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# Economics of Adaptation to Climate Change

# VIETNAM

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# *Economics of Adaptation to Climate Change*

## VIETNAM

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# Acronyms

| | |
|---|---|
| **ADB** | Asian Development Bank |
| **AEZ** | Agroecological Zone |
| **CGE** | Computable general equilibrium |
| **CMI** | Climate moisture index |
| **CSIRO** | Commonwealth Scientific and Industrial Research Organisation |
| **DFID** | Department for International Development (UK) |
| **EACC** | Economics of Adaptation to Climate Change |
| **FHH** | Female-headed household |
| **GCM** | General circulation model |
| **GDP** | Gross domestic product |
| **GIS** | Geographical information system |
| **GoV** | Government of Vietnam |
| **GSO** | General Statistics Office |
| **IAE** | Institute for Agriculture and Environment |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **MARD** | Ministry of Agriculture and Rural Development |
| **MoLISA** | Ministry of Labor, Invalids, and Social Affairs |
| **MoNRE** | Ministry of Natural Resources and Environment |
| **NCAR** | National Center for Atmospheric Research |
| **NGO** | Non-governmental organization |
| **NTP-RCC** | National Target Program to Respond to Climate Change |
| **ppt** | Parts per thousand |
| **SIWRP** | Southern Institute for Water Resources Planning |
| **SLR** | Sea level rise |
| **UNDP** | United Nations Development Programme |
| **VHLSS** | Vietnam Household Living Standards Survey |
| **VNĐ** | Vietnamese Đong |

*Note:* Unless otherwise noted, all dollars are U.S. dollars, all tons are metric tons.

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# Executive Summary

The Economics of Adaptation to Climate Change (EACC) study aims to support countries to understand the risks posed by climate change and to design better strategies to adapt to climate change. In doing so, a key objective of the study is to help decision makers at the national level to integrate robust adaptation strategies into their development plans and budgets in a context of high uncertainty, competing needs, and limited financial resources. In addition to providing estimates of adaptation costs at the global level,[1] the EACC study has implemented country-level studies for Bangladesh, Bolivia, Ethiopia, Ghana, Mozambique, Samoa, and Vietnam.[2]

This report provides a synthesis of key findings of sector studies undertaken in Vietnam in the context of the EACC study. The sector studies were on agriculture (Zhu & Guo 2010), a separate computable general equilibrium [CGE] analysis based on agriculture findings (Adams et al. 2010), aquaculture (Kam et al. 2010), forestry (Phuong et al. 2010, Almeida et al. 2010), social (McElwee et al. 2010), and coastal ports (VIMARU 2010). Further details can be found in the individual sector reports prepared by teams of national and international experts.

## Vulnerability to Climate Change

Vietnam is a long narrow country consisting of an extensive coastline, two major river deltas, and mountainous areas on its eastern and northeastern borders. Vietnam is heavily exposed to the risks of weather variability and climate change. Its vulnerability to weather risks has given the country experience in designing and implementing measures to mitigate the effects of droughts, flooding, storms, and similar events on agriculture and other sectors of the economy. Assessing the potential impacts of climate change and determining how best to adapt represents a new challenge, for which past experience may be a guide but which is accompanied by large uncertainties.

In June 2009, the Ministry of Natural Resources and Environment (MoNRE) published Vietnam's official scenario for climate change. The MoNRE scenario falls in the middle of a range of

1 At the global level, the EACC study estimates that it will cost between $70 and $100 billion each year to adapt to climate change over the period 2010 to 2050.

2 The study was funded by the governments of the United Kingdom, Netherlands, and Switzerland. Further details may be found at: www.worldbank.org/eacc. In addition, the synthesis report from Vietnam and the six underlying national sector reports can be downloaded from the Environment site of the World Bank's web site for Vietnam: www.worldbank.org/vn/environment.

**TABLE ES-1 REGIONAL VULNERABILITY TO CLIMATE CHANGE**

| Region | North-west NW | North-east NE | Red River Delta RRD | North Central Coast NCC | South Central Coast SCC | Central High-lands CHL | South-east SE | Mekong River Delta MRD |
|---|---|---|---|---|---|---|---|---|
| **EXPOSURE** | | | | | | | | |
| Storms | 1 | 3 | 4 | 4 | 4 | 2 | 2 | 3 |
| Flooding | 1 | 1 | 4 | 4 | 4 | 2 | 2 | 4 |
| Salinity | 0 | 0 | 1 | 2 | 2 | 0 | 1 | 4 |
| SLR | 0 | 0 | 2 | 2 | 2 | 0 | 3 | 4 |
| Landslides | 3 | 3 | 1 | 3 | 3 | 2 | 1 | 1 |
| Drought | 2 | 2 | 1 | 4 | 4 | 4 | 2 | 2 |
| **Average** | **1.2** | **1.5** | **2.2** | **3.2** | **3.2** | **1.7** | **1.8** | **3.0** |
| **SENSITIVITY** | | | | | | | | |
| Poverty | 4 | 3 | 2 | 4 | 2 | 4 | 1 | 2 |
| Economic diversification | 4 | 4 | 2 | 4 | 3 | 4 | 2 | 2 |
| Education | 4 | 3 | 1 | 2 | 2 | 2 | 1 | 3 |
| Health & sanitation | 4 | 1 | 2 | 1 | 1 | 1 | 1 | 3 |
| Ethnic minorities | 4 | 3 | 0 | 1 | 1 | 4 | 1 | 2 |
| Women & children | 4 | 3 | 1 | 2 | 3 | 3 | 1 | 2 |
| Migrants | 0 | 0 | 2 | 2 | 1 | 4 | 4 | 1 |
| Urban households | 0 | 0 | 2 | 1 | 1 | 0 | 4 | 3 |
| **Average** | **3.0** | **2.1** | **1.5** | **2.1** | **1.8** | **2.8** | **1.9** | **2.3** |

alternative climate scenarios for Vietnam when these are arranged by their climate moisture indices. In addition to the MoNRE scenario, the EACC study has made use of two other climate scenarios—Dry (IPSL-CM4) and Wet (GISS-ER)—which represent the extremes of the distribution by climate moisture indices.

Rainfall projections across seasons are of particular interest. The dry seasons are projected to get drier, with the March–May rainfall reductions being higher in the southern part of the country; the wet seasons are projected to get wetter, with the June–August rainfall increases being higher in the northern part of the country. Hence, it is expected that rainfall will be concentrated even more than now in the rainy season months, leading to an increase in the frequency, intensity, and duration of floods, and to an exacerbation of drought problems in the dry season. Sea level is projected to rise approximately 30 cm by 2050 and up to 75 cm by 2100 under the medium scenario.

An analysis of vulnerability to climate change at the sub-national level was carried out as part of the social analysis. Exposure to climate change is assessed by considering the number of households potentially threatened by the effects of storm, flooding, salinity intrusion, sea level rise (SLR) and storm surges, landslides and flash floods, and drought. Each region is assigned to categories ranked from 0 to 4 (low to severe exposure).

Similarly, sensitivity to the impacts of climate is assessed on criteria that reflect vulnerability to the consequences of climate change based on specific socioeconomic characteristics—poverty, economic diversification, education, and health and sanitation—and for specific social groups, including ethnic minorities, women and children, migrant populations, and urban populations. Again, each region is assigned to categories ranked from 0 to 4 (low to extreme sensitivity). Unweighted averages of the classifications were computed to generate indices of exposure and sensitivity. These are shown in Table ES-1 (see also Figure 13 in main text which shows the regions on a map).

The analysis indicates that exposure to the effects of climate change is highest in the Central Coastal regions (NCC & SCC) and in the Mekong River Delta. On the other hand, sensitivity to the effects of climate change is highest in the North-West and Central Highland regions. The correlation between exposure and sensitivity is negative, so that regions with high exposure tend to have low sensitivity and vice versa. The only region with indices that are above the average on both measures is the Mekong River Delta.

## Methodology

The sectors were chosen based on interest of the Government, availability of data, the opportunity to pilot different methodological approaches, and the feasibility of carrying out an analysis. Some other sectors that were not looked at (e.g., urban infrastructure) could well be be subject to more important climate change impacts. Detailed studies were carried out for agriculture (crop production), aquaculture, forestry, and coastal ports, as well as a broader study on social vulnerability. Each of the sector studies follows a broadly similar approach with the following steps:

*Step 1:* Establish a baseline scenario consisting of projections of land use, production, value-added, population growth, urbanization, and other variables without climate change. This provides the reference scenario against which the impacts of climate change without and with adaptation are measured.

*Step 2:* Consider the relevant climate variables for the sector and identify changes projected to 2050 or beyond for each of the climate scenarios. This makes use of detailed information on precipitation by season and/or region.

*Step 3:* Identify the impact of changes in climate on resource productivity and land use. This included, for example, the effect of changes in seasonal temperatures on rice yields or of seasonal precipitation on coffee yields, as well as the effect of flooding or saline intrusion on the amount of land that can be used for rice production in the Mekong River Delta.

*Step 4:* Using geographical information systems (GIS) and other techniques, combine the information collected in Steps 2 and 3 to estimate the overall impact of climate change on land use and production by comparing estimates of yields and production under (a) no climate change, and (b) with climate change but no adaptation.

*Step 4A:* For agriculture, incorporate the results from Step 4 into a macroeconomic model to assess the consequences of changes in agricultural output on agricultural prices, trade, GDP, economic activity in other sectors, and household consumption.

*Step 5:* Identify opportunities for (a) autonomous adaptation undertaken by farmers and other producers in responses to changes in climate and other conditions, and (b) planned adaptation, which is likely to be initiated and at least partly funded by the government.

*Step 6:* Estimate the production of crops, timber, and so on under the new climate conditions after the adaptation measures have been implemented.

This provides the basis for identifying (a) the effect of climate change with adaptation (the difference between the baseline scenario and the scenario of climate change with adaptation), and (b) the impact of adaptation itself (the difference between the scenarios of climate change without and with adaptation).

*Step 6A:* As for Step 4A, incorporate the results from Step 6 into the macroeconomic model to assess the benefits of adaptation in terms of aggregate and sectoral economic activity and household consumption.

Many of the adaptation options are "no regrets" options that increase yields or production even without climate change. This is not invariably the case, for example there would be no need to upgrade ports if sea level and storm surges do not change. However, for agriculture and other sectors it is difficult to identify measures that are only justified under a specific set of climate conditions. For these sectors, adaptation is often a matter of doing things that would in any event have been economic under a wide range of climate conditions.

## Agriculture

The impact of the alternative climate scenarios on crop production has been examined using projections of runoff, which affects the availability of irrigation water, plus agronomic models that take account of temperature and rainfall patterns, water availability for rainfed and irrigated crops, and other factors to estimate the impact of climate change on crop yields.

Changes in yields *without adaptation* vary widely across crops, agroecological zones, and climate scenarios. As for other EACC studies, the results reported do not take account of $CO_2$ fertilization, because of the uncertainties about the extent of this effect; taking this into effect might have reduced the severity of some predicted productivity declines. For rice, the Dry scenario would lead to reductions in yields ranging from 12 percent in the Mekong River Delta to 24 percent in the Red River Delta. The primary factors influencing rice yields are the increase in average temperatures and seasonal reductions in runoff.

There would be more extensive inundation of crop land in the rainy season and increased saline intrusion in the dry season as a consequence of the combination of sea level rise and higher river flooding. For the Mekong River Delta, it is estimated that about 590,000 ha of rice area could be lost due to inundation and saline intrusion, which accounts for about 13 percent of today's rice production in the region.

Table ES-2 shows the potential impact of climate change without adaptation under alternative climate scenarios on production of six major crops or crop categories relative to a 2050 baseline of no climate change. Paddy rice production may fall by 5.8 (MoNRE) to 9.1 (Dry) million tons (mmt) per year.

**TABLE ES-2 CHANGE IN CROP PRODUCTION IN 2050 DUE TO CLIMATE CHANGE WITH NO ADAPTATION (MILLION METRIC TONS)**

| Climate scenario Impact | Paddy rice | | | Maize | Cassava | Sugar cane | Coffee | Vegetables |
|---|---|---|---|---|---|---|---|---|
| | Yields | Sea level | Total | Yields | Yields | Yields | Yields | Yields |
| Dry | -6.7 | -2.4 | -9.1 | -1.1 | -1.9 | -3.7 | -0.4 | -1.7 |
| Wet | -5.8 | -2.5 | -8.4 | -1.0 | -2.6 | -2.9 | -0.4 | -3.1 |
| MoNRE | -3.4 | -2.4 | -5.8 | -0.3 | -0.6 | -1.4 | -0.1 | -0.9 |

*These figures are not forecasts of what will actually happen.* Farming involves a continuous process of adaptation to weather, technology, economic and other influences, so adaptation will certainly take place. Rather, these projections provide a starting point—based on the best available information and subject to substantial uncertainty—for (a) understanding the potential importance of climate change for crop production holding other factors constant, and (b) assessing the type and scale of adaptation that may be required, which will require a combination of autonomous adaptation (by farmers) and planned adaptation (as a consequence of government policy).

Further, this assessment of the potential impact of climate change on crop production needs to be interpreted in a larger context. Changes in diets and consumer preferences with falling demand for rice, market liberalization, trade (which will expose Vietnam to lower-cost competition), and conversion opportunities to aquaculture and more salt-tolerant varieties will all have important effects on the demand for and the supply of agricultural products over the coming decades. The impacts of climate change have to be assessed against a background of wider economic and social development.

***Macroeconomic impacts.*** As in the other EACC country studies, a computable general equilibrium (CGE) model has been used to examine the macroeconomic impacts of climate change. In Vietnam, the CGE model was only used to take into account the effects of climate change and adaptation for the agricultural sector, so it does not attempt to take account of all of the macroeconomic impacts of climate change. The CGE model establishes a baseline composition of economic activity up to 2050, given data and assumptions about interindustry linkages for 158 sectors, including regional crop production for the six crops examined above, consumption for ten rural/urban household groups, population, investment, and productivity growth. This is used to simulate the effect of exogenous "shocks;" that is, deviations from the baseline scenario, such as a reduction in crop production due to climate change. The model is run assuming that the aggregate level of investment and savings remains constant in real terms, so that aggregate consumption moves with gross domestic product (GDP). The model takes account of the effects of exogenous shocks on industry and services, international trade, commodity prices and the distribution of consumption. A broad picture of its results may be obtained by examining changes in total GDP, aggregate consumption, and other variables under

### TABLE ES-3 MACROECONOMIC EFFECTS OF CLIMATE CHANGE WITHOUT/WITH ADAPTATION IN 2050(PERCENTAGE DEVIATIONS FROM BASELINE WITH NO CLIMATE CHANGE)

| | *No adaptation (%)* | | | *With adaptation (%)* | | | *Adaptation benefits (%)* | | |
|---|---|---|---|---|---|---|---|---|---|
| | *Dry (1)* | *Wet (2)* | *MoNRE (3)* | *Dry (4)* | *Wet (5)* | *MoNRE (6)* | *Dry (7)* | *Wet (8)* | *MoNRE (9)* |
| GDP | -2.4 | -2.3 | -0.7 | -1.1 | -0.7 | 0.7 | 1.3 | 1.6 | 1.3 |
| Aggregate consumption | -2.5 | -2.5 | -0.7 | -1.4 | -0.8 | 0.6 | 1.1 | 1.7 | 1.3 |
| Agricultural value-added | -13.9 | -13.5 | -5.8 | -3.8 | -3.4 | 5.4 | 10.0 | 10.1 | 11.2 |
| REGIONAL GDP | | | | | | | | | |
| North-Central Coast | -6.6 | -6.1 | -2.6 | 0.5 | -0.3 | 4.8 | 7.1 | 5.8 | 7.4 |
| South-East | 1.1 | 0.8 | 1.0 | 0.0 | 1.1 | 0.2 | 1.1 | 0.3 | 0.9 |
| RURAL HOUSEHOLD CONSUMPTION | | | | | | | | | |
| Bottom quintile | -6.5 | -6.3 | -2.6 | -1.9 | -1.4 | 2.4 | 4.7 | 4.9 | 5.0 |
| Top quintile | -1.6 | -1.7 | -0.4 | -1.5 | -1.0 | 0.0 | 0.1 | 0.7 | 0.0 |

the alternative climate scenarios in 2050 relative to a baseline with no climate change.

Total GDP and aggregate consumption in 2050 with no adaptation will be 2.4–2.3 percent lower than the baseline under the Dry/Wet scenarios but only 0.7 percent lower under the MoNRE scenario, shown in columns (1) through (3) of Table ES-3. The reason for the reduction in GDP is the decline in agricultural value-added of 13.9/13.5 percent under the Dry/Wet scenarios, which is marginally offset by small increases in value-added in industry and services. There are significant differences between the impact of climate change on different regions, as illustrated by the estimates for changes in regional GDP for the North- Central Coast and South-East regions. The gain in the South-East is a consequence of the concentration of industry and services in the region.

The impact on household incomes is skewed, with greater losses for those in the bottom rural quintile (the poorest 20 percent of rural households arranged by expenditure per person) than for the top quintile. Poor rural and urban households are most vulnerable because they rely more heavily on the agricultural sector for their incomes and they spend a higher proportion of their income on food, which becomes relatively more expensive.

***Adaptation in agriculture.*** The study examined a range of adaptation options including autonomous adaptations undertaken by farmers as well as planned adaptation underpinned by government spending in areas that will enhance the capacity of farmers to adapt. The autonomous adaptations include changes in sowing dates, switching to drought-tolerant crops, adoption of salinity-tolerant varieties of rice, adoption of new varieties for other crops, and switching to rice-fish rotations. The planned adaptations focus on (a) increased spending on research, development, and extension with the goal of raising average crop yields by 13.5 percent relative to the baseline, and (b) extending the area of irrigated land by about 688,000 ha, roughly half for rice and the remainder mainly for maize and coffee. The total cost of these measures is estimated at about $160 million per year at 2005 prices without discounting over the period 2010–50.

Deviations in GDP and other macroeconomic variables from the baseline with adaptation for the alternative climate scenarios are shown in columns (4) through (6) of Table ES-3, while columns (7) through (9) give the net benefits of adaptation after allowing for the costs that are incurred. The adaptation measures substantially reduce the impact of climate change under all scenarios. The expenditures on adaptation for agriculture are clearly justified as the ratio of their benefits to the costs that are incurred is much greater than 1. The combination of the MoNRE scenario with adaptation leads to an increase in aggregate consumption, indicating that some, perhaps many, of the adaptation measures are "no regrets" options that would be justified even without climate change.

An important aspect of adaptation is that it offsets most of the disproportionate impact of climate change on poorer households. The bottom quintile of rural households benefit most from adaptation and the gap between the changes in household consumption for the bottom and top quintiles is almost eliminated. Adaptation partly or wholly offsets both the reduction in agricultural incomes and the increase in food prices that accompany climate change without adaptation.

Investments in flood and coastal protection were not incorporated in the macroeconomic analysis. Separate studies have indicated that the costs of building/upgrading sea dikes and flood defenses to protect urban infrastructure and the most valuable agricultural land would be about 1 percent of total investment—about $540 million per year at 2005 prices.

## Other Sectors

***Aquaculture.*** Aquaculture, especially in the Mekong River Delta, is an important source of employment and rural income. It is estimated that some 2.8 million people are employed in the sector, while export revenue is expected to be about $2.8 billion in 2010. Higher temperatures, an increased frequency of storms, sea level rise, and other effects of climate change are likely to affect fish physiology and ecology as well as the operation of aquaculture. Some fish species, such as catfish, may grow more rapidly with higher temperatures but be more vulnerable to disease. The main impacts of climate change on aquaculture seem likely to be a consequence of increased flooding and salinity.

Parts of the aquaculture sector, particularly catfish farming, currently face uncertain economic prospects, particularly as a result of rising prices for feedstuffs and the costs of maintaining water quality. Without adaptation, it is likely that climate change will reduce profit margins, so that only the most efficient aquaculturists who adopt best practices will survive. Successful adaptation will require a combination of better feed conversion and improvements in marketing together with investments in upgrading dikes to reduce flooding and salinity intrusion that will benefit other sectors as well as aquaculture. Semi-intensive and intensive shrimp producers may incur additional costs of water pumping to maintain water and salinity levels. Since the industry is both capital-intensive and growing rapidly, adaptation is likely to be autonomous with the costs borne by operators. The total cost of adaptation is estimated at an average of $130 million per year from 2010–50, which is equivalent to 2.4 percent of total costs.

***Forestry.*** The impact of climate change on forests is likely to be complex and long term. For natural forests, the analysis suggests that there will be a substantial reduction in the area of land that is suitable for humid semi-deciduous forest, which would be replaced by other forest types. Mangrove forests will be affected by sea level rise unless they are able to migrate inland. The area of land under plantation forests with short rotations has increased rapidly over the past 20 years. A forestry growth model suggests that climate change will increase the variability of plantation yields across the country without having a major impact on the average yield. Thus, an important adaptation need will be to ensure the best match between soil, climate, and management practices to obtain the highest yields from plantations.

A range of adaptation options was considered. The key measures identified were (a) changes in land use planning to facilitate the migration of mangroves; (b) adoption of plantation species and methods of silviculture that are more resilient to droughts; (c) improvements in pest management, including genetic selection and integrated pest control strategies; and (d) use of herbicides or biological controls to limit the effect of exotic weed species on tree growth. The financial costs of adaptation are likely to be modest, but the institutional issues may be more difficult to deal with.

***Coastal ports.*** Along its 3,200 km coastline, Vietnam has a total of 116 ports. In addition, new terminals are being constructed and planned all along the coastline, particularly in the south around Ho Chi Minh City and in the north around Hai Phong. Given the nature of its location, this infrastructure is at risk from sea-level rise and storm surges. Impacts include accelerated depreciation of structures and flooding of port facilities such as warehouses.

Adaptation options examined in the study include (a) raising quay walls, (b) improving surface drainage to reduce flooding, and (c) increased expenditure on the maintenance and replacement of port infrastructure. The cost of adaptation for all ports would be less than $500 million, or about $12 million per year without discounting at 2005 prices.

## Social Analysis

Up to now government policies have focused on sector-wide assessments for the whole country and on "hard" adaptation measures—such as sea dikes, reinforced infrastructure, and durable buildings. Little attention has been paid to "soft" adaptation measures like increasing institutional capacity or the role of collective action and social capital in building resilience. Most adaptation options identified at the field sites and during participatory scenario development workshops were aimed at improving response capacity and disaster risk reduction—such as forecasting, weather monitoring—and managing climate risk. Notably, adaptation options that reduce poverty and increase household resilience or that integrate climate change into development planning were not emphasized.

Overall, many of the adaptation options observed at the field sites and/or proposed in workshops were highly cost-effective and do not require large expenditures. Moreover, they were largely in line with the adaptation options considered for the climate scenarios in the sector analyses. These adaptation measures included shifting planting dates, adopting drought-tolerant crops, and switching to salinity-tolerant varieties of rice. The diversity of preferred adaptation responses reflected the impressive variety of Vietnam's vulnerability zones and confirm the need for a mix of both autonomous and planned adaptation, a mix of hard and soft options, and adaptation to be carried out at the national, subnational, and community levels.

## Lessons and Recommendations

Climate change will have a significant impact on some regions and sectors of Vietnam's rural economy. Still, in macroeconomic terms the impacts of climate change on agriculture and related sectors, even with no adaptation, appear to be relatively modest. In practice, there will be substantial autonomous adaptation even without active government intervention, since farmers will change the crops and crop varieties that they grow and their methods of farming.

The major concern is the extent to which climate change will hit poor households, partly because of the decline in agricultural incomes and partly because of an increase in food prices relative to the general cost of living. The lowest 20 percent of households—either urban or rural—arranged by household expenditure per person will experience larger reductions in real standards of living due to climate change than the top 20 percent of households.

Thus, the primary focus of policies to adapt to climate change for the sectors covered under the EACC studies, should be to protect the poor, the vulnerable, and those least able to respond to changing climatic stresses. The goal should be to provide farmers and others with the tools and resources that will enable them to respond to climate change itself and to the new risks that will accompany climate change. The key elements will be:

- Increased expenditures on research, development, and extension for crop production, aquaculture, and forestry to develop new crop varieties that are more tolerant to drought, salinity, higher temperatures early in the growing season, and so on. Both the public and private sectors should be involved in efforts to increase yields and productivity.

- Investment in expanding irrigation infrastructure, especially in the central regions where the opportunities for irrigation expansion are greatest. In the short term, this should build upon achieving fuller utilization of existing irrigation infrastructure and improvements in operations and maintenance.

- Increased spending on the maintenance and extension of coastal and flood defenses to minimize the impacts of sea inundations, salinity intrusion, and river flooding, especially in the Mekong River and Red River Deltas.

Many of these expenditures would be justified even without climate change, so adaptation to climate change is primarily a matter of building upon no-regrets measures. Under the intermediate MoNRE climate scenario, the program of agricultural adaptation outlined in this study would increase agricultural incomes relative to the baseline, especially in the Central Highlands region, illustrating the general benefits of the strategy.

If this program of adaptation were to be implemented, the adverse impacts of climate change on poorer households would largely be avoided. There would still be a net loss of agricultural value-added and aggregate consumption in the Wet and Dry climate scenarios, but the magnitude of the losses would be significantly smaller and the skewed impact on the distribution of income would be corrected.

Year-to-year weather variability is much greater than the long-term trends associated with climate change. Policies and systems that can cope effectively with current weather variability will be more successful in adapting to future climate change than those that cannot. Strengthening the capacity of the rural sector to cope with current weather variability and build resilience into such systems will yield benefits both now and in the future. It is also important to collect, analyze, and report data on how the climate is changing in different regions of the country so that those who have to take account of climate change in planning new infrastructure or implementing investment programs should have access to the best possible information.

Climate change, including sea level rise, will affect the country's infrastructure and require expenditures on adaptation. The case study of coastal ports indicated the lesson that the costs of adaptation are likely to be modest. The total cost of protecting existing ports that are exposed to flooding as a result of a higher sea level, combined with greater storm surges, is estimated as no more than $500 million over 40 years, or about 1 percent of planned investment in ports over the period 2010–30.

An equally important lesson from the case study is that it is essential to plan ahead for climate change. Ports that are built over the next 10–20 years should be designed to cope with sea levels and storms to which they may be exposed 50 or more years from now. It may be cheaper to build margins of resilience and safety into new infrastructure than to upgrade assets during the course of their life. The same lesson emerges from the analyses for infrastructure and coastal protection undertaken as part of the EACC global study. The total cost of adaptation for these sectors amounts to about 2 percent of total investment for the Global Wet (NCAR) scenario, and about 1.3 percent of total investment for the Global Dry (CSIRO) scenario, on the assumption that adaptation measures are combined with new investments anticipating climate change up to 2100.

# ONE

# Introduction

As a long narrow country with an extensive coastline, one of the world's major river deltas, and mountains on its eastern and northeastern borders, Vietnam is heavily exposed to the risks of weather variability and climate change. Its vulnerability to weather risks has given the country experience in designing and implementing measures to mitigate the effects of droughts, flooding, storms, and similar events on agriculture and other sectors of the economy. Assessing the potential impacts of climate change—and how best to adapt—represents a new challenge, for which past experience may be a guide, but which is accompanied by large uncertainties.

