GMS Economic Corridors. This initiative focuses, among other things, on local livelihoods and ecosystem services; agriculture and food security; energy (particularly hydropower); and tourism (specifically ecotourism)—all of which can contribute to climate change adaptation and mitigation.

- Funding modalities related to climate change (and accessibility of these funds by the vulnerable people), such as a reformed CDM that includes agricultural mitigation and streamlined administration, payment for environmental services, or other mechanisms to mitigate GHGs, must be implemented by Asian development planners and policy makers. Climate action plans, including NAPAs, need to be integrated into Poverty Reduction Strategy Papers and 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.

- Beyond Asia and the Pacific, agricultural adaptation and mitigation need to be incorporated into the ongoing international climate negotiations. This will help to assure that appropriate incentive mechanisms and innovative institutions, technologies, and management systems can be developed, along with the necessary financing opportunities. Mitigation strategies that support adaptation should be favored. Final negotiation outcomes will have direct consequences for adaptation requirements. Also at the international level, agricultural trade should be liberalized to help spread the risks of climate change and thus increase resilience to its impacts.

Based on our results, the study identifies six key messages for the governments of 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 to those countries with the highest vulnerability to climate change.** These highly vulnerable countries are Afghanistan, Bangladesh, Cambodia, India, Lao PDR, Myanmar, and Nepal, taking into account the 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 in 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 immediately 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

investments in market and climate information and disaster preparedness information systems. Key policy measures to be implemented include those that improve the efficient use of land, water, and ecosystems; reduce inefficient subsidies; support the development of carbon markets and other ecosystem services; and promote open and transparent trade. Remaining uncertainty as to where climate change will have impacts should be reduced through more spatial analysis, as well as 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.** Completion of the Doha Round of Agricultural Trade Negotiations would be an important step forward.

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 of current and future funding mechanisms to address climate change.** Regional cooperation initiatives in Asia, such as CACILM and 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 and the South Asian Association for Regional Cooperation, 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.