The potential consequences of climate change have received considerable attention in Vietnam (World Bank 2010). The government has prepared the country's National Target Program to Respond to Climate Change (NTP-RCC), which was adopted in 2008. The strategic objectives of the NTP-RCC focus on assessing the impacts of climate change on sectors and regions in specific periods and developing plans to respond to climate change to ensure the sustainable development of the country. For this purpose, the tasks to be implemented over the period 2009–15 include: (a) enhancing the understanding of the impacts of climate change on socioeconomic activities; and (b) assessing the costs and benefits of measures to respond to climate change.[3]

A question of key interest pertains to the identification of the nature of the adaptation measures available for key sectors of economic activities and regions of the country, and the assessment of the possible costs and benefits of these measures. The current absence of such information represents a significant factor limiting the capacity of governments at all levels to plan and implement the most cost-effective adaptation options.

The *Economics of Adaptation to Climate Change* (EACC) study aims to support countries to understand the risks posed by climate change and to design better strategies to adapt to climate change. A key objective of the study is to help decision makers at the national level to integrate robust adaptation strategies into their development plans and budgets in a context of high uncertainty, competing needs, and limited financial resources. In addition to providing estimates of adaptation costs at the global level,[4]

3 Prime Minister, *Decision No. 158/2008/QĐ-TTg on Approval of the National Target Program to Respond to Climate Change*, Hanoi, December 2, 2008.

4 At the global level, the EACC study estimates that it will cost between $70 and $100 billion each year to adapt to climate change over the period 2010 to 2050.

the EACC study has implemented country-level studies for Bangladesh, Bolivia, Ethiopia, Ghana, Mozambique, Samoa, and Vietnam.[5]

This report provides a synthesis of the key findings of the sector studies undertaken in Vietnam in the context of the EACC study. The sectors covered by the study are agriculture, aquaculture, forestry, social, and coastal ports. Further details can be found in the individual sector reports prepared by teams of national and international experts. Not all vulnerable sectors have been studied, and the studies themselves could not consider all possible impacts or adaptation measures. The analyses do not aim to provide the "final word" on the economics of adaptation in Vietnam. In most cases the studies highlight areas of significant uncertainty pertaining to the projected changes in climate variables, the relationship between these changes and their impacts on resource productivity, and the vulnerability as well as the adaptive capacity of those who will be affected. The findings presented here should be regarded as a starting point to provide guidance for future investigations.

Each of the sector studies follows a broadly similar approach with the following steps:

*Step 1:* Establish a baseline scenario consisting of projections of land use, production, value-added, population growth, urbanization, and other variables without climate change. This provides the reference scenario against which the impacts of climate change without and with adaptation are measured.

5 The study was funded by the governments of the United Kingdom, Netherlands, and Switzerland. Further details may be found at www.worldbank.org/eacc. In addition, the synthesis report from Vietnam and the six underlying national sector reports can be downloaded from the Environment site of the World Bank's web site for Vietnam: www.worldbank.org/vn/environment.

*Step 2:* Consider the relevant climate variables for the sector and identify changes projected to 2050 or beyond for each of the climate scenarios. For some purposes, this requires detailed information on, say, precipitation by season and/or region. An important qualification is that general circulation models (GCMs), used to generate scenarios, are not generally designed to produce reliable projections in such detail. The general direction of change may be well-understood, but there may be wide margins of uncertainty about the precise projections for specific grid cells in specific months. Hence, the necessity of using detailed climate information requires an acceptance of relatively wide margins associated with the projected changes. Some of the potential differences may be captured by examining different climate scenarios, but large residual uncertainty cannot be removed.

*Step 3:* Identify the impact of changes in climate on resource productivity and land use. This includes, for example, the effect of changes in seasonal temperatures on rice yields or of seasonal precipitation on coffee yields as well as the effect of flooding or saline intrusion on the amount of land that can be used for rice production in the Mekong River Delta.

*Step 4:* Using GIS and other techniques, combine the information collected in Stages 2 and 3 to estimate the overall impact of climate change on land use and production.

*Step 4A:* For agriculture, incorporate the results from Step 4 into a macroeconomic model to assess the consequences of changes in agricultural output on agricultural prices, trade, GDP, economic activity in other sectors, and household consumption.

*Step 5:* Identify opportunities for (a) autonomous adaptation undertaken by farmers and other producers in response to changes in climate and other conditions, and (b) planned adaptation, which is likely to be initiated and at least partly funded by the government. Such opportunities include the development and/or adoption of different crop varieties or new species that respond better to the changed climate conditions, plus investments in irrigation and other infrastructure.

*Step 6:* Estimate the production of crops, timber, and so on under the new climate conditions after the adaptation measures have been implemented as a basis for calculating the extent to which adaptation can offset the impacts of climate change without adaptation.

*Step 6A:* As for Step 4A, incorporate the results from Step 6 into the macroeconomic model to assess the benefits of adaptation in terms of aggregate and sectoral economic activity and household consumption.

A final remark about the adaptation options. In many cases, these are "no regrets" options that increase yields or production even without climate change. This is not invariably the case, for example there would be no need to upgrade ports if sea level and storm surges did not change. However, for agriculture and other sectors it is difficult to identify measures that are only justified under a specific set of climate conditions. For these sectors, adaptation is often a matter of doing things that may be economic under a wide range of climate conditions, but either more or better.

# TWO

# Projections of Climate Change and Sea Level Rise

In this section, projected changes in climate variables and sea level are briefly described at the regional and national levels. A general overview of historical and projected future climate change is provided in World Bank (2010).

## Regional Projections

Table 1 summarizes the projected changes in seasonal air temperature and precipitation in Southeast Asia, as reported by the Intergovernmental Panel on Climate Change (IPCC, 2007). Regional averages of temperature and precipitation projections were calculated from a set of 21 global models in the multi-model ensemble approach, for 1980–99 and 2080–99 under the A1B SRES. The table shows the minimum, maximum, and median (50 percent) values among the 21 models, for temperature (°C) and precipitation ( percent) changes. The results suggest seasonal temperature increases of 2.4–2.7°C and precipitation increases of 6–7 percent as median estimates.

Because climate change predictions incorporate the results of many physical and chemical models, each containing their own uncertainties and errors, there is a high level of uncertainty about the projections under these scenarios. In their assessment of eleven GCMs in the Asian-Australian monsoon region, Wang et al. (2004) found that the models' ability to simulate observed inter-annual rainfall variations was poorest in the Southeast Asian portion of the domain.

**TABLE 1 PROJECTED CLIMATE CHANGE FOR SOUTHEAST ASIA, 2080–99 AGAINST 1980–99**

| | Temperature response (°C) | | | Precipitation response (%) | | |
|---|---|---|---|---|---|---|
| *Season* | *Min* | *Median* | *Max* | *Min* | *Median* | *Max* |
| DJF | 1.6 | 2.5 | 3.6 | -4 | 6 | 12 |
| MAM | 1.5 | 2.7 | 3.9 | -4 | 7 | 17 |
| JJA | 1.5 | 2.5 | 3.8 | -4 | 7 | 17 |
| SON | 1.6 | 2.4 | 3.6 | -2 | 6 | 21 |
| Annual | 1.5 | 2.5 | 3.7 | -2 | 7 | 15 |

*Source:* Adapted from Christensen et al. (2007)

Lacombe (2009) compares projected temperature and precipitation changes for the general Southeast Asian region from different downscaled GCMs reported by various studies on regional projections of climate change. While the trend is clear regarding rising air temperatures, there is greater variation in projections of precipitation changes among different climate models, different emission scenarios, and across different parts of the region. Projections on changes in seasonality of rainfall patterns generally suggest the tendency toward wetter rainy seasons and drier dry seasons, but with geographical variation over the land and sea masses.

An increase in the frequency of extreme weather events such as heat waves and storms is also projected throughout Southeast Asia (Walsh 2004). Similarly, it has been projected that an increase in sea surface temperature of 1°C will lead to an increase of 3–5 percent in tropical cyclone intensities (Knutson and Tuleya 2004). However, changes in ocean temperatures only follow land temperatures with a considerable lag, so any increase in storm intensities up to 2050 is likely to be modest.

## National Projections

In June 2009, MoNRE published Vietnam's official climate change scenario (MoNRE 2009). While climate change estimates were developed for three different emissions scenarios low (B1), medium (B2), and high (A2 and A1FI), the medium emission scenario (B2) was retained by MoNRE for the purpose of impact assessment and adaptation planning. The official scenario includes projected changes in temperature, rainfall, and sea level over the period 2020 to 2100. Projected changes in temperature and rainfall are estimated for each of Vietnam's seven climatic zones.

***Temperature.*** According to MoNRE (2009), the annual average temperature in Vietnam increased by 0.5 to 0.7°C over the period 1958–2007. The report further notes that winter temperatures have increased faster than summer temperatures, and that temperatures in northern Vietnam have increased faster than those in the south. Annual average temperatures observed in Hanoi, Danang, and Ho Chi Minh City have all been higher over 1991–2000 decade than the 1931–40 decade, and still higher in 2007 than over the 1991–2000 decade. These observations are all consistent with measured increases in global average temperature.

Table 2 shows the projected increase in temperature assessed against average temperatures recorded during the period 1980–99. The projected increases in average temperature are slightly higher in the northern part of the country (2.4–6.8°C by 2100) than in the south (1.6–2.0°C).

***Precipitation.*** As noted in the official scenario (MoNRE 2009), changes in rainfall patterns are complex, seasonal, and region-specific. Over the last century, changes in annual average rainfall were not systematically either upward or downward: periods with declining rainfalls were followed by periods with increasing rainfalls. However, the annual rainfall appears to have decreased slightly over climate zones in the North, and increased over climate zones in the South. Despite the lack of obvious and definite trends in historical data, annual rainfall is projected to increase by 4–5 percent in Northern Vietnam by 2060 and by 7–8 percent by 2100. The changes in southern Vietnam are rather smaller, 1.5–3 percent by 2100 (Table 3).

As important as the projected changes in annual rainfall are, projected changes in rainfall across seasons are likely to be of greater significance. The dry seasons are projected to get drier, with the March–May rainfall reductions being higher in the southern part than in the northern part. The wet seasons are projected to get wetter, with the June–August rainfall increases being higher in the northern part than in the southern part.

**TABLE 2 PROJECTED INCREASES IN ANNUAL AVERAGE TEMPERATURES RELATIVE TO 1980–99 (MONRE MEDIUM SCENARIO, °C)**

| Climatic zone | 2020 | 2040 | 2060 | 2080 | 2100 |
|---|---|---|---|---|---|
| North-West | 0.5 | 1.0 | 1.6 | 2.1 | 2.6 |
| North-East | 0.5 | 1.0 | 1.6 | 2.1 | 2.5 |
| North Delta | 0.5 | 0.9 | 1.5 | 2.0 | 2.4 |
| North-Central | 0.5 | 1.1 | 1.8 | 2.4 | 2.8 |
| South-Central | 0.4 | 0.7 | 1.2 | 1.6 | 1.9 |
| Central Highlands | 0.3 | 0.6 | 1.0 | 1.4 | 1.6 |
| South | 0.4 | 0.8 | 1.3 | 1.8 | 2.0 |

**TABLE 3 PROJECTED CHANGES IN ANNUAL RAINFALL RELATIVE TO 1980–99 (MONRE MEDIUM SCENARIO, %)**

| Climatic zone | 2020 | 2040 | 2060 | 2080 | 2100 |
|---|---|---|---|---|---|
| North-West | 1.4 | 3.0 | 4.6 | 6.1 | 7.4 |
| North-East | 1.4 | 3.0 | 4.7 | 6.1 | 7.3 |
| North Delta | 1.6 | 3.2 | 5.0 | 6.6 | 7.9 |
| North-Central | 1.5 | 3.1 | 4.9 | 6.4 | 7.7 |
| South-Central | 0.7 | 1.3 | 2.1 | 2.7 | 3.2 |
| Central Highlands | 0.3 | 0.5 | 0.9 | 1.2 | 1.4 |

**TABLE 4 PROJECTED SEA LEVEL RISE IN VIETNAM (CM)**

| | 2020 | 2040 | 2060 | 2080 | 2100 |
|---|---|---|---|---|---|
| Low scenario | 11 | 23 | 35 | 50 | 65 |
| Medium scenario | 12 | 23 | 37 | 54 | 75 |
| High scenario | 12 | 24 | 44 | 71 | 100 |
| South | 0.3 | 0.6 | 1.0 | 1.2 | 1.5 |

Hence, it is expected that rainfall will be concentrated even more than now in the rainy season months, leading to an increase in the frequency, intensity, and duration of floods, and to an exacerbation of drought problems in the dry season.

***Sea level rise.*** Observations along the Vietnamese coast show that sea level has been rising at the rate of approximately 3 mm per year during the period of 1993–2008, consistent with the rate of 3.1 mm/yr reported at the global level over the period 1990–2000 (World Bank 2010). At the Hon Dau station, in the past 50 years, sea level rose approximately by about 20 cm, in the past 50 years. These observations are comparable with the global sea level rise trend (MoNRE 2009).

Sea-level rise is projected to rise at an increasing rate over the period 2020–2100 (Table 4), leading to an increase of approximately 30 cm by 2050 and up to 75 cm by 2100 under the medium scenario. As indicated earlier and as pointed in MoNRE's official scenario, it is possible that IPCC projected changes in sea levels have been underestimated (Dasgupta et al. 2009).

The expected changes in climate variables and sea level discuss above form the background for

## TABLE 5 INCREASES IN ANNUAL AVERAGE TEMPERATURES BY CLIMATE SCENARIO AND ZONE (°C)

| Agroecological zone | Dry (IPSL) | | Wet (GISS) | | MoNRE | |
|---|---|---|---|---|---|---|
| | 2030 | 2050 | 2030 | 2050 | 2030 | 2050 |
| NW | 1.2 | 2.2 | 0.9 | 1.4 | 0.8 | 1.3 |
| NE | 1.2 | 2.2 | 0.9 | 1.4 | 0.7 | 1.3 |
| RRD | 1.2 | 2.2 | 0.9 | 1.4 | 0.7 | 1.3 |
| NCC | 1.1 | 2.0 | 0.9 | 1.4 | 0.9 | 1.6 |
| SCC | 0.9 | 1.6 | 1.0 | 1.6 | 0.5 | 0.9 |
| CHL | 0.8 | 1.6 | 0.9 | 1.6 | 0.5 | 0.9 |
| SE | 0.8 | 1.5 | 0.8 | 1.3 | 0.6 | 1.0 |
| MRD | 0.8 | 1.5 | 0.8 | 1.3 | 0.6 | 1.0 |

## TABLE 6 INCREASES IN ANNUAL PRECIPITATION BY CLIMATE SCENARIO AND ZONE (%)

| Agroecological zone | Dry (IPSL) | | Wet (GISS) | | MoNRE | |
|---|---|---|---|---|---|---|
| | 2030 | 2050 | 2030 | 2050 | 2030 | 2050 |
| NW | -16.5 | -12.7 | 9.8 | 19.4 | 1.7 | 2.8 |
| NE | -16.5 | -11.8 | 10.5 | 13.5 | 1.8 | 3.0 |
| RRD | -14.2 | -9.2 | 8.6 | 10.1 | 2.1 | 3.5 |
| NCC | -11.9 | -7.0 | 7.6 | 10.0 | 2.2 | 3.6 |
| SCC | -7.8 | -9.7 | 5.2 | 5.7 | 1.6 | 2.8 |
| CHL | -11.0 | -5.6 | 4.3 | 6.0 | 0.1 | 0.0 |
| SE | -10.7 | -5.0 | 5.1 | 6.3 | 0.7 | 1.3 |
| MRD | -10.5 | -6.3 | 5.2 | 6.3 | 0.9 | 1.5 |

estimating the impacts of climate change on economic sectors of activities as well as the nature, costs, and benefits of adaptation measures.

## Climate Scenarios

To take account of differences in the projections generated by different GCMs, a selection of climate scenarios was based on the ranking of GCMs with sufficient geographical detail by the climate moisture index (CMI) for the IPCC SRES A2 emission scenarios. There were 14 GCMs that met the criteria for consideration. The historical climate for 1971–2000 is roughly in the middle of the 14 projections, implying that there is nearly an equal opportunity for the climate to become dryer or wetter by 2050, if each of the projections had similar probabilities of being true. The driest (IPSL-CM4) and wettest (GISS-ER) scenarios were used as the Dry and Wet scenarios in the analysis. In addition, MoNRE's climate projection for the medium emission scenario was included in the analysis to represent the middle of the distribution of GCMs in terms of the climate moisture index. Temperature increases and precipitation changes were estimated in all agroecological zones for all three climate change scenarios in the two future periods, 2030 and 2050.

The results are shown in Tables 5 and 6. The Dry scenario is warmer than the Wet scenario and both are warmer than the MoNRE scenario. However, the largest differences concern the changes in annual precipitation. For most of the country, the Dry scenario projects a significant decline up to 2030, which is partly reversed in the period 2030–50. On the other hand, the Wet scenario shows a substantial increase in annual precipitation, especially in northern Vietnam, but again the rate of change is greater up to 2030 than in the following two decades. In contrast, the MoNRE scenario shows much smaller changes in precipitation, so that it lies in between the Dry and Wet scenarios.

# THREE

# Agriculture

Despite the country's rapid rate of industrialization in the last two decades, agriculture remains a major economic sector in Vietnam. It generates employment and income for a significant part of the population.[6] Climate change is expected to affect the sector significantly and in a number of different ways (Table 7). Much attention has focused on the potential impact of changes in temperature on rice yields, but any assessment of the impact of and adaptation to climate change on agriculture must take account of changes in land use due to salinization and flooding. Not all of the impacts will be negative because higher temperatures and/or changes in rainfall may permit the cultivation of some crops in areas where they were previously not viable. Hence, it is necessary to examine the full set of adjustments to changes in crop yields, land suitability, market incentives and other factors in the context of a changing climate. One of the EACC sector studies (Zhu & Guo 2010) looked at these issues for a small number of crops.

The agricultural sector cannot be examined in isolation from the rest of the economy and world markets. Vietnam is a large exporter of rice, but agricultural markets and its comparative advantages may change in fundamental ways over a time horizon of four decades. Changes that affect the agricultural sector may affect economic growth and the distribution of incomes for the country as a whole. Equally, the impacts of climate change on the agricultural sector will be partly shaped by developments in the rest of the economy, so that the assessment must account for the dynamics of economic growth outside agriculture. For these reasons the analysis of the impacts of climate

### TABLE 7 POSSIBLE IMPACTS OF CLIMATE CHANGE ON AGRICULTURE

| *Climate change* | *Possible impacts* |
|---|---|
| Increasing temperature | Decreased crop yields due to heat stress and increased rate of evapotranspiration<br>Increased livestock deaths due to heat stress<br>Increased outbreak of insect pests and diseases |
| Changes in rainfall | Increased frequency of drought and floods causing damages to crops<br>Changes in crop growing season<br>Increased soil erosion resulting from more intense rainfall and floods |
| Sea level rise | Loss of arable lands<br>Salinization of irrigation water |

*Source:* Adapted from Agricultural Development Bank (ADB 2009).

6 In the ten years from 1995 to 2005, "agriculture, forestry, and fisheries" saw its relative contribution to the economy fall from 27.2 percent to 20.5 percent, while the industrial sector's contribution increased from 28.8 percent to 41 percent over the same period. However, the agriculture, forestry, and fisheries sector continues to employ 57 percent of the total labor force (General Statistics Office 2009).

### TABLE 8 EXPOSURE TO HYDRO-CLIMATIC RISKS BY AGROECOLOGICAL ZONE

| *Risk* | *NW* | *NE* | *RRD* | *NCC* | *SCC* | *CHL* | *ES* | *MRD* |
|---|---|---|---|---|---|---|---|---|
| Storms | +++ | +++ | ++++ | ++++ | ++++ | ++ | +++ | +++ |
| River flooding | - | - | ++++ | ++++ | +++ | +++ | +++ | +++++ |
| Flash floods | +++ | +++ | - | +++ | +++ | +++ | +++ | + |
| Droughts | +++ | +++ | + | ++ | +++ | ++ | +++ | + |
| Salinity intrusion | - | - | + | ++ | ++ | + | ++ | +++ |
| Sea inundation | - | - | +++ | ++ | ++ | - | ++ | +++ |

*Note:* Very severe (++++), severe (+++), medium (++), light (+), none (-).

change on agriculture is linked to a macroeconomic model of economic development up to 2050 to account for interactions between the agricultural sector and the rest of the economy.

The structure of the analysis is as follows:

- Stage 1. Identify the direct impact of climate change on crop yields, land use, and crop production for three different scenarios of climate change (Wet, Dry, and Intermediate).
- Stage 2. Incorporate the results from Stage 1 into the macroeconomic model to assess the direct and indirect impacts of climate change without adaptation.
- Stage 3. Examine options for mitigating the impact of climate change on crop production and estimate the costs of the most economic measures and crop production if they are implemented.
- Stage 4. Incorporate the results from Stage 3 into the macroeconomic model to assess the net costs of climate change after allowing for adaptation.

One point to note is that the analysis focuses on crop production—no attempt is made to analyze the impacts of climate change on livestock production, since there is not good evidence to assess how different climate scenarios may affect animal growth rates and dairy yields. Climate change is likely to alter the balance of land use for crop production (including animal feedstuffs) and grazing, so the impacts identified here will impinge on livestock production. This limitation reflects the level of analysis that is feasible at present. In future, it will be desirable to extend the scope of the analysis to take account of interactions between crop and livestock production. Similarly, forestry and aquaculture—both of which compete with crop production for land and other resources—are examined separately because of the absence of a good basis for modeling resource allocation in the wider rural economy.

Vietnam is divided into eight agroecological zones: North-West (NW); North-East (NE); Red River Delta (RRD); North-Central Coast (NCC); South-Central Coast (SCC); Central Highlands (CHL); South-East (SE); and Mekong River Delta (MRD). Climate, soil, and terrain conditions vary considerably across these zones, while the nature and severity of hydro-climatic risks differ across zones (Table 8). Hence, the study treats each of the eight agroecological zones plus the three largest river basins as separate units.

Vietnam grows a wide variety of crops and it is not possible to examine them all in detail. This study focuses on five main crops—rice, maize, cassava, sugarcane, and coffee—plus vegetables.[7]

7 "Vegetables" is a generic category dominated by production of beans, other pulses, and onions.

**TABLE 9 HARVESTED AREAS AND CROP YIELDS BY AGROECOLOGICAL ZONES, 2007 (AREAS IN THOUSAND HA, YIELDS IN TON/HA)**

| | Paddy rice | | Maize | | Cassava | | Sugar cane | | Coffee | | Vegetables | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AEZ | Area | Yield | Area | Yield | Area | Yield | Area | Yield | Area | Yield | Area | Yield |
| NW | 157.7 | 3.6 | 172.0 | 3.1 | 42.9 | 9.8 | 12.1 | 58.1 | 3.5 | 1.6 | 91.1* | 11.1 |
| NE | 552.5 | 4.6 | 236.0 | 3.2 | 55.4 | 13.0 | 13.4 | 48.5 | 0 | 0 | | |
| RRD | 1111.6 | 5.7 | 84.7 | 4.2 | 7.5 | 12.0 | 2.3 | 52.3 | 0 | 0 | 158.6 | 18.0 |
| NCC | 683.2 | 4.7 | 137.3 | 3.6 | 58.9 | 15.4 | 63.4 | 57.0 | 7.0 | 1.6 | 68.5 | 9.8 |
| SCC | 375.8 | 5.1 | 42.1 | 4.0 | 65.3 | 15.6 | 49.8 | 48.7 | 1.6 | 1.1 | 44.0 | 14.0 |
| CHL | 205.0 | 4.2 | 233.4 | 4.4 | 129.9 | 15.2 | 33.5 | 52.5 | 458.2 | 2.0 | 49.0 | 20.2 |
| SE | 431.6 | 4.2 | 126.1 | 4.6 | 130.8 | 21.2 | 49.4 | 60.8 | 36.1 | 1.4 | 59.6 | 13.0 |
| MRD | 3683.6 | 5.1 | 36.3 | 5.6 | 6.3 | 11.6 | 66.9 | 76.3 | 0 | 0 | 164.3 | 16.6 |
| Total | 7201.0 | 5.0 | 1067.9 | 3.8 | 497.0 | 16.1 | 290.8 | 59.8 | 506.4 | 2.0 | 635.1 | 15.2 |

*Note:* *Total of North-West and North-East agroecological zones.
*Source:* General Statistics Office (GSO) (2009).

**TABLE 10 PERCENTAGE SHARES OF CROP PRODUCTION BY AGROECOLOGICAL ZONE, 2007**

| Agroecological zone | Paddy rice | Maize | Cassava | Sugar cane | Coffee | Vegetables |
|---|---|---|---|---|---|---|
| NW | 18 | 16 | 13 | 22 | 0 | 12 |
| NE | 54 | 16 | 15 | 14 | 0 | 13 |
| RRD | 65 | 4 | 1 | 1 | 0 | 29 |
| NCC | 36 | 6 | 10 | 41 | 0 | 8 |
| SCC | 31 | 3 | 17 | 39 | 0 | 10 |
| CHL | 11 | 14 | 26 | 23 | 12 | 13 |
| SE | 20 | 6 | 31 | 33 | 1 | 9 |
| MRD | 70 | 1 | 0 | 19 | 0 | 10 |
| Total production (mmt) | 36.0 | 4.1 | 8.0 | 17.4 | 1.0 | 9.6 |

*Source:* GSO (2009).

Table 9 shows crop harvested area and yield in 2007 by agroecological zone, while Table 10 shows the share of production by agroecological zone (AEZ) for the six crop categories.

Rice is by far the most important crop. About 52 percent of paddy rice production is from the Mekong River Delta: 82 percent of the summer-autumn rice is produced in the Mekong River Delta, and another 18 percent in the Red River Delta. Other important rice-growing regions are the North-East and the North-Central Coast. In most zones, irrigated rice is cultivated in two to three crops per year. The continued rise in rice production is largely due to improved irrigation, new rice varieties, new rice technologies, and increased triple cropping in the Mekong River Delta (Young et al. 2002).

Maize is the second most important food crop. It is the substitute staple in periods of rice shortage, especially for people in rural areas and mountainous regions. Maize is also the primary source of feed for Vietnam's poultry and livestock industry, and is therefore an important source of income for many farmers (Thanh Ha et al. 2004).

Cassava plays an important socioeconomic role as a secondary crop. In the North cassava is an important source of food and feed at the household level, while in the South, it is mainly a source of cash income. It is predominantly used as a raw material for processing into a wide range of products, both at the household and small-scale processor level, generating employment in the rural sector (Kim 2001). More than half of cassava was produced in the Central Highlands and South-East zones.

Northern Vietnam, as well as large parts of the southeast and Central Highlands areas, are planted to perennial and non-rice crops. The South-East and Central Highland zones have the largest areas planted to perennial crops such as rubber, coffee, tea, cashew nut, and black pepper. Perennial crops in the Mekong Delta are mainly fruit trees. More than 90 percent of coffee is produced in the Central Highlands zone.

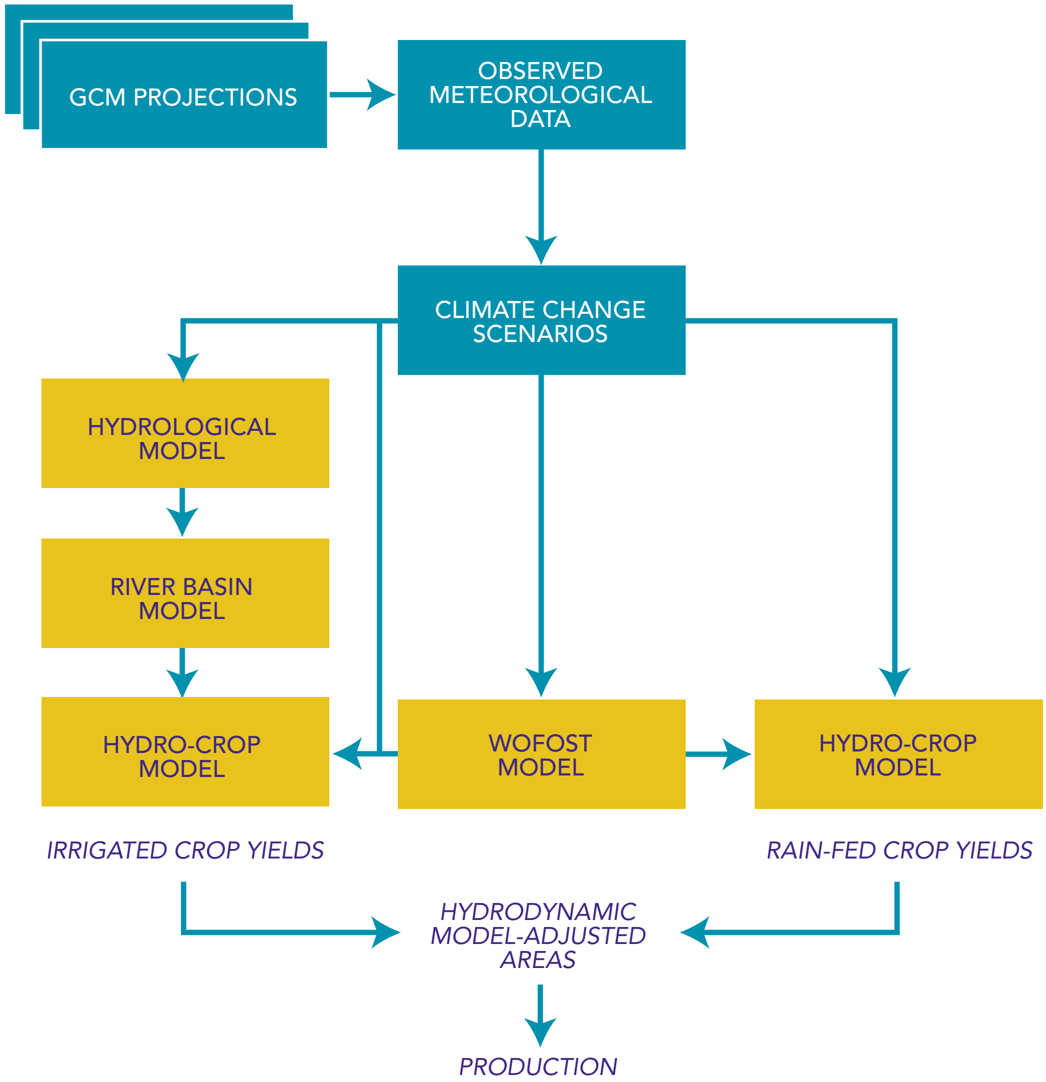
Vietnam has complex seasonal crop rotations and the crop calendar and pattern vary across agroecological zones (Table 11). The details of crop rotations matter because all the climate scenarios show that changes in rainfall are likely to be far from uniform across seasons and zones.

Finally, the uneven distribution of rainfall over the year (typically 80–85 percent of the total rainfall occurs in the wet season) means that irrigation systems play an important role in managing water resources for agricultural production. Government investment in irrigation has increased the percentage of arable land that is irrigated land from 18 percent in 1961 to 70 percent in 2002 (Fan et al. 2004). Total use of water for irrigation was 76.6 billion $m^3$ in 2000, representing 84 percent of total water demand. The Vietnamese government expects irrigation demand to increase to 88.8 billion $m^3$ by 2010, representing an irrigated area of 12 million ha. Today, most of the flat land is under irrigation, and a large percentage of crops are produced from irrigated land. Again, this is relevant because some of the consequences of climate change—notably changes in the seasonal pattern of rainfall, flooding, and sea level rise—will affect the availability of water for irrigation and the performance of irrigation systems.

**TABLE 11 TYPICAL SEASONAL CROP ROTATIONS BY AGROECOLOGICAL ZONE**

| *Agroecological zone* | *Spring Crop* | *Summer Crop* | *Winter Crop* |
|---|---|---|---|
| NW | Spring rice, maize, soybean, sweet potato, vegetables | Summer rice, maize, soybean, vegetables | Vegetables |
| NE | Spring rice, maize, soybean | Summer rice and soybean | Maize, soybean or sweet potato |
| RRD | Spring rice, vegetables | Summer rice, vegetables | Winter rice, vegetables, upland crops |
| NCC | Spring rice, peanut, upland crops | Summer rice, soybean, other upland crops | Vegetables |
| SCC | Spring rice, vegetables, cotton | Summer rice, vegetables | Vegetables |
| CHL | Winter-spring rice, maize, soybean, vegetables, cassava | Summer rice, maize, soybean, cotton, cassava | Winter-spring rice, upland crops |
| SE | Spring rice, maize, cotton, vegetables, other upland crops | Summer rice, maize | Autumn-winter rice |
| MRD | Rice, vegetables | Rice, vegetables | Rice, vegetables |

FIGURE 1 FRAMEWORK FOR ANALYSIS OF THE IMPACTS OF CLIMATE CHANGE

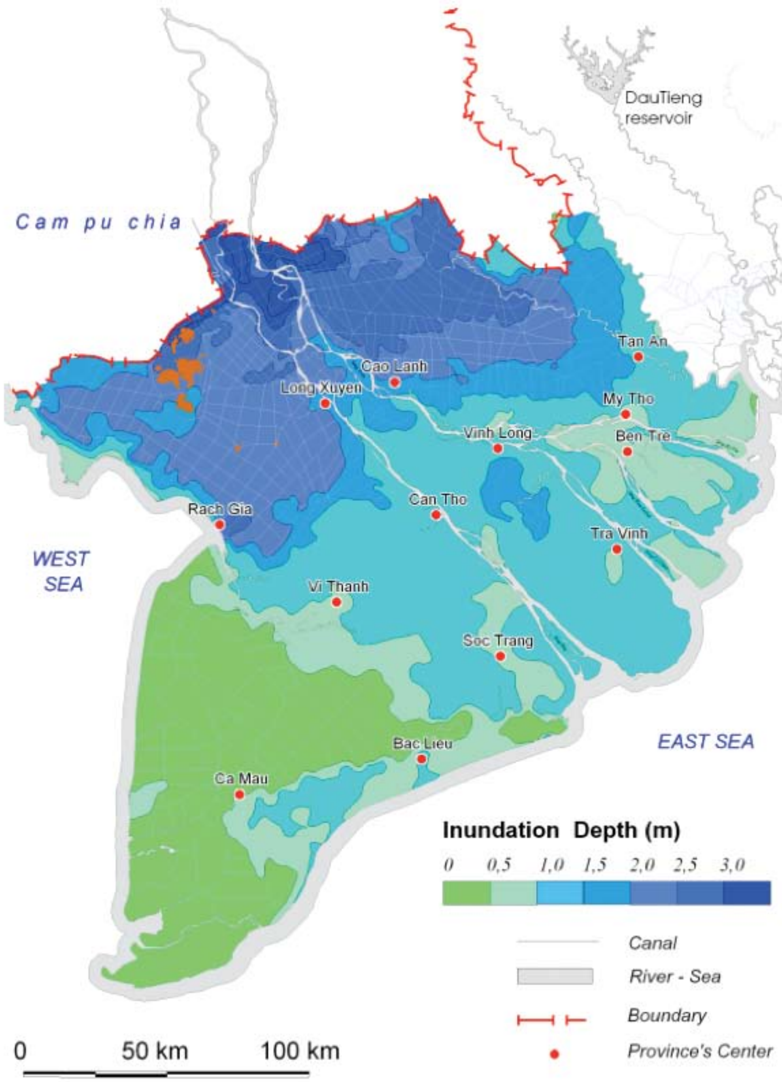



## The Impact of Climate Change on Crop Production

***Methodology.*** Assessing the impact of climate change on agriculture requires an integrated approach using three types of models: (1) agronomic or crop simulation, (2) hydrologic simulation, and (3) river basin models. For the river deltas, a hydrodynamic model is also required to evaluate the effect of sea level rise on inundation and salinity intrusion. Figure 1 illustrates the integrated modeling framework, including models and data flow.

***Climate scenarios.*** The scenarios for climate change used in the analysis are the Dry, Wet, and MoNRE scenarios described in section 2. These represent the full range of GCM projections in terms of the climate moisture index and they

**FIGURE 2 FLOOD INUNDATION WITH 30 CM SEA LEVEL RISE IN THE MEKONG DELTA**




provide a basis for assessing the extent of variation in the impacts of climate change across GCMs. While Tables 5 and 6 summarize the projections by showing changes in average temperature and annual precipitation, the agricultural analysis is based upon projected changes in monthly minimum, mean, and maximum temperatures and on monthly precipitation—in each case by agroecological zone.

Hydrodynamic simulations by the Southern Institute of Water Resources Planning (SIWRP) were used to estimate the changes in sea inundation from 2000 to 2030 and 2050 on the assumption of a sea level rise of 17 cm by 2030 and 30 cm by 2050, which corresponds to the medium SLR assumption discussed in section 2. Figure 2 shows the projected situation for inundation in the Mekong River Delta with a 30 cm sea level rise by

**TABLE 12 POTENTIAL IMPACTS OF CLIMATE CHANGE ON CROP YIELDS**

| *Agroecological zone / River basin* | *Potential impacts of climate change without adaptation* |
|---|---|
| North-West | Rice yield declines by 11.1 percent to 28.2 percent; yields of other crops decline by 5.9 percent to 23.5 percent. Generally, the Dry scenario results in more yield reduction than the Wet scenario. MoNRE scenario has the least yield reduction. |
| North-East | Rice yield declines by 4.4 percent to 39.6 percent; yields of other crops decline by 2.7 percent to 38.3 percent. The largest yield reduction can be with either the Dry or Wet scenarios, depending on crops. MoNRE scenario has the least yield reduction. |
| Red River Delta | Rice yield declines by 7.2 percent to 32.6 percent; yields of other crops decline by 4.1 percent to 32.9 percent. The largest yield reduction can be with either the Dry or Wet scenarios, depending on crops. MoNRE scenario has the least yield reduction. |
| North-Central Coast | Rice yield declines by 7.2 percent to 32.6 percent; yields of other crops decline by 4.1 percent to 32.9 percent. The largest yield reduction can be with either the Dry or Wet scenarios, depending on crops. MoNRE scenario has the least yield reduction. |
| South-Central Coast | Rice yield declines by 8.4 percent to 27.0 percent; yields of other crops decline by 4.0 percent to 20.9 percent. Generally, the Dry scenario results in more yield reduction than the Wet scenario. MoNRE scenario has the least yield reduction. |
| Central Highlands | Rice yield declines by 11.1 percent to 42.0 percent; yields of other crops decline by 7.5 percent to 45.8 percent. The largest yield reduction can be with either the Dry or Wet scenarios, depending on crops. MoNRE scenario has the least yield reduction. |
| South-East | Rice yield increases by 4.3 percent in the dry scenario, remains the same in the wet scenario, and declines by 8.8 in the MoNRE scenario. Yields of other crops decline by 3.0 percent to 22.7 percent. The largest yield reduction can be with any of the three scenarios, depending on crops. |
| Mekong River Delta | Rice yield declines by 6.3 percent to 12.0 percent; yields of other crops decline by 3.4 percent to 26.5 percent. The largest yield reduction can take place under any of the three scenarios, depending on crops. |

2050, assuming no additions to current hydraulic structures. The area inundated to a depth greater than 0.5 m will increase from 2,813,000 ha to 3,089,000 ha—a net increase of 276,000 ha, or about 10 percent. Sea level rise will also increase the area in the Mekong River Delta affected by salinity intrusion. With a SLR of 30 cm, the total area affected by salinity intrusion with concentrations greater than 4 g/l increases from 1,303,000 ha to 1,723,000 ha, a net increase of 420,000 ha.

***Impacts on yields and production.*** Climate change and sea level rise will affects both yields and production. The impacts used in this study rely upon projections generated by a series of models, from climate models to crop-growth models. Thus, there is a large degree of uncertainty regarding these estimates. In addition, the impacts estimated in the analysis are based upon projected changes in climate variables and sea level, so they assume that all other variables—for example, upstream development in the Mekong River basin—remain unchanged over the period. Changes in such variables would have their own effects on yields and production.

The impacts of climate change on yields are summarized in Table 12. Yield changes vary widely across crops and agroecological zones under climate change. There is also a crucial issue of how to deal with $CO_2$ fertilization. $CO_2$ fertilization should theoretically tend to increase yields, but its potential role is both contentious and difficult to estimate since it depends on which factors constrain plant growth. The EACC study has adopted a consistent strategy of overestimating the impacts of climate change and the costs of adaptation where such choices have to be made. Hence, in this case the study has focused on changes in yields without $CO_2$ fertilization. These are the figures used in the tables and the later analysis.

**TABLE 13 IMPACT OF YIELD CHANGES ON PRODUCTION BY SCENARIO IN 2030 AND 2050 (MMT)**

| Year | Scenario | Rice | Maize | Cassava | Sugar cane | Coffee | Vegetables |
|---|---|---|---|---|---|---|---|
| 2030 | Dry | -6.4 | -1.1 | -1.8 | -3.1 | -0.4 | -1.5 |
| | Wet | -4.0 | -0.7 | -2.1 | -1.8 | -0.4 | -2.4 |
| | MoNRE | -2.2 | -0.2 | -0.4 | -0.8 | -0.1 | -0.5 |
| 2050 | Dry | -6.7 | -1.1 | -1.9 | -3.7 | -0.4 | -1.7 |
| | Wet | -5.8 | -1.0 | -2.6 | -2.9 | -0.4 | -3.1 |
| | MoNRE | -3.4 | -0.3 | -0.6 | -1.4 | -0.1 | -0.9 |

**TABLE 14 TOTAL IMPACT OF CLIMATE CHANGE ON PRODUCTION BY SCENARIO IN 2050 (MMT)**

| Climate scenario Impact | Paddy rice | | | Maize Yields | Cassava Yields | Sugar cane Yields | Coffee Yields | Vegetables Yields |
|---|---|---|---|---|---|---|---|---|
| | Yields | Sea level | Total | | | | | |
| Dry | -6.7 | -2.4 | -9.1 | -1.1 | -1.9 | -3.7 | -0.4 | -1.7 |
| Wet | -5.8 | -2.5 | -8.4 | -1.0 | -2.6 | -2.9 | -0.4 | -3.1 |
| MoNRE | -3.4 | -2.4 | -5.8 | -0.3 | -0.6 | -1.4 | -0.1 | -0.9 |

For rice, the key factors influencing yields are (a) the projected reduction in runoff in the Mekong River Delta, particularly for the Dry scenario, and (b) the impact of higher temperatures (especially minimum temperatures). It is estimated that yields will decline by 0.6 tons per ha per 1°C increase in average temperature. The worst yield reductions (for the Dry scenario) are about 12 percent in the Mekong River Delta and about 24 percent in the Red River Delta. Across zones, the Central Highland zone tends to have the highest decline in crop yields under both the Dry and the Wet scenarios. Countrywide, rice yield decreases between 10 percent and 20 percent in 2050. If $CO_2$ fertilization were included, rice yields fall by less than 12 percent for the Dry and Wet scenarios and increase marginally for the MoNRE scenario.

The Wet scenario generally results in lower reductions in yields than the Dry scenario, but there are exceptions. The Red River Delta has a greater reduction in yields under the Wet scenario for both the 2030 and 2050 periods. This is because the Wet scenario has higher increases in minimum and average temperatures during the spring rice season in the Red River Delta, which can shorten the growing period, leading to lower yields.

Table 13 shows changes in countrywide crop production as a result of the effects of climate change on yields in 2030 and 2050 relative to the baseline of no climate change for the three scenarios. By 2050, climate change may reduce rice production by 2 to 7 million tons per year. Consistently, the MoNRE scenario generates the smallest impacts on crop production.

These estimates do not allow for the impact of sea level rise on harvested areas as a result of more extensive inundation of cropland in the rainy season and increased salinity intrusion in the dry season. In the Mekong River Delta, the assumption of a 30 cm rise by 2050 will result in a loss of 193,000 ha of rice area due to inundation and 294,000 ha due to salinity intrusion, both without adaptation. The loss of rice area will lead to a decline in rice production of about 2.6 million tons per year at current yields. This is more than 13 percent of today's rice production in the Mekong River Delta. The loss of rice area to inundation in the lower Dong Nai River basin is relatively small—about 11,000 ha by 2050—and the loss of production is less than 0.1 mmt. Allowing for the changes in rice yields discussed above, the total loss of paddy rice due to sea level rise will be 2.–2.5 mmt in 2050. Table 14 shows the combined effect of changes in yields and sea level rise on production.

Note that these figures are not forecasts of what will actually happen. All farming involves a continuous process of adaptation to weather, technology, economic, and other influences, so adaptation will certainly take place. Rather, they provide a starting point—based on the best available information and subject to substantial uncertainty—for (a) understanding the potential importance of climate change for crop production, holding other factors constant; and (b) assessing the type and scale of planned adaptation that may be required.

## The Macroeconomic Consequences of Climate Change

***Baseline forecast.*** The effects of climate change on Vietnam's economy up to the year 2050 were assessed using a large-scale computable general equilibrium (CGE) model of Vietnam developed

### BOX 1 CGE MODELING

Computable general equilibrium (CGE) models are a class of economic models that use actual economic data to estimate how an economy might react to changes in policy, technology, or other external factors. CGE models are descended from the input-output models. CGE model consists of (a) equations describing model variables; and (b) a database consistent with the model equations.

The MONASH-VN model uses data from the General Statistics Office such as the input-output table for 2000, data from Enterprise Surveys 2002–2005, and the 2004 Vietnam Household Living Standard Survey 2004. The MONASH-VN is calibrated to 2005 Vietnamese input-output data. The MONASH-VN database contains 113 sectors of Vietnam's economy, six of these relating to crop production. The MONASH-VN model distinguishes 79 industries and 37 commodities. For further details on data sources see the full report.

The equations of a CGE model, including those of the MONASH-VN, assume that optimizing behavior governs decision making by industries and households. Each industry is assumed to minimize unit costs subject to given input prices, while each household is assumed to maximize utility subject to a resource constraint.

CGE models are useful to estimate the effect of changes in one part of the economy (such as a change in the agriculture sector) upon the rest of the economy. They are also used to assess the distributional impacts of policies or shocks experienced by any given sector of the economy. They have been used widely to analyze the impacts of trade policy on overall economic growth and development. In recent years, CGE models have been used to estimate the economic effects of measures to reduce greenhouse gas emissions.

by the Centre of Policy Studies of Monash University and known as MONASH-VN (Box 1). The EACC sector study on the CGE (Adams et al. 2010) provides the full details of the analysis that was carried out. MONASH-VN (as all CGE models) provides a framework for simulating how Vietnam's economy may change as a result of changes (sometimes known as "shocks") in one sector of the economy—in this case, shocks in the agriculture sector caused by climate change. These macroeconomic changes are estimated by assessing how the economy may evolve over time *with* the sectoral shock when compared to how it may evolve *without* the sectoral shock, referred to as the baseline forecast.

The principal features of the baseline forecast used in this study are shown in Table 15. At the macro level, the projected rate of growth of GDP is high, albeit declining, over the forecast period. The GDP growth rate averages 4.8 percent over the period 2010–50. Employment grows at a slower pace, at an annual average rate of 0.8 percent. The capital stock grows at an annual average rate of about 5 percent. Returns to labor and capital comprise approximately 44 and 34 percent of GDP respectively. In the baseline forecast, all sectors in the economy grow, but at different rates. Agriculture has the lowest growth rate, averaging 2.7 percent over the period 2010–50. The average growth rates of industry (mining, manufacturing, utilities, and construction) and services over the same period are 4.7 and 6.4 percent respectively. As a result, agriculture's share in GDP declines from 21.3 percent in 2005 to 15.9 percent by 2050. Industry's share in GDP declines from 41 percent in 2005 to 37.5 percent in 2050. The share of services in GDP rises from 37.7 percent in 2005 to 46.6 percent by 2050.

Macroeconomic impacts of agriculture shock. The changes in crop production discussed above have been introduced into the macroeconomic model as "climate shocks" to the baseline in order to simulate the macroeconomic impact of the changes caused by climate change without adaptation. Table 16 shows the differences between the baseline results and the results with the climate shocks for real GDP and real aggregate consumption in the years 2030 and 2050.

### TABLE 15 POPULATION, GDP, AND EMPLOYMENT PROJECTIONS, 2005–50

| *Year* | *Population[a] million* | *GDP[b] $ bn* | *Annual growth rates (%)* | | |
|---|---|---|---|---|---|
| | | | *Population* | *GDP* | *Employment[c]* |
| 2005 | 85.0 | 44.8 | 1.6 | 8.4 | 2.3 |
| 2010 | 90.9 | 60.9 | 1.3 | 6.3 | 1.9 |
| 2015 | 96.5 | 85.4 | 1.2 | 7.0 | 1.8 |
| 2020 | 101.7 | 110.6 | 1.1 | 5.3 | 1.2 |
| 2025 | 106.4 | 137.0 | 0.9 | 4.4 | 0.9 |
| 2030 | 110.4 | 170.1 | 0.8 | 4.4 | 0.8 |
| 2035 | 113.9 | 212.2 | 0.6 | 4.5 | 0.6 |
| 2040 | 116.7 | 265.6 | 0.5 | 4.6 | 0.5 |
| 2045 | 118.7 | 325.0 | 0.4 | 4.1 | 0.4 |
| 2050 | 120.0 | 397.3 | 0.2 | 4.1 | 0.2 |

*Notes:* (a) ILO (2008) for 2005–20, and predictions produced by the global EACC study team for the remaining periods; (b) actual data from World Development Indicators for 2005–08, forecast from World Economic Outlook (IMF 2009a, 2009b) for 2009–15, and forecasts produced by the global EACC study team for the remaining periods; and (c) authors' calculation from population, ratio of economically active population to total population, and the unemployment rate.

**TABLE 16 CHANGES IN BASELINE GDP AND AGGREGATE CONSUMPTION DUE TO CLIMATE CHANGE (PERCENTAGE CHANGES FROM THE BASELINE)**

| Climate scenario | Dry | | Wet | | MoNRE | |
|---|---|---|---|---|---|---|
| | 2030 | 2050 | 2030 | 2050 | 2030 | 2050 |
| Real GDP without adaptation | -3.1 | -2.4 | -2.2 | -2.3 | -1.0 | -0.7 |
| Real consumption without adaptation | -3.8 | -2.5 | -2.7 | -2.5 | -1.3 | -0.7 |

**TABLE 17 CHANGES IN VALUE-ADDED BY SECTOR DUE TO CLIMATE CHANGE (PERCENTAGE CHANGES FROM THE BASELINE)**

| Climate scenario Sector | Dry | | Wet | | MoNRE | |
|---|---|---|---|---|---|---|
| | 2030 | 2050 | 2030 | 2050 | 2030 | 2050 |
| Agriculture | -11.5 | -13.9 | -9.0 | -13.5 | -5.0 | -5.8 |
| Industry | 0.2 | 1.0 | 0.4 | 1.0 | 0.4 | 0.7 |
| Services | -0.8 | 0.1 | -0.4 | 0.1 | -0.1 | 0.3 |

Real GDP and aggregate consumption are expected to be reduced by the climate shocks by approximately 1 to 4 percent in 2030 and by somewhat less in 2050. Reflecting the pattern of changes in crop production under different scenarios, the reductions in GDP and consumption are greatest for the Dry scenario and smallest for the MoNRE scenario. There is a greater degree of agreement between the impact of climate change for the Dry and Wet scenarios in 2050 than in 2030, as differences tend to even out over time. For the Dry and MoNRE scenarios, the relative impact of climate change declines over time.

The macroeconomic impacts are shown at the sector level in Table 17 using three broad sectors: agriculture, industry, and services. Agriculture is the sector most affected. As crop yields and harvested areas decline relative to the baseline, value-added in the sector falls under all climate scenarios. The impact is largest for the Dry scenario and smallest for the MoNRE scenario. The industry and services sectors are only marginally affected. Prospects for the services sector are largely determined by outcomes for aggregate real consumption, since this sector sells a large share of its output to this final demand category. The industry sector experiences a small increase in value-added under all climate scenarios. The logic is as follows: agricultural output falls, which leads to a lower level of agricultural exports and a depreciation in the real exchange rate to offset the impact on the balance of payments. Manufacturing activities that are exposed to international trade—either exporting to world markets or competing with imports—benefit from the exchange depreciation.

In addition to estimating the impact of climate change on aggregate consumption, the macroeconomic model provides estimates of the distribution of the change across income groups, which are defined by residence (rural or urban) and by expenditure quintile given their residence. The lowest rural quintile (RQ1) covers the 20 percent of rural households with the lowest levels of household expenditure per person, while the highest rural quintile (RQ5) covers the 20 percent of rural households with the highest levels of household expenditure per person. Thus, for either urban or rural, the quintiles run from the poorest to the richest households as reflected by their levels of household expenditure.

Table 18 shows that the impact of climate change with no adaptation would be to reduce consumption for all household groups relative to the

**TABLE 18 CHANGES IN HOUSEHOLD CONSUMPTION BY INCOME GROUP DUE TO CLIMATE CHANGE (PERCENTAGE DEVIATIONS FROM THE NO CLIMATE CHANGE BASELINE, UNLESS OTHERWISE STATED)**

| | Dry | | Wet | | MoNRE | |
|---|---|---|---|---|---|---|
| | 2030 | 2050 | 2030 | 2050 | 2030 | 2050 |
| Urban households | | | | | | |
| Quintile 1 (UQ1) | -5.4 | -4.5 | -4.0 | -4.4 | -1.9 | -1.5 |
| Quintile 2 (UQ2) | -4.1 | -3.0 | -3.0 | -3.0 | -1.4 | -0.9 |
| Quintile 3 (UQ3) | -3.7 | -2.3 | -2.6 | -2.4 | -1.2 | -0.6 |
| Quintile 4 (UQ4) | -3.3 | -1.7 | -2.3 | -1.7 | -1.0 | -0.3 |
| Quintile 5 (UQ5) | -2.6 | -0.6 | -1.8 | -0.8 | -0.7 | 0.0 |
| Rural households | | | | | | |
| Quintile 1 (RQ1) | -6.9 | -6.5 | -5.2 | -6.3 | -2.8 | -2.6 |
| Quintile 2 (RQ2) | -5.8 | -5.2 | -4.3 | -5.0 | -2.3 | -1.9 |
| Quintile 3 (RQ3) | -5.0 | -4.2 | -3.7 | -4.0 | -1.9 | -1.5 |
| Quintile 4 (RQ4) | -4.0 | -2.9 | -2.9 | -2.9 | -1.4 | -0.9 |
| Quintile 5 (RQ5) | -3.1 | -1.6 | -2.2 | -1.7 | -1.1 | -0.4 |

baseline. What is worse is that the burden of the reduction in consumption falls more heavily on rural households and on the poorest household groups within each location. The differences are greatest for the Dry scenario in 2050, but the pattern is consistent both over time and across climate scenarios. It implies an increase in overall inequality of household consumption.

There are two reasons why poorer households, especially in rural areas, are harder hit by the impacts of climate change.

- These households derive large shares of their income directly or indirectly from agriculture, so the reduction in agricultural value-added falls more heavily on them.
- They spend comparatively high proportions of their income on crop-related food items, so they suffer disproportionately from the increases in crop prices that follow the reduction in crop yields and production.

Nonetheless, the adverse impacts of climate change on the level and distribution of consumption should be seen in context. Under the baseline scenario of no climate change, the index of real average consumption per person will increase from 100 in 2005 to about 610 in 2050. Even under the worst of the climate scenarios with no adaptation, the increase for income group RQ1 will be from 100 in 2005 to about 570 in 2050. The impact of climate change will be to reduce the average real growth in consumption from 4.1 percent per year to 3.95 percent per year. It would be better if this loss can be reduced or eliminated through adaptation, but the big picture is that the impacts of climate change are small relative to the gains provided by rapid economic growth.

## Adaptation to Climate Change in the Agricultural Sector

Adaptation to climate change in the agricultural sector can and will take a number of forms. At the lowest level, farmers will respond to changes in crop yields, land availability, and market incentives by altering cropping patterns, adopting different crop varieties where these are available, using different combinations of inputs, and perhaps by pursuing opportunities for non-agricultural employment. All of these form part of what is referred to as *autonomous adaptation*. The role of public policy is quite limited in this sphere, other than to minimize any barriers to changes in farming practice.

The government's role will focus on *planned adaptation,* which covers policies and expenditures (not always from the state budget) designed to promote adaptation both directly and indirectly. Direct adaptation covers measures that are designed to offset the direct impacts of climate change on, for example, crop yields or land availability. This includes spending on research and development to produce new crop varieties, the construction and extension of irrigation schemes, and the construction of dikes to protect land from inundation or saline intrusion. Indirect adaptation covers policies that are designed to offset the effects of climate change by promoting economic development that can generate incomes in place of agricultural incomes that may be lost. This includes spending on improvements in transport and other infrastructure, promoting the development of non-agricultural businesses in rural areas, and some combination of education and training to upgrade the skills of workers transferring from agriculture to other sectors.

This study has examined options for autonomous adaptation and direct planned adaptation. There are a variety of options for indirect planned adaptation but these need to be considered in the larger context of strategies to promote economic development.

***Autonomous adaptation by farmers.*** As part of this study, the Institute for Agriculture and Environment (IAE) conducted surveys on current climate stresses in different provinces and the ways in which farmers have responded to these stresses. The surveys revealed that farmers are already adapting to changes in climate conditions, relying upon various coping strategies.

*Change of sowing date for winter-spring rice in the Red River Delta.* According to the survey conducted by IAE, in the Red River Delta farmers have delayed winter-spring rice planting to avoid cold weather in winter since improved varieties of quick maturing rice were made available. During 1994–2004, late winter-spring rice area increased from 10–20 percent before 2000 to 80–90 percent after 2004. On average, the yield for winter-spring rice increased by 0.47 ton per hectare by moving from early- and middle-winter-spring rice to late winter-spring rice.

*Change of crops—switching to drought-tolerant crops in the Central Coast region.* According to the survey of IAE, due to rainfall decreasing in the Central Coastal region, rice cultivated area declined from 450,000 hectares in 1995 to less than 350,000 hectares in 2008. In contrast, maize and cassava areas increased by two times. These drought-tolerant crops—such as cassava, maize, and groundnuts—help farmers avoid risks of rice crop failure due to declining rainfall.

*Reinvigorating local varieties in the Red River Delta*. This strategy has been adopted in areas of Hai Phong Province, where flooding and salinity affect agricultural land. Constructing or rehabilitating the drainage system is not economically viable and modern varieties do not adapt to the current conditions. Local varieties with high tolerance for salinity and flooding have been implemented and selected by local farmers through the years.

Introducing hybrid salinity-tolerant *varieties of rice in coastal provinces*. This practice has been observed in the coastal provinces. According to IAE, this practice started in the northern provinces but soon spread to coastal provinces in the central and southern regions.

*Shifting the water inlet/ finding new water sources.* This practice is implemented in coastal areas where seawater intrusion increases the salinity concentration in river water used for irrigation. Farmers move the water inlet upward along the river in order to gain access to freshwater for irrigation.

*Introducing a rice-fish rotation*. This rotation is increasingly implemented in the Mekong River Delta to take advantage of the flood season. In some cases, farmers diversify away from rice and construct ponds to engage in aquaculture farming.

These examples illustrate the simple and well-established point that farmers can and will respond to changes in climate and environmental conditions when suitable opportunities and incentives exist.

***Planned adaptation.*** The study examined two main options for planned adaptation: (a) an increase in public spending on agricultural research, development, and extension activities; and (b) irrigation expansion. Other options for planned adaptation include the construction of dikes and sluice gates to cope with sea level rise in the Mekong Delta. Unfortunately, it is not possible to estimate the costs and potential benefits of such measures in the absence of detailed information and hydrodynamic modeling. Hence, the costs of adaptation are likely to be overestimated if other options prove to be cost-effective under appropriate conditions.

*Public spending on agricultural research and extension.* Rapid agricultural growth has been driven by the adoption of more productive crop varieties and farming practices. Rice yields grew at an average of 2.3 percent per year between 1990 and 2007 (Yu et al. 2009). Agricultural research and extension has often been a cost-effective investment in promoting agricultural productivity. Improved yields from existing irrigated lands resulting from increased investment in agricultural research focused on adaptation can reduce the impact of climate change. In modeling adaptation, it has been assumed that yields will be 13.5 percent higher than the baseline in 2050 as a consequence of this spending.

*Expansion of irrigated areas.* Irrigation expansion has played a key role in the rapid agricultural production growth in Vietnam. Irrigation helps cope with current weather variability and can assist adaptation to future climate change.

The first priority should be to improve the utilization of existing irrigation infrastructure, which is sometimes little better than 60–70 percent, and to implement effective mechanisms to fund regular spending on operations and maintenance. This is a "no regrets" measure that will pay off with no climate change, but will enhance the capacity of farmers to adapt to climate change.

With respect to additional investments in irrigation, the baseline projection, which takes account of investments planned up to 2020, assumes no further expansion in irrigated area after 2020. The analysis of adaptation via an expansion of the area of irrigated land is based upon general land and water constraints by agroecological zone.

- In the Red River Delta, there are limited opportunities for irrigation that have not already been developed. Land available for reclamation usually suffers from poor drainage and may require pumping.

- In the Mekong River Delta, the expansion of irrigated area is constrained by prolonged and extensive flooding in the southern parts of the delta and the prevalence of acid sulphate soils. Most of the formerly deep-water rice areas have been converted to double cropping of short-duration and high-yielding varieties. The opportunities for further expanding irrigated rice production are in the tidal saline areas by preventing salinity intrusion. However, sea level rise makes irrigation expansion in these areas more difficult and costly. Generally, irrigation in the delta has reached its potential (Kirby and Mainuddin 2009). In addition, the relatively high profitability of

### TABLE 19 EXPANSION IN CROP IRRIGATION BY 2050 (IN 000 HA)

| AEZ | Rice | Maize | Cassava | Sugarcane | Coffee | Vegetables |
|---|---|---|---|---|---|---|
| NW | 6.4 | 30.1 | 0 | 1.2 | 0.7 | 1.5 |
| NE | 15.5 | 41.3 | 0 | 1.3 | 0.0 | 1.5 |
| RRD | 90.9 | 14.8 | 0 | 0.2 | 0.0 | 5.3 |
| NCC | 119.6 | 24.0 | 0 | 6.3 | 1.4 | 2.3 |
| SCC | 65.8 | 7.4 | 0 | 5.0 | 0.3 | 1.5 |
| CHL | 35.9 | 40.8 | 0 | 3.4 | 91.6 | 1.6 |
| SE | 21.3 | 22.1 | 0 | 4.9 | 7.2 | 2.0 |
| MRD | 0.0 | 0.9 | 0 | 6.7 | 0.0 | 5.5 |
| Total | 355.3 | 181.4 | 0.0 | 29.1 | 101.3 | 21.2 |

### TABLE 20 CHANGES IN REAL GDP AND AGGREGATE CONSUMPTION WITHOUT/WITH ADAPTATION (PERCENTAGE DEVIATIONS FROM THE BASELINE)

| | Dry | | Wet | | MoNRE | |
|---|---|---|---|---|---|---|
| | 2030 | 2050 | 2030 | 2050 | 2030 | 2050 |
| REAL GDP | | | | | | |
| No adaptation | -3.1 | -2.4 | -2.2 | -2.3 | -1.0 | -0.7 |
| With adaptation | -0.9 | -1.1 | -1.9 | -0.7 | +0.4 | +0.7 |
| Adaptation gain | +2.3 | +1.3 | +0.3 | +1.6 | +1.4 | +1.4 |
| REAL CONSUMPTION | | | | | | |
| No adaptation | -3.8 | -2.5 | -2.7 | -2.5 | -1.3 | -0.7 |
| With adaptation | -1.1 | -1.4 | -2.3 | -0.8 | +0.5 | +0.6 |
| Adaptation gain | +2.8 | +1.1 | +0.4 | +1.7 | +1.8 | +1.3 |

rice-aquaculture systems that typify flood-prone environments also reduces the potential for irrigation expansion in the Mekong River Delta (Young et al. 2002).

- Central Vietnam has the largest potential for expansion in irrigated area..

The study's assumptions for potential expansion of irrigated areas by 2050 are shown in Table 19, with a total increase in irrigated area of 688,000 ha.

For the period 2010–49, average annual spending on agricultural research, development, and extension activities is assumed to increase by about 45 percent to achieve a 13.5 percent increase in crop yields by 2050, equivalent to a total cost of $1.5 billion at 2009 prices.[8] Similarly, the total cost of additional investment in irrigation expansion to meet the assumptions in Table 19 is estimated as $4.8 billion at 2009 prices. Hence, the total cost of implementing these two adaptation options is estimated to be $6.3 billion at 2009 prices.

8 This estimate is based upon actual spending up to 2009 on research and development and extension for food crops, industrial crops and fruit and irrigation plus 50 percent of spending on training, communication, and capacity building.

## Macroeconomic Effects of Adaptation

The macroeconomic effects have been assessed by modifying the MONASH-VN model to incorporate the costs and benefits of adaptation. Table 20 shows that the reduction in real GDP and aggregate consumption under the three climate scenarios with adaptation is much less severe than for climate change without adaptation. In fact, the results for the MoNRE scenario demonstrate that the measures identified encompass no regrets investments that would be justified even if there were no climate change, because the benefits go beyond merely offsetting the loss of income caused by climate change. Table 21 shows that the present value of the benefits of adaptation (measured by the increase in aggregate consumption) exceed the costs by a large margin for each of the climate scenarios. The net present value of adaptation varies from $13 billion for the Wet scenario to $32 billion for the Dry scenario.

Table 22 compares the without and with adaptation results for sector value-added and regional GDP so as to illustrate where the benefits of adaptation are strongest. As would be expected, adaptation has the strongest effect on value-added in the agricultural sector, with increases of 10–11 percent. The consequence is that the shift from agriculture to industry is significantly reduced under the with-adaptation scenarios. Total value-added in industry and services with adaptation is only marginally different from the baseline projections for 2050.

At the regional level, the Central Highlands region is projected as being most affected by climate change. This is because coffee production, which is especially important in the region, experiences the largest reduction in yields due to climate change.[9] Adaptation greatly reduces the impact of climate change in the region, though the projected reduction in regional value-added remains significant in the Wet scenario, largely because of flooding. Measures to reduce vulnerability to flooding, not covered in this sector study but examined in other EACC work, would mitigate the impact of the Wet scenario on GDP in the Central Highlands region. The South-East region gains from climate change, because crop production contributes a relatively small share to the region's GDP while the region gains from the expansion in the industry and services sectors.

Finally, Table 23 shows that adaptation greatly reduces the impact of climate change on inequality. With adaptation the lowest quintiles (UQ1 and RQ1) suffer a slightly greater reduction in household consumption than the highest quintiles for the Dry and Wet climate scenarios, but the differences are very small by comparison with the impact of climate change without adaptation. Relative to the without-adaptation scenarios, agricultural incomes rise and crop prices fall, benefiting poor rural and urban households. The results for the MoNRE scenario suggest that the adaptation measures are strongly pro-poor, both without climate change and under moderate climate. This reinforces the point that the adaptation options are no regrets measures that would be justified even without concerns about the impact of climate change.

9 This result is subject to a high degree of uncertainty. It is based upon the projection that changes in temperature and moisture conditions will greatly reduce coffee yields with no adaptation. There is evidence that the areas of land suitable for growing Arabica coffee in East Africa and Central America will be strongly affected by climate change, but the potential impact on Robusta coffee is less documented. In practice, climate change may reinforce existing economic factors that are encouraging the gradual replacement of coffee by other tree crops and the general diversification of agriculture in the region with the consequence that the actual impact of climate change will be much less than the estimates generated by the model.

### TABLE 21 PRESENT VALUES OF CHANGES IN AGGREGATE CONSUMPTION ($ BILLION @ 5%)

| Changes in consumption relative to baseline | Climate scenario | | |
|---|---|---|---|
| | Dry | Wet | MoNRE |
| No adaptation | -47.9 | -37.8 | -16.3 |
| With adaptation | -15.6 | -24.7 | 7.8 |
| Net benefit of adaptation | 32.3 | 13.1 | 24.2 |

### TABLE 22 ADAPTATION RESULTS BY SECTOR AND REGION, 2050 (PERCENTAGE DEVIATIONS FROM THE BASELINE)

| | No adaptation | | | With adaptation | | | Adaptation benefits | | |
|---|---|---|---|---|---|---|---|---|---|
| | Dry | Wet | MoNRE | Dry | Wet | MoNRE | Dry | Wet | MoNRE |
| SECTOR VALUE-ADDED | | | | | | | | | |
| Agriculture | -13.9 | -13.5 | -5.8 | -3.8 | -3.4 | 5.4 | 10.0 | 10.1 | 11.2 |
| Industry | 1.0 | 1.0 | 0.7 | 0.0 | 0. | -0.3 | -1.0 | -0.7 | -1.0 |
| Services | 0.1 | 0.1 | 0.3 | -0.3 | 0.1 | 0.0 | -0.4 | 0.0 | -0.3 |
| REGIONAL GDP | | | | | | | | | |
| Red River Delta | -2.2 | -2.5 | -1.5 | -1.0 | -0.5 | 0.2 | 1.3 | 1.9 | 1.7 |
| North East | -6.5 | -6.6 | -4.7 | 0.0 | -4.3 | 2.2 | 6.5 | 2.2 | 6.9 |
| North West | -6.3 | -5.5 | -1.4 | -1.5 | -1.0 | 3.0 | 4.9 | 4.5 | 4.4 |
| North Central Coast | -6.6 | -6.1 | -2.6 | 0.5 | -0.3 | 4.8 | 7.1 | 5. | 7.4 |
| South Central Coast | -3.4 | -2.5 | 0.5 | 0.2 | 0.9 | 3.7 | 3.6 | 3.5 | 3.2 |
| Central Highland | -24.6 | -24.7 | -18.8 | -2.5 | -16.3 | 8.5 | 22.2 | 8.4 | 27.2 |
| South East | 1.1 | 0.8 | 1.0 | 0.0 | 1.1 | 0.2 | -1.1 | 0.3 | -0.9 |
| Mekong River Delta | -3.5 | -1.8 | 1.1 | -3.5 | -1.1 | -1.1 | 0.0 | 0.7 | -2.1 |

### TABLE 23 CHANGES IN HOUSEHOLD CONSUMPTION BY INCOME GROUP WITHOUT/WITH ADAPTATION (PERCENTAGE DEVIATIONS FROM THE NO CLIMATE CHANGE BASELINE, UNLESS OTHERWISE STATED)

| | No adaptation | | | With adaptation | | | Adaptation benefits | | |
|---|---|---|---|---|---|---|---|---|---|
| | Dry | Wet | MoNRE | Dry | Wet | MoNRE | Dry | Wet | MoNRE |
| URBAN HOUSEHOLDS | | | | | | | | | |
| Quintile 1 (UQ1) | -4.5 | -4.4 | -1.5 | -1.5 | -0.6 | 1.9 | 3.0 | 3.8 | 3.4 |
| Quintile 2 (UQ2) | -3.0 | -3.0 | -0.9 | -1.1 | -0.3 | 1.3 | 1.9 | 2.7 | 2.2 |
| Quintile 3 (UQ3) | -2.3 | -2.4 | -0.6 | -1.2 | -0.3 | 0.9 | 1.2 | 2.0 | 1.5 |
| Quintile 4 (UQ4) | -1.7 | -1.7 | -0.3 | -1.2 | -0.3 | 0.4 | 0.4 | 1.4 | 0.7 |
| Quintile 5 (UQ5) | -0.6 | -0.8 | 0.0 | -1.2 | -0.3 | -0.2 | -0.6 | 0.5 | -0.2 |
| RURAL HOUSEHOLDS | | | | | | | | | |
| Quintile 1 (RQ1) | -6.5 | -6.3 | -2.6 | -1.9 | -1.4 | 2.4 | 4.7 | 4.9 | 5.0 |
| Quintile 2 (RQ2) | -5.2 | -5.0 | -1.9 | -1.6 | -1.1 | 1.9 | 3.6 | 3.9 | 3.8 |
| Quintile 3 (RQ3) | -4.2 | -4.0 | -1.5 | -1.5 | -1.0 | 1.4 | 2.7 | 3.1 | 2.9 |
| Quintile 4 (RQ4) | -2.9 | -2.9 | -0.9 | -1.4 | -0.8 | 0.8 | 1.6 | 2.1 | 1.8 |
| Quintile 5 (RQ5) | -1.6 | -1.7 | -0.4 | -1.5 | -1.0 | 0.0 | 0.1 | 0.7 | 0.4 |

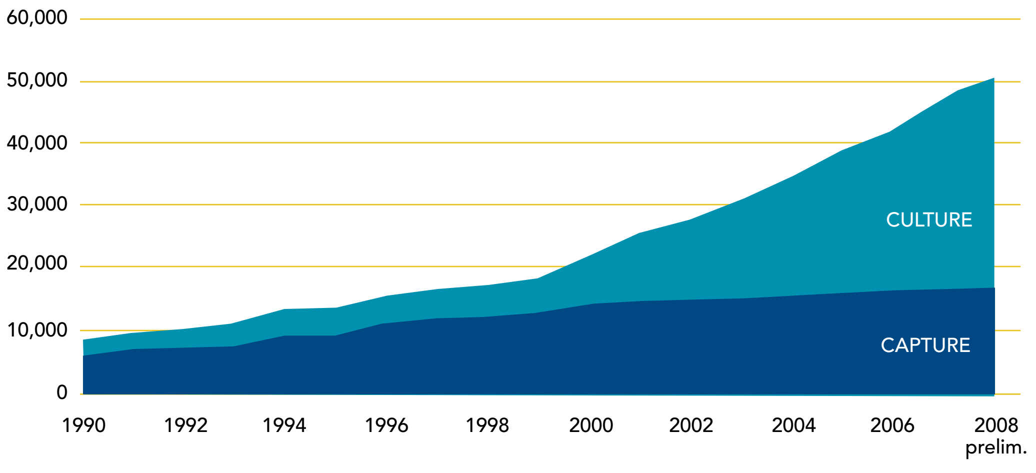
# FOUR

# Aquaculture

## The Growth of Aquaculture in Vietnam

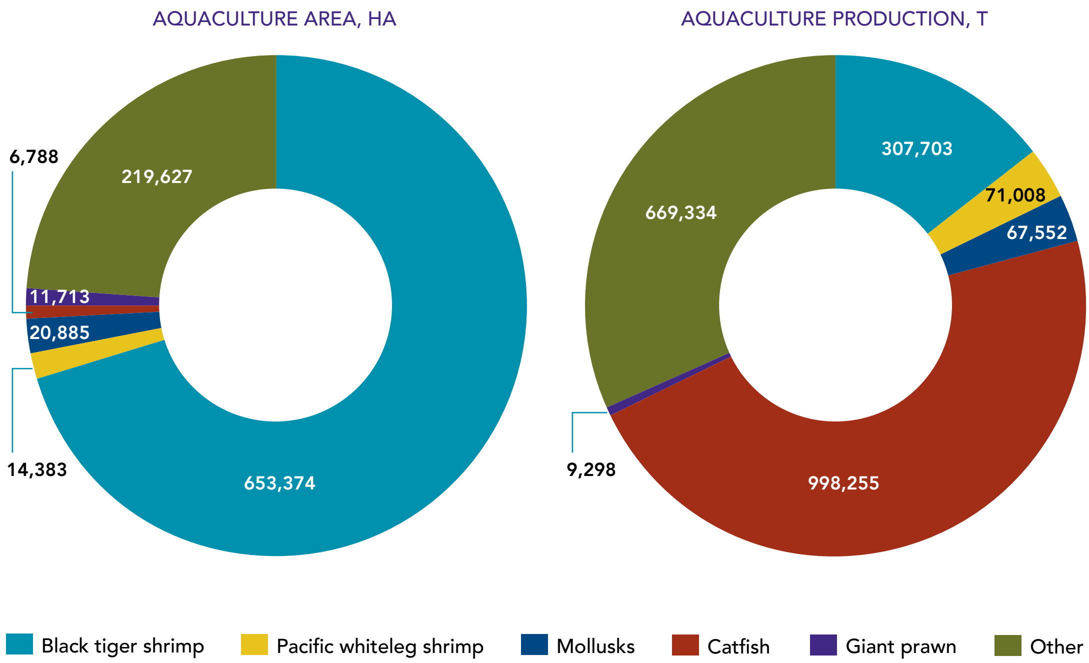
Given Vietnam's long coastline, capture fisheries have always been important as a source of food and incomes. With slower growth of capture fisheries, aquaculture has overtaken capture fisheries in both the quantity and value of production (Figure 3). In 2008, aquaculture production was valued at 33 trillion VNĐ, accounting for 6.6 percent of the national GDP, up from 2.2 percent a decade ago. Over the same period, capture fisheries' share of GDP fell from 5.0 percent to 3.6 percent (Trong 2008). The rapid growth of the sector has been a major source of agricultural diversification over the past decade. It is a direct result of adapting operating practices together with a focus on the production of exportable species at increased levels of intensification. The EACC sector study on

FIGURE 3 VALUE OF PRODUCTION FROM CAPTURE FISHERIES AND AQUACULTURE (VNĐ BILLION AT CONSTANT 1994 PRICES)




*Source:* General Statistical Office of Vietnam, 2009

**FIGURE 4 AQUACULTURE AREA AND PRODUCTION IN VIETNAM'S SOUTHERN PROVINCES, 2009**




*Source:* VASEP (2010)

aquaculture (Kam et al. 2010) looked at the economics of adaptation to climate change for some aquaculture products and for some areas.

Aquaculture in Vietnam is dominated by brackish-water and freshwater production systems. Shrimp dominates the brackish-water aquaculture production, accounting for 98 percent of the production volume, while fish accounted for 99 percent of freshwater production in 2005. Estimates by the Department of Aquacultureof the Ministry of Agriculture and Rural Development (MARD) put the 2009 aquaculture area in the southern provinces (from Da Nang to Ca Mau) at 927,000 ha with total production of 2.1 million tons, accounting for 79 percent of the country's total aquaculture area and 80 percent of the total aquaculture output (VASEP 2010). Pond culture of brackish-water shrimp dominates in terms of farm area (71 percent of all aquaculture area is used for shrimp production), while freshwater catfish farming accounts for 47 percent of total aquaculture production by weight (Figure 4).

The regional distribution of cultured shrimp and fish are reasonably representative of the geographical differences in the dominance of brackish-water and freshwater aquaculture production respectively. The Mekong River Delta accounts for about 80 percent of the country's total shrimp production (which includes brackish-water shrimp and freshwater prawns), while the coastal provinces in central Vietnam account for about 15 percent. The Mekong River Delta has also increased its share of the country's cultured fish production from 67 percent in 2005 to an estimated 75 percent in 2008, mainly due to the expansion of the catfish industry. Freshwater catfish production now dominates cultured fish production in the Mekong River Delta, but there are also many other freshwater and marine fish species that are cultured throughout the country. The Red River Delta region ranks second in cultured fish production, but its share declined from about 20 percent to 15 percent from 2005 to 2008.

In the Mekong River Delta, striped catfish are grown primarily in ponds with earth walls that are sited adjacent to rivers to permit a high level of water exchange between river and ponds. It is an air-breathing species that can tolerate low levels of dissolved oxygen—that is, highly polluted water—and high stocking rates, so it can be grown in locations where the water is not suitable for other uses. Catfish cultivation is mostly a small-scale activity. The typical pond has an area of 0.4 ha, and less than 10 percent of operators have more than four ponds. Extensive shrimp production takes place in large coastal ponds relying upon tidal water exchange but stocked from hatcheries, with the use of fertilizers to promote the growth of natural organisms to feed the shrimp. Semi-intensive or intensive production methods use smaller ponds and higher stocking rates, relying upon water pumps and aeration to maintain water quality as well as a variety of formulated feedstuffs. The most intensive production methods require substantial inputs of capital and skilled labor.

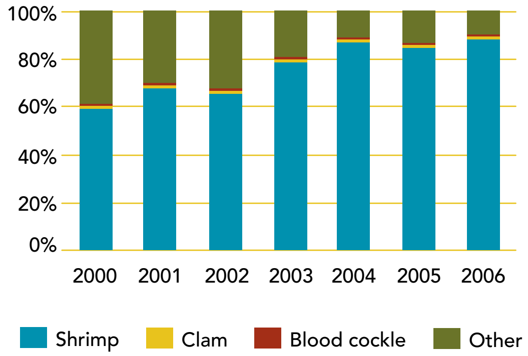
In summary,

- Aquaculture in Vietnam has grown rapidly in the course of the last decade and has overtaken capture fisheries in terms of growth of the sector.
- The aquaculture sector is dominated by shrimp and catfish.
- Geographically, the Mekong River Delta accounts for the largest share of the sector's activities.

Hence, this study focuses on freshwater catfish and brackish-water shrimp in the Mekong River Delta (Figure 5).

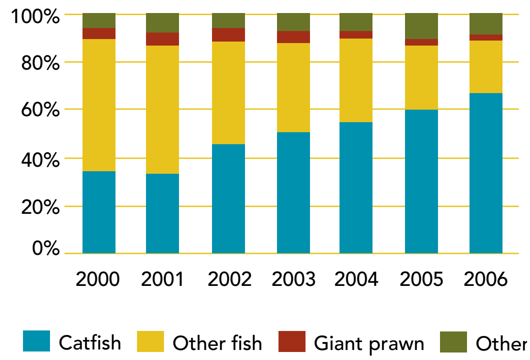
**FIGURE 5 VALUE OF (A) BRACKISH WATER AND (B) CATFISH PRODUCED IN THE MEKONG RIVER DELTA**

BRACKISH WATER AND MARINE PRODUCTION VALUE




| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|
| Other | 3227 | 3852 | 4917 | 3228 | 2223 | 3028 | 2436 |
| Blood cockle | 18 | 18 | 23 | 24 | 56 | 123 | 160 |
| Clam | 133 | 226 | 248 | 306 | 270 | 278 | 342 |
| Shrimp | 4964 | 8759 | 10133 | 13592 | 17790 | 19700 | 23367 |

FRESHWATER PRODUCTION VALUE




| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|
| Other | 105 | 143 | 150 | 218 | 367 | 721 | 869 |
| Giant prawn | 73 | 98 | 133 | 168 | 155 | 178 | 270 |
| Other fish | 941 | 1021 | 1034 | 1144 | 1783 | 1811 | 2216 |
| Catfish | 595 | 640 | 1124 | 1612 | 2841 | 4209 | 6825 |

*Note:* Tabulated values are in billion VNĐ.
*Source:* Research Institute of Aquaculture No.2 (RIA2).

A recent strategy document (MARD 2009) provides targets for fisheries production up to 2020. The production target for aquaculture is 4.5 million metric tons in 2020 (Table 24). It estimated that about 1.3 million ha of water bodies will be exploited for aquaculture activities, of which there are 0.6 million ha of freshwater area and 0.7 million ha of brackish-water and marine areas. A second plan approved by MARD focuses exclusively on catfish production. From 2010 to 2020, the total area under catfish culture is expected to increase by 4.2 percent per year, reaching 13,000 ha by 2020. Export turnover is expected to grow at 5.9 percent per year, reaching $1.85 billion, which will account for 45–50 percent of the projected aquaculture exports of $5.0–$5.5 billion.

## The Impact of Climate Change on Aquaculture

Climate change will affect the aquaculture sector through a number of direct and indirect pathways. Examples of potential impacts are illustrated in Figure 6. The direct impact of sea level rise may be particularly important as increased flooding and salinity intrusion will affect coastal aquaculture installations, especially ponds that are located right along the coast. Higher tides will obstruct river discharge into the sea and exacerbate flooding further inland. Any increase in the intensity and frequency of extreme climatic events such as storms may affect aquaculture production by damaging production assets and transport infrastructure required for access to markets.

***Vulnerability of aquaculture in the Mekong River Delta.*** A vulnerability analysis of aquaculture in the Mekong River Delta focusing on the shrimp and catfish industry was carried out using an approach that follows the general IPCC conceptual framework. Four production systems were identified, two for catfish and two for shrimp:

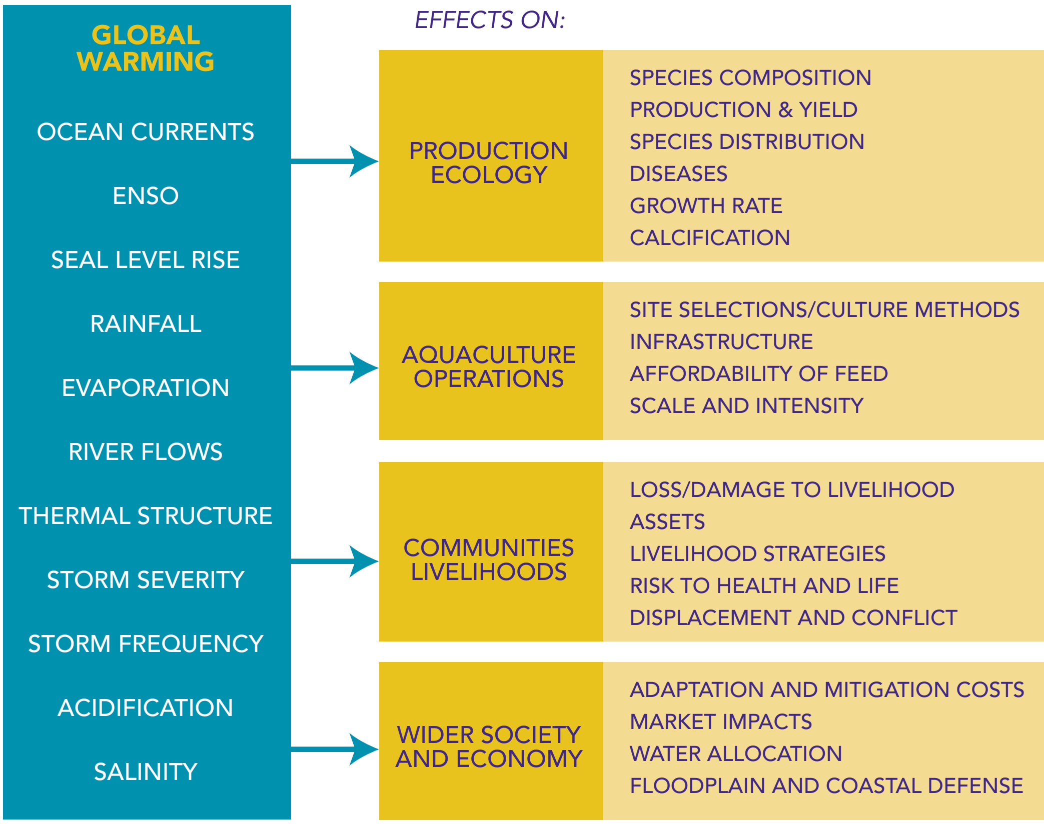
- Catfish (I).—pond culture of the tra catfish (*Pangasianodon hypophthalmus*) in inland

**TABLE 24 AQUACULTURE DEVELOPMENT TARGETS UP TO 2020**

| | | Targets for: | | |
|---|---|---|---|---|
| | | 2010 | 2015 | 2020 |
| **Total production** | 000 tons | **2,600** | **3,650** | **4,500** |
| Brackish-water shrimp | 000 tons | 400 | 550 | 700 |
| Catfish | 000 tons | 1,250 | 1,800 | 2,000 |
| Mollusk | 000 tons | 200 | 250 | 300 |
| Marine fish | 000 tons | 50 | 150 | 200 |
| Tilapia | 000 tons | 70 | 100 | 150 |
| Sea weed | 000 tons | 75 | 100 | 150 |
| Freshwater prawn (Macrobrachium) | 000 tons | 20 | 40 | 60 |
| Other species | 000 tons | 35 | 60 | 90 |
| Traditional fish | 000 tons | 500 | 600 | 850 |
| **Export turnover** | billion US$ | **2.8** | **3.5–4.0** | **5.0–5.5** |
| **Labor** | 000 people | **2,800** | **3,000** | **3,000** |

Source: MARD (2009).

**FIGURE 6 GLOBAL WARMING AND FISHERIES/AQUACULTURE: POTENTIAL IMPACTS**




*Source:* Based on Badjeck et al. (2009).

provinces of An Giang, Dong Thap, Cantho and Vinh Long.

- Catfish (C)—pond culture of tra catfish in coastal MRD provinces of Soc Trang and Ben Tre: the movement of freshwater catfish culture towards the coast began in 2002.
- Shrimp (Ext)—the black tiger shrimp (*Peneaus monodon*) cultured at improved extensive scale mainly in Ca Mau province in the Mekong River Delta.
- Shrimp (SII)—*P. monodon* cultured at semi-intensive/intensive scale in most other coastal provinces of the Delta (and also in Central Vietnam and the Red River Delta).

To assess vulnerability, a combination of qualitative and quantitative methods was used. At Step 1, the exposure, sensitivity, and adaptive capacity of production systems were assessed. At Step 2, secondary data and expert knowledge were used to identify exposure and sensitivity at the farm level. At Step 3, geographical information system (GIS) methods were used to map the potential impacts of sea level rise on catfish and shrimp farms. Finally, at Step 4 the capacity of the catfish and shrimp industries to adapt to change was investigated. The vulnerability analysis produced the following results.

**TABLE 25 MAIN SALINITY AND TEMPERATURE REQUIREMENTS FOR CATFISH AND SHRIMP**

| | *Catfish* | *Shrimp* |
|---|---|---|
| To in ponds (oC) | Optimum range for channel catfish growth is 28–30°C (Hargreaves and Tucker 2003) | 29.8 ± 1.0 °C (Duong, N.D., 2006)<br>Morning: 28.3 ± 0.5 °C<br>Afternoon: 30.5 ± 0.5 °C |
| Salinity tolerance (ppt) | Channel catfish can survive and grow in *slightly* salty water (Buttner, n.d) | Range 15–30 ppt; optimum growth 25 ppt. Survival rates not significantly affected by salinity in the range 10–35 ppt |

*Note:* ppt = parts per thousand.

*Exposure.* Lower rainfall during the dry season coupled with increased air temperature will result in higher water losses from ponds, especially the larger extensive-scale shrimp ponds, hence increasing water salinity in the ponds. This may require the addition of freshwater to ponds during the dry season, when there will likely be competing demands for freshwater from other sectors (agricultural, industrial, and domestic).

In general, the effects of projected changes in localized rainfall on water availability for aquaculture ponds are not likely to be as significant as those of changes in sea level and upstream hydropower development in the Mekong Basin. Projections of climate-related changes in mean annual flow in the Mekong River range from 5 percent (Hoanh et al. 2003) to 20 percent (Eastham et al. 2008). In comparison, planned large hydropower projects in the Mekong are projected to increase dry-season flows by 10–50 percent and decrease wet season flows by 6–16 percent (Hang and Lennaerts 2008).

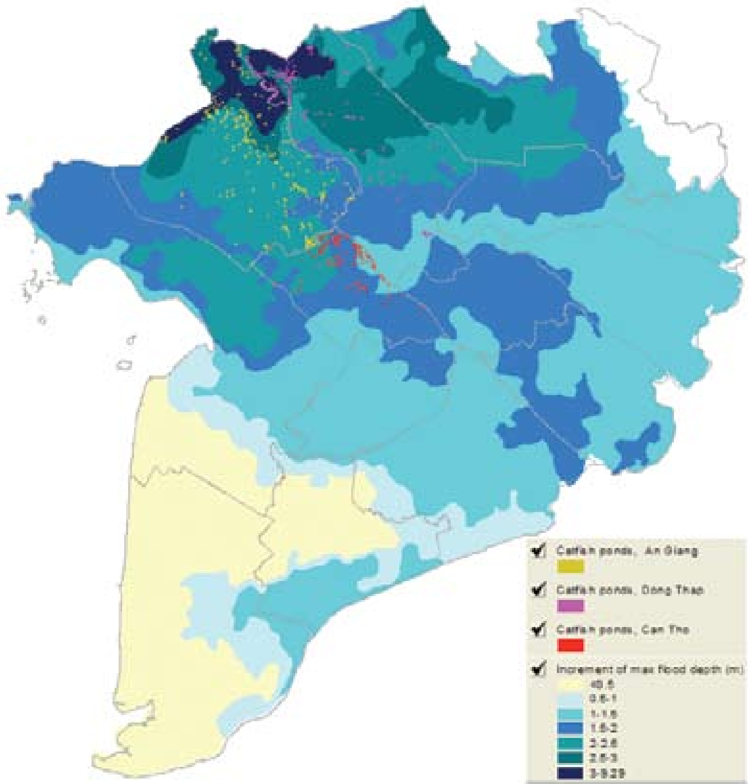
*Sensitivity.* Catfish and shrimp species have different physiological characteristics, especially in terms of salinity tolerance, with catfish being able to tolerate only slightly salty water (Table 25). Effects of temperature rise and salinity increase on cultured species in the Mekong River Delta are still not well-studied and data are scant on maximum salinity thresholds.

The increased temperature would be within the tolerance range of the main cultured species— particularly the river catfish—that perform well in high water temperatures of around 30°C.[10] The main effect of temperature rise is increased metabolic rates, which can enhance growth rates provided that feeding is correspondingly increased, hence incurring increased cost but reduced time to grow to the preferred size. Another effect is increased organic decomposition rates, which may lead to fouling of the water, particularly in closed culture systems such as ponds. Decreased dissolved oxygen may require increased aeration, particularly in intensive culture of shrimp, which are more sensitive to reduced oxygenation than catfish. River catfish can tolerate poor water quality, including high organic matter or low dissolved oxygen levels. It is important to note that temperature responses are species specific. While some species will be adversely affected, others are better adapted to high temperature and possess a wide thermal tolerance zone—such as the catfish *H. brachysoma*—and could be introduced in tropical freshwaters (Dalvia et al. 2009).

Sea level rise will gradually impact marine and brackish aquaculture with saltwater intrusion, requiring the farming of species that tolerate high salinity. Increasing extremes of weather patterns and storms will be another hazard to coastal industries. Storm surges, waves, and coastal erosion could have a larger effect than the rise in mean high water level (2WE Associates Consulting Ltd.

10 http://www.richardsbrothersseafoods.com.au/basa_farming.htm.

**FIGURE 7 AREAS IN AN GIANG, DONG THAP, AND CAN THO PROVINCES SUBJECTED TO INCREMENTS OF MAXIMUM FLOODING DEPTHS FOR 50-CM SLR SCENARIO**




2000). There is already evidence of coastal erosion as a result of damages to sea dikes in the Cau Mau Province.

*Potential impacts: flooding.* Extensive shrimp and inland catfish farming are particularly sensitive to flooding. The catfish-rearing areas of An Giang, Dong Thap, and Can Tho are most likely to be affected by increased flooding during the rainy season as a result of a combination of sea level rise and changes in rainfall patterns. Figure 7 illustrates the geographical pattern of projected increases in maximum flood levels during the rainy season for a 50-cm SLR scenario. The greatest increments in flooding depth are projected to occur in the inland provinces, which already experience floods from the discharge of the Mekong River yearly during the rainy season and where catfish farmers already have experience in dealing with these seasonal floods. Table 26 provides the estimates of areas of catfish ponds that will be affected by successive increments of maximum flooding depths during the rainy season.

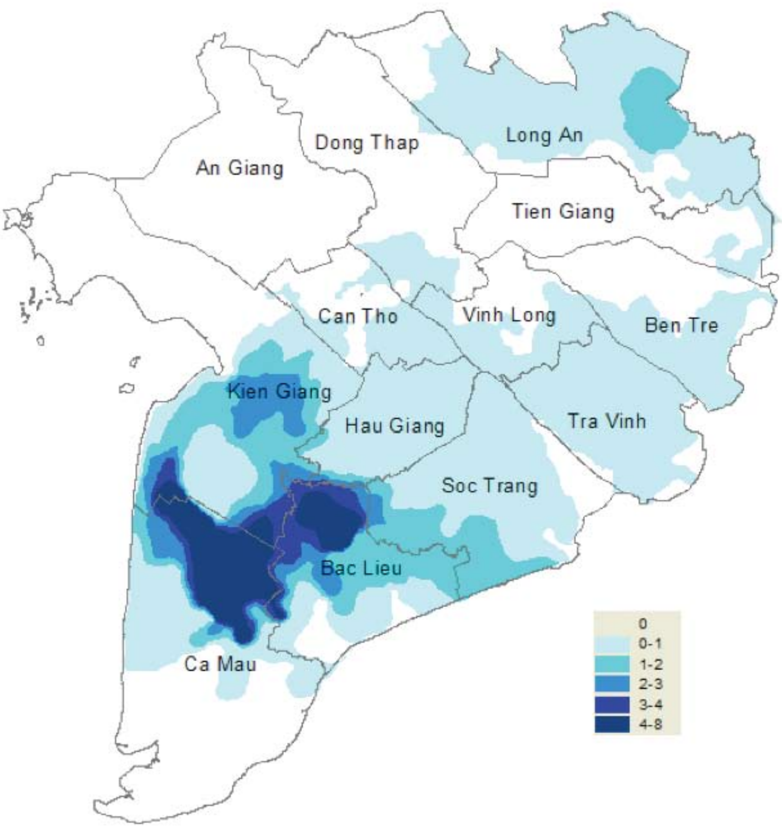
An increase in flooding depth directly due to sea-level rise will be experienced along the coastal strip facing the South China Sea that is not protected by salinity control systems. This is most evident south of the national road 1 joining the towns of Bac Lieu and Ca Mau.

*Potential impacts: salinity.* Salinity intrusion is especially important for shrimp and coastal catfish aquaculture. The brackish-water shrimp areas in

### TABLE 26 ESTIMATES OF CATFISH POND AREA (HA) THAT WILL BE SUBJECTED TO INCREMENTS OF MAXIMUM FLOODING DEPTHS IN THE RAINY SEASON UNDER 50-CM SLR SCENARIO

| *Increment of max flood depth (m)* | *Affected catfish pond area* | | | | | |
|---|---|---|---|---|---|---|
| | *An Giang* | | *Dong Thap* | | *Can Tho* | |
| | *ha* | *%* | *ha* | *%* | *ha* | *%* |
| <0.5 | | | | | | |
| 0.5–1 | | | | | | |
| 1–1.5 | | | 178 | 13 | 273 | 26 |
| 1.5–2 | 163 | 8 | 89 | 6 | 509 | 48 |
| 2–2.5 | 1,236 | 62 | 211 | 15 | 286 | 27 |
| 2.5–3 | 394 | 20 | 497 | 36 | | |
| > 3 | 210 | 10 | 402 | 29 | | |
| Total | 2,003 | 100 | 1,376 | 100 | 1,068 | 100 |

### FIGURE 8 AREAS SUBJECTED TO INCREMENTS OF MAXIMUM WATER SALINITY OR 50-CM SLR SCENARIO



the coastal provinces stretching from Tra Vinh to Ca Mau are likely to be affected by increased salinity intrusion during the dry season, especially where the shrimp ponds are outside of the areas protected by the coastal embankments and water control sluices. Even though the salinity tolerance of black tiger shrimp can be as high as 35–40 ppt, this tolerance is limited by disease problems.

Figure 8 shows where increments in maximum water salinity under the 50-cm SLR scenario are projected to occur. The greatest increments in maximum salinity are expected to occur around the area where Ca Mau, Bac Lieu, and Kien Giang provinces meet. The shrimp ponds in this area would be subjected to increments of maximum salinity exceeding 2 ppt in the dry season. Increased water salinity, particularly in the dry season, would require additional pumping of freshwater to maintain the required salinity levels for brackish-water shrimp culture. For most other parts of the delta, which are already protected from salinity intrusion by existing water control infrastructure, increments in maximum salinity are relatively smaller, not exceeding 1 ppt. Where catfish rearing has expanded toward the coast, in Vinh Long and Ben Tre provinces, it is possible that the ponds may be exposed to slightly higher salinity levels.

Table 27 shows the types of agricultural and aquaculture land use that may experience increases in maximum salinity levels exceeding 4 ppt under the 50-cm SLR scenario. Substantial areas of irrigated and rainfed rice or rice-aquaculture may be affected in this way. While this would be bad for rice production, it represents an opportunity to extend either the period or the area of brackish-water aquaculture in the Mekong River Delta.

**TABLE 27 LAND USE TYPES THAT WILL BE SUBJECTED TO > 4 PPT MAXIMUM SALINITY INTRUSION IN THE DRY SEASON UNDER 50-CM SLR SCENARIO**

| *Land use category* | *Area (000 ha)* |
|---|---|
| Irrigated rice | 159 |
| Mangrove | 66 |
| Mangrove + shrimp pond | 77 |
| Rainfed rice | 190 |
| Rice-aquaculture | 83 |
| Shrimp pond | 384 |

## Economic Analysis of Adaptation

The economic analysis of adaption to climate change in aquaculture focuses on the two main export-oriented activities in Vietnam—freshwater catfish (in particular the tra catfish, *Pangasianodon hypophthalmus*) and brackish-water shrimp (in particular the black tiger shrimp, *Peneaus monodon*). For catfish, the analysis focused on the pond culture system, since about 95 percent of catfish are now cultured in ponds. For shrimp, the economics of production focused on the black tiger shrimp, which is the dominant species, although the Pacific white leg shrimp (*Litopenaeus vannamei*) has recently been introduced into the Mekong River Delta. The classification of production systems used in the vulnerability analysis is retained in considering adaptation.

The main steps in the economic analysis are shown in Figure 9. Steps 1 to 3 were conducted at the farm level for the four production systems. Adaptation measures undertaken at the farm level in response to the impact of climate change are mainly autonomous in nature. For Step 4, the analysis was conducted at the industry level for the Mekong River Delta to estimate the overall costs of adaptation measures. Step 5 deals with planned adaptation measures undertaken beyond individual farms, and are mainly government-initiated and funded. Many of these planned adaptation measures, such as building protective sea and river dikes, will serve various purposes, of which adaptation for the aquaculture sector is only one.

**FIGURE 9 STEPS IN THE ECONOMIC ANALYSIS**

| | |
|---|---|
| STEP ONE | FARM-LEVEL COSTS AND EARNINGS FOR FOUR PRODUCTION SYSTEMS (TWO CATFISH, TWO SHRIMP) |
| STEP TWO | EXPERT ELICITATION: CHANGE IN LAST TEN YEARS, PERCEPTIONS FOR THE NEXT TEN YEARS AND ATTRIBUTION TO CLIMATE CHANGE IMPACTS |
| STEP THREE | DIRECT COSTS PLUS **AUTONOMOUS ADAPTATION** COSTS, AND BENEFITS, AT FARM LEVEL FOR THE NEXT TEN YEARS AND BEYOND TO 2050 |
| STEP FOUR | SCALE UP TO INDUSTRY LEVEL TO ASSESS COST IMPLICATIONS FOR AQUACULTURE |
| STEP FIVE | BENEFITS TO FARMERS DUE TO **PLANNED ADAPTATION** MEASURES UNDERTAKEN BY THE GOVERNMENT |

***The economic impact of climate change at the farm level.*** The results generated at Steps 1 and 2 of the analysis must be interpreted very carefully. They are not projections for the future profitability of different aquaculture systems. Instead they are intended to provide a baseline for assessing (a) the net impact of climate change on future profitability, and (b) the viability of various options for autonomous and planned adaptation to offset the impact of climate change. The baselines for the next decade to 2020 reflect general perceptions about changes to the catfish and shrimp sectors in the near future. For the period after 2020, the baseline relies on fairly simple extrapolation of long trends. In reality, there is a large amount of uncertainty about demand for seafood, input prices, and other costs of production. Thus, the only relevance of the baseline is to provide a starting point for the analysis of climate change.

*Catfish.* The direct impact of climate change on net income from both inland and coastal catfish farming is strongly negative. Without adaptation, the net income from inland catfish production may fall by 3,000 million VNĐ per ha in 2020 as a consequence of climate change. This reduction may nearly treble by 2050 (Figure 10). If this analysis of the impact of climate change is even roughly correct, autonomous and planned adaptation is critical for the future success of the industry.

*Shrimp.* The direct impact of climate change on net income from both extensive and (semi-) intensive shrimp farming is negative, more strongly so for extensive farming. Without adaptation, the net income from (semi-)intensive shrimp production may fall by 130 million VNĐ per ha in 2020. This reduction may increase to 950 million VNĐ in 2050 (Figure 11). Again, adaptation to climate change is critical for the future success of the industry.

***Autonomous adaptation.*** The primary options for autonomous adaptation whose costs can be estimated are (a) the replacement or upgrading of pond dikes to reduce the extent of flooding and saline intrusion, and (b) additional expenditures on electricity and fuel to maintain water levels and salinity in ponds. However, these are only part of what is likely to be a much larger response to climate change. A combination of selective breeding programs with changes in farming practices should permit the farming of catfish species that can tolerate higher levels of salinity. Funding the breeding programs would fall to the government as an aspect of planned adaptation, but the adoption of different species and the modification of farming practices will fall to those responsible for managing aquaculture operations.

It is important to recognize that autonomous adaptation will not take place in isolation from other changes. The scale of the aquaculture sector has increased more than 5 times over the last decade. If it is to continue to grow, it will face a variety of challenges that will require changes in farming practices, marketing, investment , and many other activities. Autonomous adaptation should be seen as one aspect of a much broader process by which the sector reaches maturity after a period of quite exceptional growth. While some of the specific costs of autonomous adaptation may be identified for analytical purposes, the reality will be one of continuing change in response to a wide variety of economic, physical, and climatic factors, in which the specific role of adaptation to a changing climate may be difficult to distinguish from other factors.

**FIGURE 10 REDUCTION IN NET INCOME FROM CATFISH FARMING DUE TO CLIMATE CHANGE WITHOUT ADAPTATION (VNĐ MILLION PER HA)**

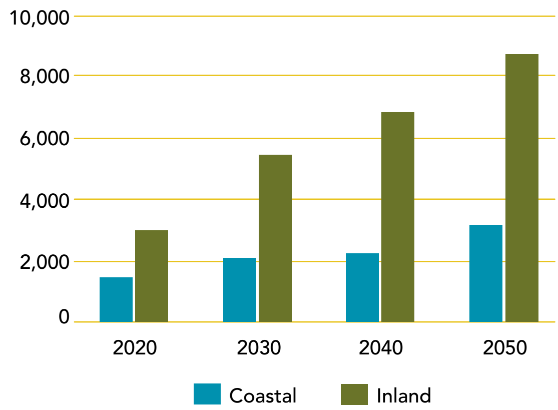
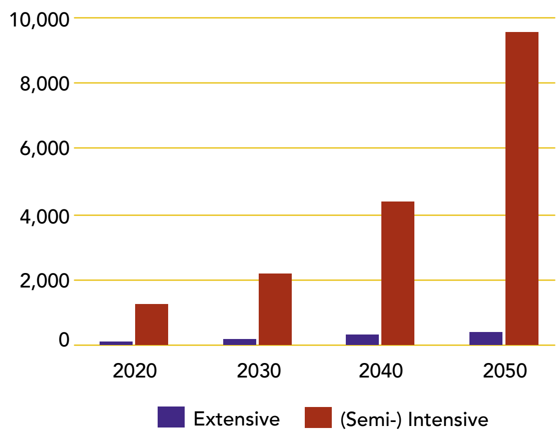



**FIGURE 11 REDUCTION IN NET INCOME FROM SHRIMP FARMING DUE TO CLIMATE CHANGE WITHOUT ADAPTATION (VNĐ MILLION PER HA)**




*Catfish.* On current trends, catfish farming faces an uncertain future because gross revenues may not keep pace with the increase in input costs, particularly for feed, which constitutes the largest cost. Only the most efficient and adaptable farmers may be able to survive such a squeeze on farming margins, which are currently in the 3–5 percent range. The additional costs of adapting to climate change will intensify this squeeze, but they will also reinforce the benefits of "no regrets" strategies, which will increase margins and enable operators to underwrite the costs of adaptation. Such strategies include:

- Improving feed conversion ratios by the development and adoption of better practices, including breeding, feed formulation, and disease control.


- Consolidation of the value chain by vertical integration. Transferring the very high margin from retailers in importing countries and export processing companies to farmers either through actions by the companies and/or the retailers—that is, market responses to maintain the supply to meet growth in demand—or by government intervention will increase both the incentive and capacity of aquaculture operators to adapt to climate change.

The catfish industry is more heavily capitalized than the shrimp industry, making restructuring of the sector and quick response from medium- or large-scale farmers to salinity intrusion and floods possible with the right market (demand) and government incentives. To the extent that dike construction to mitigate river and coastal flooding or saline intrusion provides ancillary benefits to agriculture and other sectors, then adaptation costs borne by the aquaculture sector could be significantly lower. At the moment, however, there appears to be no mechanism for either assessing or sharing the joint benefits of such infrastructure. This is a matter that deserves further investigation and consideration in the future.

*Shrimp.* Current trends for shrimp production are not as unfavorable as those for catfish farming. Having had a longer history, the shrimp industry is relatively better established and more stable. The extensive shrimp system is less profitable but has a lower impact on the environment, so it may be particularly important for small-scale farmers.

Overall, it is likely that inland catfish farmers will experience the highest costs in adapting to the increased risks of floods and salinity intrusion. While costs for shrimp systems overall are likely to be lower, the cost of water pumping in semi-intensive/intensive systems will increase significantly. Water exchange and pumping of water is not practiced in extensive systems to the same high level as with semi-intensive/intensive systems for all systems. Since the industry is both capital-intensive and growing rapidly, adaptation is likely to be autonomous with the costs borne by operators. The total cost of adaptation is estimated at an average of $130 million per year from 2010–50, which is equivalent to 2.4 percent of total costs.

# FIVE

# Forestry

In 2008 about 39 percent of Vietnam's land area was forested, with 79 percent of this total as natural forests and 21 percent as plantation forests. The total area of forests declined from 1940 to 1995, but has recovered since then as a consequence of a substantial increase in the area of plantation forests. The regional distribution of forests in 2006 is shown in Table 28. In the Central Highlands, North-Central, and North-East regions, forest cover is generally high, and reaches 54 percent in the Central Highlands. However, in the Red River Delta, South-East, and South-West regions, forest cover is less than 20 percent. The main types of forests and the characteristics of climate where they are distributed are summarized in Table 29. The EACC sector study on forestry (Phuong et al. 2010, Almeida et al. 2010) carried out a preliminary analysis of what the impacts of climate change will be on natural forests and plantations.

The total standing volume of wood in the country in late 2005 amounted to 811 million $m^3$, of which natural forest accounted for 93 percent and plantation forest for the remaining 7 percent. The bulk of this volume is located in three regions: the Central Highlands (34 percent), North-Central region (23 percent), and South-Central region (17

### TABLE 28 FOREST AREA AND COVER BY REGION, 2006

| *Region* | *Forested area (ha)* | *Natural forest (ha)* | *Plantation forest (ha)* | *Forest cover (%)* |
|---|---|---|---|---|
| North West | 1,508,740 | 1,399,167 | 109,573 | 40.3 |
| North East | 3,164,873 | 2,270,803 | 894,070 | 47.9 |
| Red River Delta | 95,819 | 47,299 | 48,520 | 7.6 |
| North Central | 2,611,525 | 2,076,940 | 534,585 | 50.7 |
| Central Coastal | 1,775,770 | 1,444,856 | 330,914 | 40.6 |
| Central Highland | 2,976,951 | 2,824,837 | 152,114 | 54.6 |
| South East | 431,135 | 286,192 | 144,943 | 18.2 |
| South West | 309,037 | 60,045 | 248,991 | 7.7 |
| **Total** | **12,873,851** | **10,410,141** | **2,463,710** | **38.0** |

*Source:* MARD (2007).

## TABLE 29 CLASSIFICATION OF FOREST TYPES BY LOCATION AND CLIMATE CHARACTERISTICS

| *Forest type* | *Location* | *Climate characteristics* |
|---|---|---|
| Tropical evergreen broad-leaved forest | Widely distributed at elevations below 700 m (all altitude measures are m above sea level in the north and below 1,000 m in the south (Chan and Dung 1992; Trung 1998) | Mean annual temperature 20–25°C, annual rainfall > 1,200 mm with 2–3 dry months (Trung 1998) |
| Tropical semi-deciduous broad-leaved forest | Concentrated in northern Vietnam and the Central Highlands at the same elevation as the tropical evergreen broad-leaved forest (Chan and Dung 1992; Linh 1996; Trung 1998) | Mean annual temperature 20–25°C, annual rainfall 1,200–2,500 mm with 4–6 dry months (Trung 1998) |
| Tropical deciduous broad-leaved forest | At an elevation of less than 700 m in the north, and below 1,000 m in the south. | Low–moderate rainfall (> 600 mm) with 4–6 dry months (Trung 1998) |
| Subtropical evergreen forest | At altitudes above 700 m in the north and above 1000 min the south (Chan and Dung 1992; Hung 1996). | Subtropical with mean annual temperature ranges 15–20°C, annual rainfall 1,200–2,500 mm (Chan and Dung 1992) |
| Limestone forest | On the limestone substrate (calcareous soil) and under hard climatic conditions, mostly over a large area of the north (GoVN 1994; Truong 1996). | The area of limestone forest accounts for 5 percent of forested land (Phon et al. 2001; Dung 2005); it has been severely degraded by uncontrolled logging, wildfire, and slash and burn cultivation (GoV 1994; Phon et al. 2001) |
| Coniferous forest | Distributed in the north and the Central Highlands, at elevations of over 1,000 m where the climate is cool in summer and cold in winter (Chan and Dung 1992; Truong 1996) | Annual precipitation 600–1,200 mm (Chan & Dung 1992) with 4–6 dry months (Trung 1998) |
| Dipterocarp forest | Between the latitudes of 140 N and 110 N and at the altitudes of 400–800 m; mainly distributed in Dak Lak and Gia Lai provinces | Mean annual temperatures 21–27°C, annual rainfall 1,200–1,800 mm with 4–6 dry months; the area of dipterocarp forest is about 3 percent of forested land (Nghia 2005); Dipterocarp forest is particularly vulnerable to fire |
| Melaleuca forest | In the Mekong River Delta at or slightly above sea level under tropical conditions with no winter | Mean annual temperature 27°C, annual rainfall 1,500–2,400 mm; this forest has been severely degraded and is less than 1 percent of forested land |
| Mangrove forest | In tidal areas along the coast, especially in estuaries (Chan and Dung 1992; Sam et al. 2005); most prevalent in the south (GoV 1994) | (Sam et al. 2005). |
| Bamboo forest | Throughout the country; succession after harvesting of the natural forests or slash and burn cultivation (Chan and Dung 1992) | Bamboo forests are about 11 percent of forested land |

percent) (MARD 2007). With respect to plantation forests, the North-East, North-Central, and South-Central coastal regions have the largest plantation timber volume. These three regions are the main suppliers to the paper and wood products industries.

In terms of exploitation, the bulk of the extracted volume— approximately 2.5 to 3 million $m^3$ per year—is currently provided by plantation forest, and approximately 150,000 to 300,000 $m^3$ per year comes from natural forest (MARD 2007). Following the limitation on natural forest exploitation, the area of plantation forest, particularly the area of plantation production forest, increased sharply—from a total of 872,275 ha of plantation production forest in 1999 to nearly 1.7 million ha in 2006. Similarly, the total production forest area in 2006 rose 13 percent above that in 1999.

## The Impact of Climate Change on Forests

It is likely that climate change will have a significant impact on Vietnam's forests, but many of the effects will only be apparent over the long term because of the nature of interactions between climate and forest development. Thus it is important to distinguish between the possible effects of climate change on: (a) the productivity of existing forests over the next 20–40 years, and (b) the development and migration of different types of forest up to and beyond 2100 as a result of changes in the suitability of a given area for different forest types.

***Changes in forest productivity up to 2050***. There is considerable uncertainty as to how climate change will affect the productivity of existing forests. This will depend on the interaction between direct influences (rainfall, temperature, and solar radiation) and indirect influences (fire, pests, and disease). The outcomes will vary across types of forest and management regimes. For large areas of natural forest, the primary concerns focus on forest fires, pests, and disease. On the other hand, a substantial portion of plantation forests are managed as short-rotation crops—usually 6–8 years—that are harvested to supply industries using pulp or wood chips. Such a regime is equivalent to a perennial agricultural crop for which the impact of climate change on plant yields is likely to be of prime concern. These are discussed in more detail below.

*Forest fires.* Fire risk is a function of fuel load, weather patterns, and ignition source. In forests, growth rate is positively related to the amount of litter and woody debris produced (Paul and Polglase 2004); net fuel load is determined by the balance between production and decomposition. In some species, an elevated atmospheric $CO_2$ concentration is associated with both higher growth (Ayres and Lombadero 2000) and decreased rates of litter decomposition. If future climates in Vietnam are associated with higher growth and lower decomposition rates, fuel load will increase. However, decomposition rates increase with temperature, humidity, and moisture content so the balance between these variables in future climates in Vietnam will determine final fuel load.

As global climate models predict higher temperatures, reduced rainfall, and an increased vapor pressure deficit for Vietnam, the net effect is likely to be drier fuel and an increase in the length and severity of the fire season. Forests most at risk of fire damage will be those that are older with greater build-up of litter and debris, those associated with debris from thinning and previous harvesting, and those with a persistent woody weed understory (Pinkard et al. 2010).

According to Be Minh Chau (2008):

- In the North-Central coast, the risk of forest fires will increase in the coming decades.

Compared to existing risk, the risk of forest fires is projected to increase by 6–40 percent by 2020, 16–52 percent by 2050, and 51–85 percent by 2100.

- In the North-West region, the risk of forest fires is project to significantly increase in December and January. Compared to existing risk, the risk of forest fires is projected to increase by 5–41 percent by 2020, 16–35 percent by 2050, and by 25–113 percent by 2100.
- In other zones, the risk of forest fires is also projected to increase, though this has not yet been quantified.

*Drought.* Plant-water or drought stress occurs when pre-dawn plant-water potential drops below a critical level and triggers stomatal closure, leading to reduced levels of photosynthesis and growth. Further reductions in potential occur as available water is depleted from the soil profile. Severe drought conditions are associated with leaf shedding and mortality.

Water limitation is often the major factor determining forest productivity in current climates; future climates are likely to increase its importance (Battaglia et al. 2009), particularly in countries like Vietnam that already experience long dry seasons. Leaf area index or leaf area per unit land area is a key determinant of growth because of its influence on light interception. Leaf area index is also positively related to levels of available water. Extended dry seasons and reduced average levels of available water point to lower average LAI and reduced average growth rates.

It appears likely that drought risk will increase in future climates, though there may be periods during the growing season when higher growth rates than experienced in current climates may prevail.

*Pests and diseases.* MARD (2006) provides information on species of pests and diseases that damage forests in Vietnam. Among those species, *Dendrolimus punctatus* Walker (the Masson pine moth) has caused serious damage at intermittent intervals and in various parts of the country since 1940, with most damage occurring in pine plantations. In recent years, there have also been epidemics of leaf-eating insects, which can cause damage to large areas of forest.

Insect dynamics are a function of temperature and rainfall (Pinkard et al. 2008); insects also vary in their capacity to tolerate drought or wet conditions. Depending on species, the balance of these environmental drivers will potentially shorten or lengthen periods when the insect is quiescent. Host dynamics determine whether there is an adequate food source for the insect to complete its life cycle. Hosts suffering from drought stress often attract stem borers. Stress caused by increased frequency of typhoon and storm damage, drought, and fire are likely to encourage associated insect damage.

Temperature, rainfall, soil moisture, and relative humidity affect disease reproduction, spore dispersal, and infection by pathogens (Ayres and Lombadero 2000). The infection process is strongly influenced by the duration of surface wetness or high humidity in most terrestrial environments. All these processes will be modified by climate change signals. Susceptibility to exotic pathogens may also change. Fungal diversity is very large and this in itself complicates prediction. Pathogens most likely to respond directly and quickly to climate-change signals are those with short generation times, high rates of reproduction, and effective dispersal mechanisms (Pinkard et al. 2008). In Vietnam, as elsewhere, increased or reduced damage to forests by particular groups of pathogens may be the outcome.

Pests and diseases are often a secondary component influencing how trees respond to drought to protect themselves. Moderate water deficit has been shown to increase secondary defense compounds that strengthen defense (Ayres and

Lombadero 2000). Conversely, severe drought can lead to a decrease in defense compounds and other changes that favor pathogen development.

In summary, the key factors that are likely to determine the impact of climate change on the effects of pests and diseases will be changes in the frequency or severity of droughts and/or dry periods and levels of humidity. Higher temperatures may favor the growth and reproduction of pests and diseases, but trees that are growing vigorously may have a greater capacity to resist attack. Hence, it is changes in the pattern of monthly rainfall that may have the most significant effect on the level of losses due to pests and diseases.

*Weeds.* The economic cost of weeds to Vietnam has not been quantified. Experiments elsewhere show that effective weed control, especially at establishment and in the early years of plantation development, significantly increases seedling survival and tree growth and that these effects can be long-lasting.

The direct effects of climate change on trees and weeds are mainly expressed through changes in temperature, moisture content, and elevated $CO_2$. Responses may differ significantly depending on species and site. This asymmetry in plant response will be further modified by the indirect effects of climate change, particularly on pests and pathogens (Battaglia et al. 2009).

Most plant species have the potential to migrate in response to climate change. Weeds are expected to be some of the earliest species to shift their range as the traits that make them invasive—such as efficient dispersal mechanisms—also predispose them to respond rapidly to climate change (Sutherst et al. 2007).

Competition, predation, and parasitism contribute to weed species abundance patterns in space and time. Predicting how these factors will change under future climate scenarios remains undetermined; abundance may increase or decrease. Species niche models run with current and future climate scenarios could play an important role in defining opportunities for strategic weed management and for planning surveillance activities aimed at identifying emerging weed problems.

*Plantation productivity.* The impact of climate change on the productivity of short-rotation plantation forests in Vietnam was assessed by using 3-PG model, a tool developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The 3-PG model is designed to quantify forest production based on the main principles and concepts that drive forest growth, including solar radiation, leaf area index, and soil water, among others parameters. The tool also helps to estimate carbon production, partitioning, and water use under current and future climates.

In this study, the impacts of climate change on two plantation species were assessed using 3-PG: *Acacia mangium* and *Eucalyptus urophylla*. The two species are the most common species used for forest plantations in Vietnam. The study team examined both species using spatial information on soils, climate and other variables. Unfortunately, the 3-PG model could not be calibrated to replicate the existing distribution of plantation growth rates for *Eucalyptus urophylla* in different parts of Vietnam, so no attempt was made to assess the impacts of climate change on this species. See the forestry sector report (Phuong et al. 2010, Almeida et al. 2010) for a detailed explanation of the model.

The 3-PG model predicts stand development; stem, root, and foliage biomass pools; stand water use; and available soil water. It has five simple submodels:

- Assimilation of carbohydrates, predicted by environmental modification of light use efficiency and assuming a constant ratio of net to gross primary production

**TABLE 30 IMPACT OF CLIMATE CHANGE ON STAND VOLUMES OF 7-YEAR ACACIA MANGIUM (M3 PER HA)**

| Period | Stand volume | | | Distribution of changes in stand volume | | |
|---|---|---|---|---|---|---|
| | Minimum | Maximum | Mean | Minimum | Maximum | Mean |
| Current | 123 | 295 | 250 | - | - | - |
| 2020 | 111 | 311 | 257 | -21 | 105 | 7 |
| 2050 | 111 | 313 | 255 | -42 | 106 | 5 |
| 2080 | 95 | 317 | 253 | -79 | 112 | 3 |

- Distribution of biomass between foliage, roots, and stems, influenced by growing conditions and tree size
- Determination of stem number as determined by probability of death and self-thinning
- Conversion of biomass into variables of interest to forest managers (canopy leaf area index, basal area, stem volume, average stem diameter at breast height, mean annual stem-volume increment)
- Water balance of a single soil layer where evapotranspiration is calculated using the Penman-Monteith equation.

Data required to run 3-PG include monthly climate data (air temperature, solar radiation, rainfall, and number of frost days), site factors (latitude, soil texture, maximum available soil water storage, and soil fertility rating), initial conditions of biomass (stem, roots and foliage) and stocking rates, and management conditions (fertilizer applications, irrigation, and thinning).

The results from applying the 3-PG model to the management of *Acacia mangium* short-rotation plantations are summarized in Table 30. The ranges shown in the table refer to geographical variation taking account of differences in climate, soil, and other variables across districts in Vietnam. Note that the maximum and minimum values for the changes in stand volume refer to the maximum or minimum values of the changes predicted by the model. The average stand volume of plantations—if harvested on a 7-year rotation—increases marginally up to 2080, but this is accompanied by a significant increase in the standard deviation of yields across districts as well as large changes for specific districts. The impact of climate change is largest in the North-Central coastal area and in the Mekong Delta (decreases of more than 5 percent by 2080), while in the North-East and the South-East the change is less (decrease in the scale of 0–5 percent), but the spatial extent of the change is larger.

The results suggest that there is large scope for autonomous adaptation, which would take the form of expanding the area of plantation forests in districts where yields are increasing and reducing it in other areas. With short rotations, forestry managers are easily able to adjust choices of genotypes, cultivation practices, and where plantation forests are located to respond to changes in climate conditions that affect yields in particular locations. The main issue that is likely to constrain autonomous adaptation will be competition between timber and other crops for land in areas that have become more favorable for timber production, since the factors that increase timber yields may also increase the yields of competing crops.

***Long-term impacts of climate change on natural forests.*** Over the long term, climate change will cause the boundaries between different types of forest to move as the distributions of tree species change under new climatic conditions. The process of "migration" is likely to be

**TABLE 31 ESTIMATED AREAS CLIMATICALLY SUITED TO SOME FOREST TYPES**

| Forest type | Actual area 2000 | | Suitable area 2050 | | Suitable area 2100 | |
|---|---|---|---|---|---|---|
| | 000 ha | % | 000 ha | % | 000 ha | % |
| Dipterocarp | 375 | 1.2 | 500 | 1.5 | 300 | 0.9 |
| Tropical humid evergreen forest | 1,210 | 3.6 | 1,500 | 4.4 | 650 | 1.9 |
| Tropical humid semi-deciduous forest | 3,830 | 11.4 | 1,300 | 3.9 | 1,200 | 3.5 |

complex and will depend upon geography, patterns of land use, and forestry management. It may involve forest die-back in isolated areas of forest or the invasion of existing forest areas by species that are better suited to new conditions. Theoretically, different forest ecosystems can shift relatively easily in mountainous areas, as a small change in elevation can compensate for average changes in temperature. As conditions become warmer, most ecosystems will shift upward in elevation, but those that are already at the highest elevations will be "squeezed out." Shifts in coastal forests may be severely constrained by the lack of land to which an ecosystem can migrate, given prevailing uses of land for agriculture or urban development. For these reasons it is only possible to assess the direction of the changes that might occur. How these will work out in practice will depend upon many factors, of which forestry policies may only be a small part. It is likely that many changes in forest ecosystems, although theoretically possible, may not be able to occur at the same speed as climate change, resulting in major impacts on natural ecosystems.

A preliminary assessment of the possible changes in forest distributions was carried out by using the Climatic Mapping Program of Vietnam (Vu Tan Phuong et al. 2008). This assessment is based on the ecological requirement of each forest type and the climate change scenarios developed by MoNRE (2009) in order to identify the climatic areas suitable for different forest ecosystems. For this evaluation, the climatic factors considered are (a) average annual rainfall (mm/year); (b) rain regime; (c) length of dry season (months); (d) maximum temperature of the hottest month (°C); (e) minimum temperature of the coldest month (°C); and (f) average annual temperature (°C).

The assessment of the possible distribution of important forest types is summarized in Table 31.

*Dipterocarp forest.* The area with climate conditions suitable for *Dipterocarp* forest in 2050 is likely to be similar to that in 2000. However, the increase in average temperatures after 2050 will reduce the area with suitable conditions to two zones in the north and south, whereas existing areas in the Central Highlands may not support such forests at the end of this century.

*Tropical humid evergreen forest.* Changes in climate up to 2050 will increase the area suitable for tropical humid forests in the center and south of the country. However, longer term trends suggest that areas with suitable climate conditions in the Central Coastal region will decline substantially, leaving less than 2 percent of land area suitable for this type of forest.

*Tropical humid semi-deciduous forest.* This type of forest accounts for about 11.4 percent of Vietnam's total land area. It is likely to be heavily affected by climate change, with a contraction in the area with suitable conditions to less than 4 percent of land area by 2050 and a slow decline thereafter.

The reduction in the area suitable for semi-deciduous forest is particularly important because the change is both rapid and affects forests that represent more than 36 percent of total natural forest.

Most of the North-Central region will no longer be suitable for semi-deciduous forest because of higher temperatures and rainfall, while suitable areas will be concentrated in the Central Coastal region and the Central Highlands. It is very uncertain how existing forests will respond to changes in climate conditions. One possibility is gradual die-back of some tree species accompanied by relative growth in species that are better adapted to the changed climate. Since the regions affected by the changes in climate suitability for semi-deciduous forest are an important focus for forest rehabilitation programs, it will be important to take account of these changes when developing and implementing such programs both now and in the longer term.

Investigation of changes in areas that are suitable for plantation forest is very limited. The impacts of climate change on two tree species (*Chukrasia talbularis* and *Pinus merkusii*) have been assessed by Vu Tan Phuong et al. (2008). They conclude that:

- The area suitable for *Chukrasia talbularis* will fall from about 1 million ha in 2000 to 0.2 million ha in 2100, concentrated in Ha Giang and Cao Bang provinces next to China.

- The area suitable for *Pinus merkusii* will fall from about 5.4 million ha to 2.3 million ha, primarily in the north.

*Sea level rise.* SLR has serious long-term consequences for mangrove forests (Gilman et al. 2007). Mangrove belts provide significant coastal protection (McLeod and Salm 2006) and areas that are vulnerable to damage from typhoons and erosion. For example, in the Red River Delta in Vietnam, a 100 meter wide protective mangrove belt in front of a conventional earthen sea dike with rock is predicted to increase the lifetime of the dike from five to 50 years (Macintosh and Ashton 2002).

Mangrove ecosystems that are deprived of sediments are especially vulnerable to sea level rise as they rely on the deposition of sediment to support their growth and vitality. A net lowering of sediment elevation because of rising sea level is the greatest threat to mangroves, which will be exacerbated if there is limited means for landward migration. The area of mangrove forest will be reduced, and as a result the biodiversity and the protection function of coastal mangrove forests will be significantly reduced. Sea level rise will also affect the Melaleuca and plantation forests planted on salty land in the south (Thuc 2009).

IPCC (2007) reports that a 1-meter rise in mean sea level in Vietnam will affect 1,731 km$^2$ of mangrove forests due to inundation, so that Vietnam could lose up to 70 percent of its mangrove area by the end of the century.

In the south of Vietnam, mangrove forests are located mainly in Ca Mau, Kien Giang, and Soc Trang provinces, and in the north are in the North-East region and the Red River Delta. To date, there has not been a comprehensive study of the impacts of climate change on mangrove forests. The followings are experts' assessments of these potential impacts:

- Mangrove forests can adapt to sea level but only in circumstances where the geographical conditions allow them to do so. As a result, the general tendency is for the area of mangrove forest to become more limited. In the Red River and Mekong River deltas, the mangrove forest is projected to be severely adversely impacted by sea level rise.

- The projected increase in the frequency and intensity of storms and the associated storm surge is expected to damage the mangrove forest.

- On the other hand, it has been pointed out that temperature increases and a higher concentration of $CO_2$ in the atmosphere will speed up the process of photosynthesis of the mangrove

forest trees, so that its biological production may increase.

Beside the mangrove ecosystem, the Melaleuca forest ecosystem is also very sensitive to climate change. The biggest risk to the Melaleuca forest ecosystem is the process of salinization in the estuaries.

## Adaptation Measures in the Forestry Sector

The bulk of adaptation to climate change in the forestry sector will be autonomous adaptation for plantation forests as a result of choices made by forestry managers or natural adaptation through the longer term response of forest ecosystems to different climate conditions. The role of the public sector in supporting adaptation will focus upon research, development, and extension activities that build upon existing good practice. The cost of such support should be modest in relation to current programs for forest rehabilitation. The key initial priority will be to collect better information on the impact of climate change on forests and to use this information to develop strategies that respond to the various consequences of climate change. As explained below, this may involve the selection of drought tolerant or disease resistant varieties of plantation trees or the dissemination of silviculture regimes designed to minimize fire risks. In all cases, the essential public role is to provide forestry managers with information and advice on the best responses to changes in climate conditions.

***Forest fires.*** Adaptation options should target fire management and fuel load. Basic fire management requires the strategic placement and proper maintenance of adequate fire breaks. Inter-row plowing is regarded as good practice for fire management in plantation forests, as well as for weed control, although such treatment involves a tradeoff between minimizing fire risks and sustaining stand productivity. Debris should be removed from sites for domestic fuel as this can obviate any requirement for fuel-reduction burning, which is itself a risk, as fire damage to the outer sapwood and conducting pathways in trees will reduce stand productivity and risk mortality.

***Drought.*** For plantation forests, adaptation will involve (a) the adoption of species and varieties that are more tolerant to droughts, and (b) changes in silviculture to make best use of water in wood production. Both require an examination of how species respond to combinations of signals associated with changing climates.

- In comparison to *Acacia mangium, Acacia crassicarpa* has a higher ratio of sapwood area to leaf area, a characteristic associated with adaptation to a dry environment. This is associated with its capacity to maintain higher rates of photosynthesis during the dry season (Don White, pers. comm.). Within-species variation in these characteristics is worth investigation and may be crucial for dealing with adaptation to changing climates.

- Managing stands for their water use—for example, by planting at wider spacings or through strategic thinning—is one option. Species vary in their root development, so cultivation techniques should be used to encourage root development and improved access to water at depth.

*Pests and diseases.* The crucial issue is to develop and implement effective systems for managing pests and diseases under changing climate conditions. This will include the ability to respond effectively to changes in host resistance or in insect and pathogen life cycles.

- Quarantine—the maintenance and improvement of quarantine capabilities in respect to forest pests and pathogens will be an important element of any strategy for adaptation.

- Genetic selection—favoring forest varieties and species that are adapted or adaptable to new climatic conditions. Genotypes can also be identified that show a broad spectrum of tolerance to pests and diseases under variable climatic conditions.

- Good information—adaptive management of pests in relation to climate variability depends upon information acquired being useful and effective. An ongoing commitment to the identification of insect pests, disease (and weed) threats are fundamental and must include the routine record keeping of climate and pest damage. Monitoring and predictive systems—for example, geographically sensitive models that use projected climate information—can indicate likely changes in the timing and severity of pest and disease outbreaks for both indigenous and non-native pests.

- Integrated health management and area-wide management—responding to changes in the timing, patterns, and severity of pest outbreaks is a central part of any strategy to maintain vigor and productivity under climate change. This will include changes in silviculture practices such as rotation length, thinning, and fertilization regimes.

*Weeds.* Weed control strategies can be divided into three categories: (a) cultural, e.g. manual, mechanical, mulching, grazing, cover crops; (b) chemical; and (c) biological. In Vietnam, cultural methods provide the primary approach to weed control in plantation forests with limited use of chemical methods. Response to changes in the weed spectrum in Vietnam may involve greater focus on herbicides and biological control.

- Herbicides—the generation of herbicide-resistant weeds is one risk associated with the use of herbicides. In Vietnam, it is unlikely that herbicide-resistant weeds will be generated under current forestry management regimes in the short-to-medium term, partly because of low rates of use but also because, where herbicides are used, most sites receive less than three applications during a rotation. If the use of herbicides becomes more frequent, the risk of promoting herbicide resistance must be assessed. One option might be the development of herbicide-tolerant varieties via either conventional plant breeding or genetic modification.

- Biological control—this involves the introduction of host-specific agents, usually insects or fungi, for the control of a weed species. Biological control agents can be selected to affect only the target organism. Changing climates will affect the life cycles of both the control agentss and the weeds. The development of biological control agents as a weed-control option in Vietnam would need to recognize the large variation in climate that already exists and how this might change.

- Good information—as with pests and diseases, effective weed management when the climate is changing will involve the effective collection and analysis of data. Bioclimatic models are available to examine potential weed species distribution at a national scale. They predict an average response to climate and are a common tool for identifying the potential range of weeds (and pests and diseases) as well as changes in species distributions related to climate change. These models can be applied in the context of forestry in Vietnam.

***Mangrove forests.*** The key issue is maintaining the resilience of mangrove ecosystems. This should include maintaining the ability of mangrove forests to function naturally in their original place with rising sea level, as well as its capacity to migrate (Gilman et al., 2007). For existing forest, activities within a catchment should respect the need to maintain sediment elevation. Coastal planning should be adapted to facilitate migration. More generally, protection and rehabilitation of existing mangrove forests are important means of facilitating their capacity to manage stress, maintain habitat and, if necessary, to migrate. These actions should be underpinned by research and data collection that (a) track changes in salinity and hydrology, (b) monitor sediment elevation, and (c) develop an understanding of responses of mangroves to sea level rise (McLeod and Salm 2006).

# SIX

# Adaptation at the Local Level: Social Analysis

## Social Vulnerability to Climate Change

Social vulnerability relates primarily to how "access to resources" is distributed within and among communities. While physical vulnerabilities may be geographically mapped with some precision, it is social vulnerabilities that often are much more difficult to assess and to identify clearly because they do not easily fit into definite geographic spaces. For example, natural events, such as heavy rains or floods, are often compounded by poor local water management, such as inadequate pumps or release of water from a reservoir. The same phenomenon, like floods, also may not consistently affect the same production sectors, some of which may be more sensitive to climate than others. Similarly, in some areas poor households may be the most vulnerable, while in other areas it is the better off, who have more to lose financially in flood damage. These varying vulnerabilities make it very difficult to put forth comprehensive national-level plans, and indicate downscaled, community-level assessments are likely to be most useful. In interviews with prominent scientists and policy makers regarding whether Vietnam has a standard classification for areas with different levels of vulnerability to climate change and a system for prioritization, our interviewees have confirmed there is no such classification. The full result of the EACC's work on social issues in Vietnam can be consulted in the detailed sector report (McElwee et al. 2010).

Several of those interviewed noted that studies on climate change are often donor-driven, and thus are conducted in places where the donors are more interested. The Ministry of Labor, Invalids and Social Affairs (MoLISA) does maintain an official classification of "vulnerable" populations in general (but not specific to climate change), for whom special safety net services are targeted. These vulnerable peoples include invalids, elderly without relatives, orphans, and laborers with limited schooling (Poverty Task Force 2002). These groups of people are identified regularly by state officials in local MoLISA departments and given special priorities to social safety net programs like health insurance cards and educational subsidies (MoLISA and UNDP 2004).

To these official indicators we can add a number of other indicators of general vulnerability identified in livelihood assessments and participatory poverty assessments over the past 15 years, including women, children, ethnic minorities, the illiterate, those who suffer food shortages, those under the poverty line, the disabled, families with many children, and those in remote areas (Poverty Task Force 2002).

These indicators of social vulnerability come from a number of different studies. For example, in the 1990s there were a number of participatory poverty assessments conducted by NGOs with assistance from the World Bank, and many of these studies looked carefully at the conditions of rural poverty (World Bank 1999). More recently there have been several studies that tried to look specifically at the issue of climate change and vulnerability in Vietnam. Work led by the University of East Anglia, particularly Neil Adger (1999a, 1999b, 2000, 2003) and Adger et al. (2002) has emphasized factors of poverty and dependence on livelihoods to climate-sensitive economic activities (particularly farming and fishing) as a proxy for household sensitivity to climate change. Adger has also emphasized the strong role of institutional change, such as the erosion of collective support for mangrove planting and dike repairs that were a part of the Doi Moi process. Some recent climate change and vulnerability reports based on new field data were done by NGOs (i.e. Kyoto University and Oxfam 2007; Oxfam 2008).

***Poverty.*** Poverty relates to vulnerability and the sensitivity of livelihoods to risks because it structures access to entitlements and resources. For example, those who are poor may live farther away from good quality natural resources, have little ability to absorb risk, and have trouble recovering once a risk happens (DFID 2004). The poor tend to have less diversity of income sources, and less access to credit to fill in income gaps, which likely increases their risk of disaster when one of their sources is strongly affected by climate. Vulnerability to shocks, whether they be climate or otherwise (such as health or unemployment shocks), has long been identified as one of the major challenges for the poor in Vietnam (Poverty Task Force 2002). While the poor are not necessarily the only people impacted by climate risks, they tend to have less resilience, such as less access to insurance, and less ability to rebuild or move away from affected areas. They are more likely to live in shoddy or substandard housing that is vulnerable to climate events and be more exposed to health hazards because of the occupations available to them (Few and Pham 2010). Given that households in recent surveys (such as Oxfam 2008 and World Bank 2009) already cited weather as one of their primary vulnerability and risk factors, the rise in extreme weather events that is likely in the next 50 years should be a source of great concern. Recent successes in poverty reduction in Vietnam have the potential to be undermined by the effects of climate change.

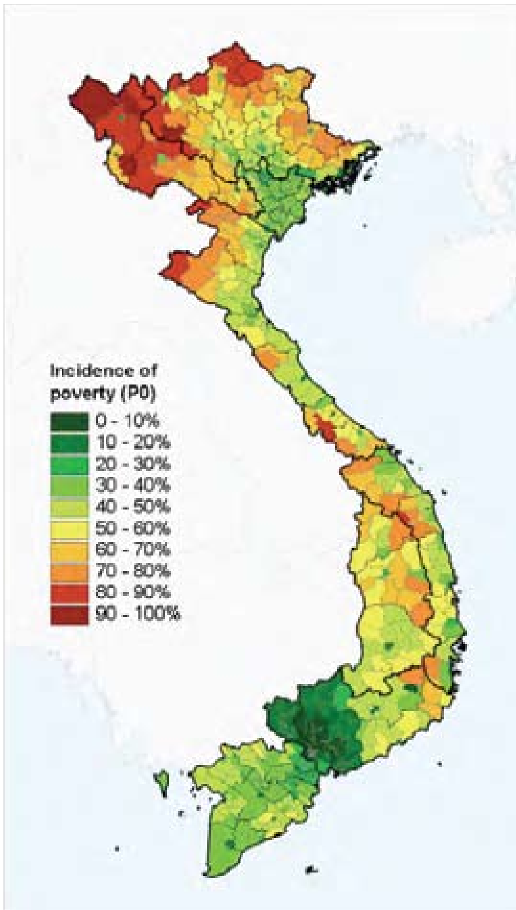
Poverty in Vietnam has been the subject of many recent in-depth analyses. Poverty is measured by a standard government measure; according to Decision 170/2005/QĐ-TTg, poor households in rural areas have a monthly income per person of below 200,000 VNĐ and below 260,000 VNĐ for urban areas. Areas with households below this standard are considered poor. There has been a strong reduction in overall poverty in Vietnam in the past 20 years, with the fraction of households living below the poverty line at less than 15 percent in 2006, compared to over 58 percent in 1993 (World Bank 2008). Poverty is now regionally concentrated in mostly rural and ethnic minority-dominated areas (Figure 12). For example, while only 14 percent of the total population, ethnic minorities currently account for 44 percent of the poor and 59 percent of the food-hungry (World Bank 2009). The main vulnerable regions for poverty include the Northern Mountains, the Central Highlands, and the North-Central Coast, which remain poorer than the rest of the country in terms of percentages of people in poverty. In terms of total numbers of poor, however, the Red River Delta and Mekong Delta are important because of their overall large populations and consequently large absolute numbers of poor people.

*Main vulnerable areas.* In terms of percentages of the population, mountainous areas with ethnic minorities are most vulnerable (Northern Mountains and Central Highlands). But in absolute numbers of poor, the Red River Delta and Mekong Delta remain significant as well. Furthermore, areas with substandard housing (Mekong Delta) and few household assets are also likely to be at risk.

***Climate-sensitive resource dependency.*** When households' livelihoods depend on a small number of sources of income without much diversification, and when those income sources are in fields that are highly climate dependent, like agriculture and fishing, households can be said to have climate-sensitive resource dependence (Adger 1999a). Agriculture and fishing make up significant parts of the overall economy of Vietnam, a topic explored in more detail in the Vietnam EACC studies for these sectors. Rice is by far the largest single crop, accounting for 43 percent of gross agriculture produced in 2007. Other significant export crops include tea, coffee, rubber, peanut, cashew nuts, and black pepper, while corn, sweet potato, cassava, vegetables, beans, and fruits are for local consumption (Nguyen Lanh 2009). While irrigation is widespread in the rice sector in particular, there are still significant portions of the country in which rainfed rice dominates, particularly in areas outside the two main deltas. Clearly the changes in precipitation predicted under climate change have the potential to significantly affect crop yields, as the sectoral report on agriculture for the EACC has made clear.

Fishing is also highly climate dependent. Storms can bring salinity into aquaculture areas and damage the health of livestock. For small farmers in particular, it can be difficult to recover from climate events. One likely consequence of climate change, for example, is consolidation of shrimp farms into larger holdings as smallholders are squeezed out and forced to sell their lands to cover debts (Adger, Kelly et al. 2002). Overall, about half a million people in Vietnam get most of their income from fishing, and another 2 million have fishing-related income in enterprises such as processing. The value of fishery exports has increased dramatically in recent years as well, as the aquaculture sectoral note for the EACC study explains.

**FIGURE 12 POVERTY MAP OF VIETNAM AT DISTRICT LEVEL**




The livestock sector is particularly important to many poor households, who count buffalos and pigs among their most important assets (World Bank 1999). When these assets are lost to disease or climate events, this can be one of the most significant sectors causing a decline in household livelihoods (Poverty Task Force 2002).

The forestry sector is a relatively small sector of the economy, and provides only small amounts of income in most regions (Table 32). It can, however, be an important informal safety net sector

**TABLE 32 DEPENDENCY ON DIFFERENT INCOME STREAMS BY REGION**

| Region | % HH involved in agriculture | % HH involved in fishing | % HH in forestry | % HH in industry | % HH in services | Other |
|---|---|---|---|---|---|---|
| All of Vietnam | 66.5 | 4.4 | 0.2 | 10.2 | 14.9 | 3.8 |
| North East | 83.5 | 0.8 | 0.5 | 3.7 | 9.5 | 2.0 |
| North West | 91.0 | 0.1 | 0.4 | 1.0 | 6.9 | 4.0 |
| Red River Delta | 58.2 | 1.8 | 0.0 | 16.5 | 17.0 | 3.0 |
| North Central Coast | 72.5 | 3.6 | 0.3 | 6.0 | 11.8 | 5.8 |
| South Central Coast | 61.5 | 7.3 | 0.3 | 10.9 | 15.2 | 1.0 |
| Central Highlands | 88.7 | 0.1 | 0.1 | 2.1 | 8.1 | 0.9 |
| South East | 51.3 | 2.8 | 0.2 | 19.5 | 23.4 | 2.7 |
| Mekong Delta | 61.8 | 11.0 | 0.2 | 8.4 | 16.6 | 1.8 |

*Source:* 2006 Rural, Agricultural and Fisheries Census

and provide income when other sectors like agriculture fail (Sunderlin and Huynh 2005; McElwee 2008). Climate damage to forests, such as dry weather leading to forest fires, can thus be an additional stressor to poor households.

*Main vulnerable areas*. Provinces with a large number of households dependent on rainfed agriculture (North-East, North-West, North and South-Central Coasts, Central Highlands) and households with little to no diversification of income sources (North-West, North-East, Central Highlands) are likely the most vulnerable. Provinces with high numbers of fishing-related businesses are also sensitive (Mekong Delta, Central Coast).

***Ethnic minorities***. Vietnam has 54 official ethnic groups. The largest minority group, the Tay, has nearly 1.5 million members, while the smallest, the O Du, has barely 300. These ethnic minority groups share some things in common; 75 percent of Vietnam's minority populations live in two regions, the Northern Mountains and Central Highlands, and most minorities remain rural residents. This means that minorities are potentially more sensitive to climate events by virtue of being more likely to be farmers and to live in rural areas. They are also more likely to be poor, as noted earlier. But ethnic minorities face specific factors of vulnerability that other rural or poor areas might not.

Compared to the Vietnamese majority (known as Kinh), minorities continue to be more dependent on staple goods and traditional agriculture, and are less diversified. They report much lower rates of agricultural investment, with resulting lower productivity (World Bank 2009). Access to credit and financial services is very uneven in minority areas. Kinh report more loans and larger bank loans than minorities on average, while ethnic minorities report a higher need for credit (Hoang Cong Dung et al. 2006). Minorities also face many barriers in adaptive capacity as well, with the major factor in this area being much lower levels of education. Dropout rates remain significantly higher for minorities, resulting in higher rates of illiteracy and lack of language fluency in Vietnamese, which hinders minorities' ability to interact with others and take advantage of outside resources (World Bank 2009). All of these factors above combined likely make ethnic minorities especially vulnerable to climate change. Table 33 indicates the regions in which minorities make up sizable percentages of the overall population, namely the Northern Mountains and Central Highlands.

The Mekong Delta, which has a relatively low percentage of minorities, does have a particularly vulnerable group, the Khmer, who have experienced high rates of landlessness and dependency on wage labor as their main sources of income in recent years (Le Ngoc Thanh et al. 2006). The number of Khmer households who are landless is estimated to be more than 25 percent, with surveys revealing that more than 75 percent of poor households were landless. Khmer landlessness was not usually due to shrimp farm debt, which is a major reason for landlessness among the Kinh in the same area. Rather, Khmer loss of land seems to relate primarily to failures in rice and crop cultivation. As a result of landlessness, over 80 percent of the incomes of poor Khmer households surveyed in a 2006 report came from wage labor (Le Ngoc Thanh et al. 2006). Many people go to work for agricultural farms in neighboring provinces, and Khmer households from the same village often form a roving band of migrant agricultural labor. This migration pattern has contributed to strong vulnerability among Khmer, as these labor seekers have become dependent on distant and often unstable income. A number of problems are also associated with migrant workers, including less access to government services and more vulnerability to poverty and social evils (Le Ngoc Thanh et al. 2006).

*Main vulnerable areas.* The regions where minorities dominate, the Northern Mountains and Central Highlands, are likely to be most sensitive. Areas with smaller, less prosperous, minorities are also likely more heavily affected (North-Central Coast, South-Central Coast, as well as the Northern Mountains and Central Highlands). And the Khmer minority group in the Mekong Delta is a vulnerable population in particular, due to very high rates of landlessness not seen in other minority populations.

***Women and children.*** It is clear that gender affects vulnerability to "natural" disasters; thus, it is to be expected that similar vulnerability to climate change would also be encountered. For example, increases in domestic violence have been widely reported after climate disasters such as hurricanes (Fordham 1998; Cupples 2007). Gender inequality also likely limits the possible range of responses for adaptation by women (Lambrou and Piana 2006). For example, changes in the physical environment as a result of climate change may increase women's workload as their access to natural resources may decline (Nelson et al. 2002). Families may break up as the women or the men need to migrate . They may have to take up low-wage labor if agriculture becomes unsuitable to their local areas (Nelson et al. 2002).

In Vietnam, gender analysis gives us an understanding of how the identities of women and men determine different vulnerabilities and capacities to deal with climate change (UNDP 2009). A UNDP desk study on gender and climate change in Vietnam notes that women face challenges from climate change in three areas: the productive, reproductive, and community spheres. In terms of production, agriculture has been increasingly feminized; 62 percent of women versus 52 percent of men are engaged in agricultural production. Thus it is likely that more women face risks from climate impacts to the agricultural sector. Climate change

**TABLE 33 REGIONAL DISTRIBUTION OF MINORITY POPULATIONS**

| Region | % rural HH who are minorities |
|---|---|
| All of Vietnam | 15 |
| North-East | 44 |
| North-West | 86 |
| Red River Delta | >1 |
| North-Central Coast | 11.3 |
| South-Central Coast | 7 |
| Central Highlands | 39 |
| South-East | 7.5 |
| Mekong Delta | 7.5 |

*Source:* 2006 Rural, Agricultural and Fisheries Census.

### TABLE 34 STATISTICS ON FEMALE STATUS BY REGION

| Region | Maternal mortality by region (per 100,000 live births)[1] | Gender gap in male/ female literacy rates[2] | % female govt workers at commune level[3] |
|---|---|---|---|
| North-East | 411 | 5.3 | 3.5 |
| North-West | (combined w/ above) | 15.2 | 2.2 |
| Red River Delta | 46 | 4.3 | 2.7 |
| North-Central Coast | 162 | 5.9 | 2.6 |
| South-Central Coast | 199 | 5.1 | 4.0 |
| Central Highlands | 178 | 6.9 | 5.0 |
| South-East | 45 | 3.1 | 10.0 |
| Mekong Delta | 143 | 6.6 | 4.8 |

*Sources:* (1) Demographic and Health Survey 2002 in ADB 2005; (2) 2004 Vietnam Household Living Standing Survey (VHLSS) in ADB 2005; (3) 2006 Rural, Agricultural and Fisheries Survey.

also adds to water insecurity, which increases the work level of women as they are more likely to be the ones in a household responsible for water collection (Le Cong Thanh 2008). Women are also much less likely to have their name on land tenure titles, which can increase their insecurity in the case of divorce or widowhood and contestation over land rights.

For those in other economic sectors outside of agriculture, there is still vulnerability. More women than men work in household-scale small enterprises, as opposed to formal employment, and these households enterprises are often worst hit and least able to recover as a result of disasters. Female-headed households (FHH) have their own special needs. In the 1990s, nearly 25 percent of all rural households were female-headed, and 75 percent of all spouse-absent female-headed households in the whole country were living in rural areas (Desai 1995). While a large part of the reason for a high percentage of FHH in the past was due to excess male mortality as a result of the wars in Vietnam, younger FHH tend to be caused by migrant male labor or divorce/separation. Women migrants can be vulnerable too, as they may be alone with little protection without social connections, as well as usually earning less than men. Table 34 provides a snapshot of female vulnerabilities across regions in Vietnam.

So far no sex-disaggregated data is available on injury or death due to climate events in Vietnam, but anecdotal evidence suggests poor women are more likely to become direct victims as they place family members' safety first. They are also often not warned in climate alarms, which go to heads of households or men. More women tend to die in floods than men because they "have not been given the same encouragement as men and boys to learn to swim. All sorts of social customs and behavior restrictions made it more difficult for them to do so" (Oxfam 2008).

Women are also less likely to engage in community activities to increase adaptive capacity. It has been estimated that female participation in local politics is less than 20 percent of official positions at local People's Councils, and sometimes much lower (Le Cong Thanh 2008). Women's involvement in local Committees for Flood and Storm Control is often limited to asking them to be in charge of child-care or food distribution and sweeping and clean up, and they are not encouraged to take a more active role in overall decision making (UNDP 2008). Children can also be strongly vulnerable to weather events, especially events like increased flooding. Evidence from interviews of people affected by floods after typhoons and storms in the Mekong Delta noted that there were many people who "had died in relatively calm waters simply because they could not swim" (Oxfam 2008), and of this number, child drownings were the largest number. More than half of households interviewed in a study of health and climate in the Mekong Delta "expressed fear for children's safety during the flood months when water levels are high and currents may be strong" (Few and Phan 2010). Climate events can also indirectly harm children, as they can cause children to drop out of school (either due to physical closure of schools due to damage, or money not being available after climate events for school fees), which will keep them from long-term advancement (Phong Tran et al. 2008).

*Main vulnerable areas.* All regions/provinces have similar vulnerability in terms of proportion of the population that is female, but more attention needs to be paid to FHH, ethnic minority women, and migrant women in particular, who are more vulnerable. Children are especially vulnerable in coastal and riverine areas where children have to cross waterways to go to school and work, or where schools are vulnerable to submersion in floods (primarily Mekong Delta, Central Coast, and Red River Delta).

***Migration.*** Vietnam has had strong patterns of migration since rules relaxing household registration went into effect in the 1990s. Since then, migration from rural to urban areas has accounted for the majority of the migration experienced. There are strong regional patterns of migration in Vietnam, with most areas sending migrants, and only two areas (the Central Highlands and South-East) absorbing most in-migration. Large numbers of urban migrants can be found in the largest cities of Hanoi and Ho Chi Minh city, and in the South-East region, which is home to a large number of industrial zones where people have moved for work in agro-processing, textiles, and other industries. In addition, the Central Highlands saw large amounts of in-migrants in the 1990s and 2000s, despite being a rural destination, due to high world prices for coffee and other cash crops, and from government encouragement to settle these areas (Winkels 2008). This influx of migrants likely increased the vulnerability of local residents (mostly minorities) as they saw their land and natural resources availability decline dramatically, while the migrants themselves have been very vulnerable to climate- and trade-related shocks in the coffee sector in the past 15 years (World Bank 2009).

Migration can be both a cause and consequence of climate vulnerability. There is evidence that natural disasters have been a strong motive for migration. In a study conducted in the central provinces in early 2000, respondents in Thua Thien-Hue stated that migration to the south had become even more popular in the wake of the severe floods in November 1999 (ADRC 2003). In the Mekong Delta, an assessment of migration as a consequence of climate change found floods to be a strong pushing factor for some households to leave for other areas (Dun 2009). Later this century, Ho Chi Minh City may face the prospect of large numbers of new migrants in the form of climate refugees leaving the Mekong Delta; estimates range as high as 5 million people who may be displaced (Carew-Reid 2008).

Additionally, those who have migrated to a new area for non-climate reasons (i.e. to get a job) may also be more vulnerable to climate events. For example, migrants in Vietnam are required to have some documentation under the national household registration system (*ho khau*) in order to access social services, but there are also numerous people who never register and remain undocumented migrants (Pincus and Sender 2008). Undocumented migrants and those without permanent status have no rights to public safety net services, and often are exploited for low wages in employment or let go if ill or injured, and they have little recourse due to their undocumented status (Dang Nguyen Anh 2005). Twenty-nine percent of the Ho Chi Minh City population is estimated to be registered temporary migrants, and migrants have tended to group in some particular districts (Go Vap, Tan Binh, Binh Thanh, and District 12), where they often make up a majority of the ward population in some places (Le Van Thanh 2002), potentially making these districts sites of particular social vulnerability.

Another consequence of migration rates are that many sending areas are losing their youngest workers, and this can limit the sending community's capacity to respond to climate events. Without young people it is difficult to form youth labor groups to support the work on shoring up dikes, for example. Some villages in the Red River Delta have seen so many of their young people leave to work elsewhere that there is almost no one left under age 50, and without strong laborers, dike maintenance and protection of houses is very difficult during severe weather events.

*Main vulnerable populations.* Places with high levels of in-migrants are vulnerable. Ho Chi Minh City has the largest absolute number, while other smaller cities, particularly in the Mekong Delta, have rising numbers as well (for example, Can Tho city).

***Urban households.*** While many studies have pointed out the strong vulnerability of rural populations to climate change, an increase in urban-specific studies shows clearly that cities face major vulnerabilities themselves, often affecting very large numbers of people (De Sherbinin et al. 2007). Although urban areas are often assumed to be less vulnerable to impacts due to higher rates of development, there are many pockets of poor, often migrants or unregistered populations in major urban centers of Vietnam who will be just as vulnerable, if not more so, than rural farming populations outside of urban areas. Furthermore, in terms of overall numbers of affected peoples, the population density of urban areas means that while the overall percentage of affected people may be lower in urban than rural areas, the total affected numbers will likely be higher in urban areas. For example, the projected population of Ho Chi Minh City is 10 million by 2020. With a current poverty rate of 6.6 percent of urban residents, that is a large number of absolute poor.

The built environment of cities can mean more exposure to climate hazards; that is, lots of concrete with poor drainage can lead to regular flooding. In Ho Chi Minh City, for example, a great deal of building has taken place in what used to be wetlands south of the city, which affects the ability of surrounding lands to drain. This has been pointed to as a reason behind increased flooding in the city (Bolay et al. 1997). Urban residents also may have more constraints to individual adaptation than rural residents. For example, urban residents may find it hard to move to a new area through migration due to higher investments in housing stock than rural farmers with lower quality or temporary housing. These urban households may also have less social capital if they have migrated and have no relatives or friends in their new city, or have low participation in community and social activity because of lack of legal residence permits. "Unofficial" work activity is a large portion of the employment of urban residents in Vietnam; for example, it is estimated that about 45 percent of the population in Ho Chi Minh City have some form of unofficial work, including small business and services such as motorbike taxis, mobile food vendors, and so on. The urban poor also often take what are known as 3D jobs—dirty, difficult, and dangerous—such as portering, sewage cleaning, and pedicab driving. These occupations can have low security of employment and low incomes, and be especially vulnerable to disruptions from events such as flooding.

*Main vulnerable populations.* Ho Chi Minh City has the largest number of urban households likely to be at risk, due to high exposure of the city to SLR and other climate events, as well as large numbers of migrant households.

***Education.*** Levels of education can play a role in climate change sensitivity, because they can reflect the inability to read and receive climate warnings, as well as information in post-climate disaster situations about recovery policies. Education can also affect people's ability to make proactive adaptation decisions. Surveys in Thua Thien Hue, for example, found that those with a high school education were much more likely to think flood damage was a result of a combination of social vulnerability and natural factors, while those with less schooling were more likely to ascribe flood damage to "fate" or an "act of God" against which they had little control (Phong Tran et al. 2008). Higher levels of education can also increase the ability to recover after climate events through better access to information and sources of support. Overall rates of literacy and education are shown in Table 35, with high rates of lack of formal education even in richer regions like the Mekong Delta.

**TABLE 35 LITERACY AND EDUCATION RATES, 2001**

| *Region* | *% labor population who is illiterate* | *% labor population with no completed education level* |
|---|---|---|
| All of Vietnam | 3.8 | 16.7 |
| North-East | 7.4 | 14.8 |
| North-West | 23.5 | 22.5 |
| Red River Delta | 0.7 | 6.4 |
| North-Central Coast | 2.3 | 10.4 |
| South-Central Coast | 3.0 | 18.9 |
| Central Highlands | 5.6 | 17.4 |
| South-East | 2.0 | 15.6 |
| Mekong Delta | 4.4 | 30.7 |

*Source:* 2005 data from GSO

*Main vulnerable populations.* The illiterate and households in which no one speaks/reads Vietnamese fluently; these are more likely to be ethnic minority households concentrated in the Central Highlands and Northern Mountains.

***Illness, health, and sanitation.*** Having ill family members is one of the main risks facing poor households in Vietnam (Poverty Task Force 2002), and climate change can bring health risks in many forms. There are the direct health problems that can be caused by floods and storms, such as injuries from falling debris, as well as the sanitation aftermath of climate events. Diarrheal diseases are a major concern after flood events, with stagnant and non-potable water spreading illness. Children and those already ill are particularly at risk. There are also "elevated risk of skin diseases and conjunctivitis, especially among children who might play in the polluted water" (Few and Pham 2010).

According to the Ministry of Health, there are a number of diseases that are on the rise, some of which may be connected to changes in climate. These include increases in the incidence of respiratory disease, rheumatism , hepatitis B, diphtheria, cholera, typhoid, plague, and malaria (Hoang Xuan Huy and Le Van Chinh 2007). A warmer climate in terms of temperature increase will likely increase health risks to the elderly and those already suffering from some diseases. Temperature changes may also increase the breeding grounds for disease carrying vectors.

Existing conditions regarding sanitation and access to clean water are not ideal, and it is likely that climate change will impact access to water, given the changes that are predicted. Table 36 indicates the areas of Vietnam that are already dependent on rainfall and surface water, and those who have more reliable supplies of well, piped, or purchased water. The Mekong Delta is particularly vulnerable to diseases spread through surface water sources, and the Red River Delta is vulnerable to changes in rainfall, given the large number of households who rely on rainfall for their water supplies.

*Main vulnerable populations.* People with existing illnesses that can be exacerbated; children; areas with poor sanitation.

**TABLE 36 HOUSEHOLD ACCESS TO WATER, 2005**
**(% OF HOUSEHOLDS WHO GET MOST OF THEIR WATER FROM DIFFERENT SOURCES)**

| Region | Piped water | Purchase | Rain | Well | Surface/ Spring |
|---|---|---|---|---|---|
| All of Vietnam | 8.2 | 0.3 | 15.0 | 61.5 | 8.3 |
| North-East | 3.4 | 0.1 | 3.0 | 70.4 | 0.6 |
| North-West | 2.0 | 0.1 | 1.1 | 41.2 | 5.1 |
| Red River Delta | 5.5 | 0.1 | 42.4 | 51.5 | 0.4 |
| North-Central Coast | 5.3 | 0.3 | 8.1 | 79.6 | 0.1 |
| South-Central Coast | 4.5 | 0.3 | 0.2 | 89.8 | 0.3 |
| Central Highlands | 1.8 | 0.13 | 0.5 | 84.7 | 1.6 |
| South-East | 10 | 1.9 | 1.1 | 84.4 | 1.4 |
| Mekong Delta | 19 | .3 | 13.3 | 32.2 | 35 |

*Source:* 2006 Rural, Agricultural and Fisheries survey.

***Indicators of adaptive capacity.*** Adaptive capacity, as noted earlier, relates to the ability of institutions or people to modify or change characteristics or behavior so as to cope better with existing or anticipated external stresses from climate. There are a number of indicators of this capacity that have been pointed out in the literature; here we focus on social capital and collective action, institutional adaptations, and government safety nets. Unlike the indicators for exposure and sensitivity that we outlined in the above sections, which can be assessed with existing data sources by region, these adaptive capacity indicators are very hard to find quantitative or qualitative assessments by region, and are much more usefully assessed at levels such as districts or communes.

*Social capital and collective action* is one such indicator. In modern Vietnam, the individual family household is the prime kin unit, but extended kin relations remain one of the strongest markers of identity, and relatives are usually the first people to be called on in cases of need. Kinship networks are well-known as being particularly important for gaining access to information (Lan Anh Hoang et al. 2006). They are also important in mutual assistance, such as in sharing work in agricultural tasks. Reciprocal help is essential at peak seasons of rice cultivation, particularly during transplanting and harvesting. Overall, more than 85 percent of the households in one survey reported regular labor exchanges, with the average number of days varying from a minimum of five to more than twenty days per season (McElwee 2007). People also can ask for help from their friends from other communes or districts; relatives are the first line of defense for households that have been affected by storms. They seek shelter in relatives' houses, rely on relatives to help them clean up afterwards, and to provide loans if financial assistance is needed.

There is a history of use of this informal system to play a role in helping households cope/adapt with climate-related events, such as floods, which could be a good buffer and source of adaptive capacity for the future. This "social capital" for climate adaptation can be partly seen through the informal financial supporting activities of women's groups, for example (Miller 2006). Particularly in the Mekong Delta, women often form into small groups to provide rotating credit, in which members contribute a specific amount of money every month to lend one member. The amount will be circulated among members monthly. This kind of practice can be among women within a village or among brothers and sisters in families or clans. The goal is to understand these informal institutions better, and help the formal system to support and encourage these informal assistance mechanisms (Adger 2003).

*Institutional capacity* thus has a role to play. Recent research shows clearly that institutions have a large role to play in understanding where vulnerability to climate change might be high, and how adaptation can happen (Agrawal 2008) Vietnam has a very hierarchical government structure, with government offices organized vertically from central to provincial to district to commune levels, the lowest level of state administration in Vietnam, with more than 10,000 communes total in the country. For example, although there may be a provincial department of a central ministry—for example, the Ministry of Agriculture and Rural Development (MARD) has provincial offices known as Departments of Agriculture and Rural Development (DARDs)—these departments are answerable both to the People's Committee of the province (lateral reporting responsibility) as well as to the central ministry (vertical reporting responsibility). This system, while useful for conveying information in a clear hierarchy from top to bottom, also results in a lot of overlap between departments at each level, and unclear chains of command between vertical and horizontal levels. This means that new approaches and new actions, such as those needed to deal with new issues like climate change, will likely only slowly be incorporated into the existing institutional system. There are also increasing numbers of new organizations that may play roles in local areas vis-à-vis climate adaptation. These include fishing and farming unions, agricultural cooperatives, and farmers' informal working groups. These groups can leverage support for their members in times of shocks and high risks. For example, many agriculture cooperatives have contracts with commercial suppliers of agricultural inputs, which the cooperative delivers to the individual farmer members on credit to be paid after harvest. There have been good examples of cooperatives acting after floods in Thua Thien Hue in 2000 to bridge a gap between the time the flooding occurred and the availability of formal support credits for the next crop by cooperatives buying inputs on credit for delivery to farmers with payment due after the subsequent harvest (ADRC 2003).

One problem for climate change planning is the wide disparity between regions in terms of their inputs to the central budget and what they receive in return, which affects the ability of localities to deal with climate adaptation. The wealthiest regions (the Red River Delta, the South Central Coast, and the South East, which includes Ho Chi Minh City) transfer much more to the central budget than they receive in return in terms of per capita budget support. Therefore, wealthier regions are not necessarily better equipped to deal with climate impacts, as so much of their wealth is transferred to other regions, and the poorer regions are dependent on these central transfers, which limits their ability to put into place flexible local adaptation measures.

*Social safety nets* can also play a role in adaptive capacity. The removal of much of the former socialist safety nets during the *Doi Moi* process has left more households paying for public services out of pocket. Many formerly state services are now funded through additional fees and contributions paid by individual citizens and are being provided by state, parastatal, and private entities (such as agricultural inputs, now sold from private agribusinesses competing with state-owned fertilizer factories). By the end of the 1990s, for example, Vietnamese had to pay out of pocket for most social services; these expenditures accounted for about 70 percent of the country's education expenditures and 80 percent of health expenditures, whereas 20 years ago these would have all been provided in exchange for work in collective enterprises or agricultural farms. For an individual household, the fees for social services have imposed an increasing burden on household incomes, and these burdens have fallen especially hard on the poor (Evans et al. 2007).

While in theory, the existing state safety net programs (primarily social security payments, disability payments, health insurance, education subsidies, and poverty alleviation programs) have the potential to mitigate the adverse impacts of climate shocks, in fact, there is low spending on social services relative to needs (Van De Walle 2004). Large numbers of eligible people simply do not receive safety net coverage. Furthermore, social benefits are often tied to one's location; undocumented migrants do not have access to social safety net services if they lack household registration cards. The provincial disparities in expenditures from the National Target Programs on Hunger Alleviation and Poverty Reduction are also of concern. While the greatest expenditures have been made largely in the poorest areas, there is significant unevenness in how much actually goes to each poor person.

*Main indicators of adaptive capacity.* There are many possible indicators of adaptive capacity that could be used in Vietnam, such as the number of social ties between households; existence of active loan and support networks in villages; number of informal community-based organizations in localities; number of informal work groups or production cooperatives; districts and localities with more budget flexibility; training and support for key government personnel in capacity for adaptation; presence of formal climate adaptation plans or strategies at local levels; experience with past climate disaster events; and communes and districts with high credit and lending rates.

## Adaptation to Climate Change at the Local Level: A Social Analysis

In order to better understand how adaptation may take place at the local as well as the determinants of the adaptive capacity of the local population, field research was undertaken in the Northern Mountains, the Central Coastal region, the Central Highlands, and the Mekong Delta (Figure 13). The focus of local field research was to validate the livelihood profiles generated from the literature review, to draw a more detailed picture of the types of people who are likely to be most vulnerable to future climate change, and how adaptation practices engaged in during past climate events might shed light on future adaptation choices and pathways, with a particular emphasis on how social vulnerability might be reduced and future adaptive capacity built up. The tools for the local research included standard tools for vulnerability and adaptation assessment methodologies: analysis of past events, analysis of root causes, risk mapping, and social assessments. These were approached through stakeholder consultations with key informants, semi-structured household interviews, and focus groups.

The questions guiding the field research included:

- What are the effects of physical and social vulnerabilities at different scales, from local to national?
- How are the most vulnerable households in the studied local communities adapting? Are these adaptation strategies different from less-vulnerable households?
- Do adaptation strategies in different environments to different hazards vary?
- How do different types of institutions (public, civic and private) either help or hinder adaptation actions taken by individual households?
- What different types of actions (behavioral, technical, financial, and otherwise) are undertaken by different types of households (poor, well-off, female-headed, etc)?

## INDICATORS OF LOCAL VULNERABILITY

*Kon Tum:* Hunger and poverty rates were key indicators of vulnerability in Kon Tum. The poor in Dien Binh commune account for 62 percent, while it is 40 percent in Dak Tram. The hunger rate is the same for the two communes, accounting for 10 percent, and the situation has become worse due to the impacts of Typhoon Ketsana in 2009. Poverty rates are closely linked to the fact that both areas are primarily ethnic minority communities, with farmers who depend on natural resources management for their livelihoods. Other sources of vulnerability were the elderly, women, children, and those with low education (also linked to poverty). The extreme nature of poverty can be seen in a wealth ranking done by members of Dien Bien commune, where even households considered to be "average" in income often suffered food shortages 2 months out of the year.

*Quang Nam.* An Thang is located in a coastal area, and Bai Huong is located in an island, therefore the exposure level to storms of these areas is very high. The changes in degrees of storm, direction, and seasonality in these communities have created difficulties in coping and adapting, and mean that physical exposure was the primary indicator of vulnerability. In Hoi An City's An Thang area, physical location near the Thu Bon River in certain low-lying streets was the primary source of vulnerability. In Bai Huong on Cu Lao Cham island, besides storms, local people also suffered high waves that made water overflow into their houses. When it rains heavily, the water flow from the highlands toward the sea meets the water flowing up from the sea in surges. Physical vulnerability also often goes along with poverty, as the poor and near-poor usually own more unstable houses with less value. Once storms or floods occur, they are the most affected since they have trouble recovering from the loss and often face bankruptcy. The field discussions also revealed that the aged,

**FIGURE 13 SURVEY LOCATION**


children, and the sick people are those who are vulnerable to extreme weather events. They are those who need support from government or their children/parents, relatives, and neighbors. In extreme events, they totally depend on those support sources.

*Ha Giang.* Group discussions and household interviews revealed that different types of climate-change-induced events have affected different groups of people, but the common denominator was that vulnerability primarily related to health risks of climate impacts. For example, cold spells have strong impacts on the elderly and children as they get sick easily with lots of diseases of the respiratory system, and suffering from lack of warm clothes spreads cold and flu among all the poor villagers. Children quit school and have to sit around the fire at home to keep warm. Extended cold spells have bad impacts on livestock, causing great loss to better-off households that have big herds of buffaloes.

Water stress is also related to health issues, as in recently years drought has affected the spring rice and corn crops, as well as causing a shortage of drinking water for people living in higher locations. The lack of water causes diseases among women; it is very difficult for mothers who just gave birth. In the morning, villagers have to stand in line to get water (each household can only have 1 can of 2 liters) for household use. Thus, households that lack labor can't get water. Without water, their food is not washed, causing diseases to the intestinal system. The commune had a record number of cases of diarrhea 2 years ago due to lack of water. Fire also easily burns down houses during the dry season without water, and traditional houses with thatched roofs and houses-on-stilts are easily exposed to fire.

Flash floods are detrimental to those who live near streams and have fields near streams. Quan Ba has nearly 20 percent of its households living near and along streams and these suffer from flash floods yearly. Tornados often cause damage to those who have non-permanent houses or houses that are located along roads.

*Bac Lieu.* The vulnerable populations in the Mekong Delta were primarily those households with livelihoods most dependent on natural resources: shrimp farmers, fishers, or rice farmers. Livelihoods of people are particularly vulnerable to changes in surface water for shrimp farming, livestock diseases, and sudden weather changes.

*Can Tho.* Poverty is the main measure of vulnerability among surveyed households in Can Tho. Extreme temperatures (hotter weather), and river floods (house flooded during extreme spring tide by river water mixed with wastewater from drainage system) are the main risks for households in An Lac ward, who make their living primarily from wage labor.

***Key conclusions from fieldwork.*** Overall, in the patterns of vulnerability and responses to existing climate events by surveyed households and communities, there is not yet a strong understanding of the long-term nature of climate change. As may be expected in poor communities with limited information pertaining to and understanding of climate change issues, most activities have been geared toward short-term coping in the face of climate events like floods or storms, not making plans for long-term adaptation.

*Vulnerabilities.* In all field sites the poor were identified as especially vulnerable. In Hoi An and Can Tho towns, the poor had unstable employment (mostly wage labor), which could be lost if excessive flooding and storms occurred. In Kon Tum and Ha Giang, poor households were usually subsistence farmers, and were less likely to have stored foods or savings to rely on during periods of famine. In Bac Lieu, the poor were former farmers who had taken out large debts or who had lost their land, and who were dependent on wage labor opportunities, which might decline during climate events.

Those dependent on natural resource occupations were also identified as vulnerable. In the Cu Lao Cham islands, fisher families are directly vulnerable to storms, especially if they are out away from shore in boats and have no warning of impending danger. They are also vulnerable as they lack alternatives to fishing: there are no agricultural opportunities on their island and no other jobs. In Kon Tum, most agriculture was subsistence-oriented and highly vulnerable to weather. In the wake of Typhoon Ketsana in September 2009, many of the residents' fields were covered with sand that had been blown in by the storm, and food production had decreased by about 50 percent compared with last year. In Ha Giang, an extended drought for 8 months had resulted in only about 20 percent of rice being irrigated this year, and there were expected drops of at least half in terms of production. Overall, losses due to climate events were strongest in climate-dependent sources of household income, such as agriculture, livestock, and aquaculture. Even urban businesses can be climate dependent; in Hoi An, businesses related to tourism were highly negatively affected by climate events.

Other vulnerable groups identified in local areas included:

- *Ethnic minorities* were also considered vulnerable, particularly in Kon Tum and Ha Giang. Many minorities lived in more remote areas and thus were harder to reach with immediate weather storm warnings, but also longer term information planning is hampered.
- *Senior citizens,* who lacked mobility to avoid sudden or disastrous weather events in Kon Tum, and who were considered to be vulnerable to cold spells and sickness in Ha Giang.
- *Women,* especially women who have recently given birth and are prone to illness as a result, and who often cannot fetch clean water for their families while they are confined at home with new babies, such as in Ha Giang, or women working multiple jobs to feed their families, such as in Quang Nam.
- *Children,* who are vulnerable to cold spells in Ha Giang and kept home from school if it is too cold.
- Those with *low levels of education*.
- Those who *lack sanitation and freshwater* were also identified in Ha Giang as vulnerable, as the recent drought has meant rationing of household water.

Vulnerabilities to weather can be compounded by vulnerabilities to external forces. For example, as Vietnam has transitioned into the World Trade Organization and global markets for goods like coffee, coffee price drops in the early 2000s strongly affected other provinces in the Central Highlands and led to high rates of indebtedness among some minorities who could not weather the price drops. Although Kon Tum was less affected because of lower rates of coffee planting, the large-scale moves in the past 10 years toward rubber production may be vulnerable to the same forces if rubber prices decline or Chinese investment (which has driven much of the change) dries up in the future. Vulnerabilities were also noted in some sites that were driven by forces out of the local areas' control, such as a decline in water volume in Ha Giang and the Mekong Delta.

*Adaptation options.* So far, households' adaptation options aimed at managing climate risk have been identified: listening to weather forecasts, building stronger houses, moving goods to upstairs rooms, evacuating out of unsafe areas, etc. These are mostly short-term coping strategies. Some medium-term to long-term adaptation practices were beginning to emerge in the most heavily subsistence-agriculture-oriented zones of Kon Tum and Ha Giang, where farmers were experimenting with new crops, changing crop calendars, or using new varieties with shorter seasons or climate resistance. The most proactive adaptation appeared to be in Ha Giang in particular, with strong social capital and indigenous traditions. For example, the erratic cold spells that have been experienced in recent years have led households to experiment with feeding different crops to animals (such as a local herb that is supposed to keep the animals' stomach warm). The Ha Giang farmers were also proactive at storing seeds and experimenting with new crops like vegetables or fodder grass that they hoped might be more hardy to weather changes.

The local authorities in the study sites have been primarily focused on building response capacity; that is, having yearly evacuation plans, training people in disaster drills, providing weather data to local authorities, etc. There has also been some small-scale infrastructure development for climate risk. For example, in Hoi An the urban authorities have constructed a cement pavement along the bank of river to prevent erosion; in Cu Lao Cham, the Army has provided safe evacuation shelters for some residents; and in Ha Giang, small hydropower projects to reserve water during the dry season have been constructed on small streams. But local efforts have been hampered by (a) the lack of a long- term perspective on planning (i.e. one and five year plans being the most used time horizon); (b) lack of a strong administrative authority dealing with climate change (i.e. no climate office, lack of direct funding); (c) lack of information (i.e. most climate work being done in research institutes in Hanoi, little capacity development or sharing of information elsewhere); and (d) lack of integration of climate change into other sectoral plans (i.e. hydropower development without considering the forecasts for water flow might be changed in 50 years).

*Coping strategies versus adaptation.* An individual or communities' "coping capacity" has been defined as "the manner in which people and organizations use existing resources to achieve various beneficial ends during and immediately after unusual, abnormal and adverse conditions of a disaster event or process" (World Bank 2010). Most actions seen in the fieldsites were short-term coping actions, not long-term adaptation. For example, most storage activities were not aimed at storing of assets and money over a longer term, although there was some strong collective contributions to pooling of money for community damage. But most of this financing is aimed at short-term storage of assets through an event of several days, not sharing of assets and money over a longer term. The poor and the hungry households in most communities could not even afford storage activities that are even aimed at short-term storage through a flood of several days, as these are households that have difficulties in making ends meet. While short-term coping can in fact build long-term resilience, the majority of households interviewed simply don't have any idea about what they should be doing into the future to help them adapt better to climate change. Coping mechanisms combined with more information and an institutional framework that facilitates longer term planning should lead to better long-term adaptation, but this is not yet in place in most areas of Vietnam. There are limited adaptation responses at either the household or the government level that either address the drivers of overall vulnerability or ones that directly confront climate change processes. These are clearly areas that need more attention.

There is some mobility in terms of short-term working opportunities, especially among younger members of households. From the household surveys and also from the group discussion, members of communities report that there are not many young laborers in their communities. In Hoi An, it is because the number of old people are high and the young people in their commune want to find a better job and the motive to leave is the change of lifestyle. They leave the shops for their parents to manage. In Cu Lao Cham, the young also leave their village to find jobs in the mainland. But in Kon Tum, very few households wanted to move permanently away from disaster areas or try to make their livelihoods outside of the area that they were born in and have grown up in.

Diversification has been adopted by only a very small number of households, and primarily the richer ones. Households in all areas were already using markets for agriculture and livestock produce, and it is not clear how this can be expanded beyond what is already being done to increase resilience to climate hazards.

*Pro-poor adaptation.* Another point to consider is the adaptive capacity of the local people, especially the poor. The issue of how to improve the resiliency of local people and what kinds of mechanisms or institutions can facilitate that capacity is still a question. In many cases, simple advance provision of information can raise awareness of self-protection from extreme weather events. Information of those weather events should be provided to local people early and accurately, so people can have enough time to prepare their house and help other houses in case of need, many respondents said. Uncertainty is one of the most cited causes that prevents households from performing adaptation activities. Information dissemination can help prevent uncertainty and increase resiliency.

To improve the adaptive capacity of the local people, especially the poor, it was suggested in most field sites that there needed to be more livelihood alternatives for local people. In case of Bai Huong fishermen, their mono-livelihood has weakened the adaptive capacity of local people, and also made them become more sensitive to weather events. This recommendation is closely related to the need to give local people more rights to access and manage the natural resource available in their region. The restrictions on land, forests, and water in Cu Lao Cham island created great resource constraints on households, and the lack of forest management rights in Kon Tum kept households from being able to fall back on forest goods during times of need.

*"Hard" adaptation vs. "soft" adaptation.* In most definitions, "hard adaptation measures usually imply the use of specific technologies and actions involving capital goods, such as dikes, seawalls and reinforced buildings, whereas soft adaptation measures focus on information, capacity building, policy and strategy development, and institutional arrangements" (World Bank 2010) There have been very few hard adaptation measures taken by individuals to protect their houses, lands and assets, such as building more permanent houses or building and improving drainage systems. The majority of actions by households have been soft, behavioral ones: preparing for storms by moving goods and tightening houses and boats; changing crops grown or seasons planted; using traditional knowledge to keep livestock alive; and diversifying incomes through migration or shifting to new sources of income. Most of these options are low-cost, flexible, adaptable, and require no input from authorities, which are major reasons why they have been pursued by households who usually lack many financial resources.

On the other hand, most planned adaptation options by authorities have been more focused on hard options, such as building new roads, placing new houses away from vulnerable areas, installing more water pumps, and building more reservoirs. In some cases, both hard and soft options, like information provision and early warning systems, have been in place, but there is very little focus on capacity building or policy changes.

*Institutional needs for adaptation.* In terms of proactive responses by institutions to adaptation needs, within governmental agencies closer cooperation among different sectors is needed. Additionally, though storm and flood control is highly prioritized by the central government and local authorities, climate change is a different type of issue and as such requires new thinking about the administrative structures and functions needed to cope with it. For example, the Committee for Storm and Flood Control at local levels only operates intensively just before the storm and flood season (late spring and summer) and members do not get salaries, so the work is another burden on the shoulders of officers or local people. Participating people often rotate year to year, so there is no long-term thinking in terms of personnel skills. Therefore, it is necessary to have financial mechanisms and other types of incentives in terms of finance and social relationships to encourage people to take a more active and long-term role in institutions to combat climate change. Overall, separate budgets for climate change adaptation and confrontation at various scales, as well as human resources for this kind of work, and the cooperation and information sharing among responsible agencies/ sectors, are likely to be the key factors in improving institutional adaptive capacity.

# SEVEN

# Coastal Ports

Within the coastal zone identified as vulnerable to the various impacts associated with climate change, including sea level rise and intensified storm surges, various types of urban and rural infrastructure are at risk (e.g. road and bridges, buildings, irrigation schemes, water supply, etc.). Along its 3,200 km coastline, Vietnam has a total of 116 seaports. The most important of these are shown in Figure 14. The largest ports, each with a throughput in excess of 20 million tons per year, are those of Ho Chi Minh City, Quang Ninh, Vung Tau, and Haiphong. The last of the EACC sector studies, on coastal ports (VIMARU 2010), examined possible impacts of climate change on port infrastructure in Vietnam.

Over the period 1995–2008, Vietnam's ports have seen a rapid growth in the volume of cargo handled, which has increased from 38 million tons in 1995 to 197 million tons in 2008 (Figure 15). Imports and exports (as opposed to domestic cargo) have dominated this large increase.

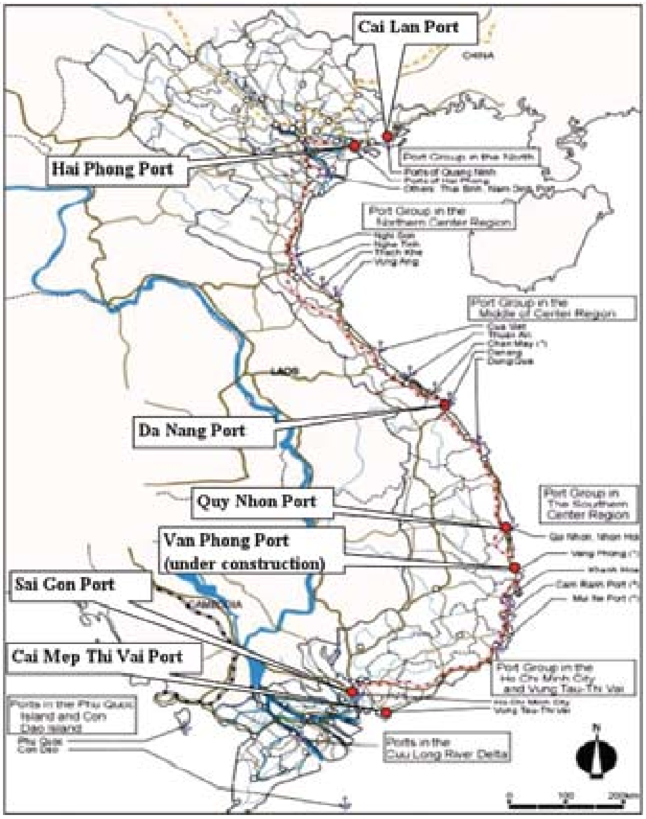
New terminals are being constructed and planned all along the coastline, particularly in the south around Ho Chi Minh City and in the north around Hai Phong. The country is expected to invest approximately $55.5 billion to build new seaports and upgrade existing ones over the period 2010–30, and total tonnage handling is expected to increase approximately 10 times over this period.

## Coastal Ports and Sea Level Rise

Althrough the design of ports and harbors allows efficient operation over a range of sea level fluctuations, sea level rise and changes in the frequency or intensity of storms will alter the stresses on port infrastructure and associated facilities, leading to a combination of greater expenditures on operations and maintenance together with an accelerated deterioration in berths, buildings, and other port assets. The effects are not invariably negative since, for example, a rise in sea level may reduce the need to dredge ports and channels, but overall the impact of climate change is likely to increase costs and require more investment to replace or upgrade infrastructure. Table 37 lists the main consequences of climate change on port operations and infrastructure.

The elevation of quays and platforms at 96 existing seaports were compared with maximum wave heights using MoNRE's climate change scenario, which assumes a 75 cm rise in sea level by 2100 in order to estimate potential flood heights for these quays and platforms. About 37 percent (36) of these ports already face problems of flooding and storm damage without taking account of the effects of climate change, though the extent of the flooding will get worse as a result of climate change. For the other

## FIGURE 14 MOST IMPORTANT SEAPORTS




## FIGURE 15 VOLUME AND DISTRIBUTION OF CARGO THROUGHPUT

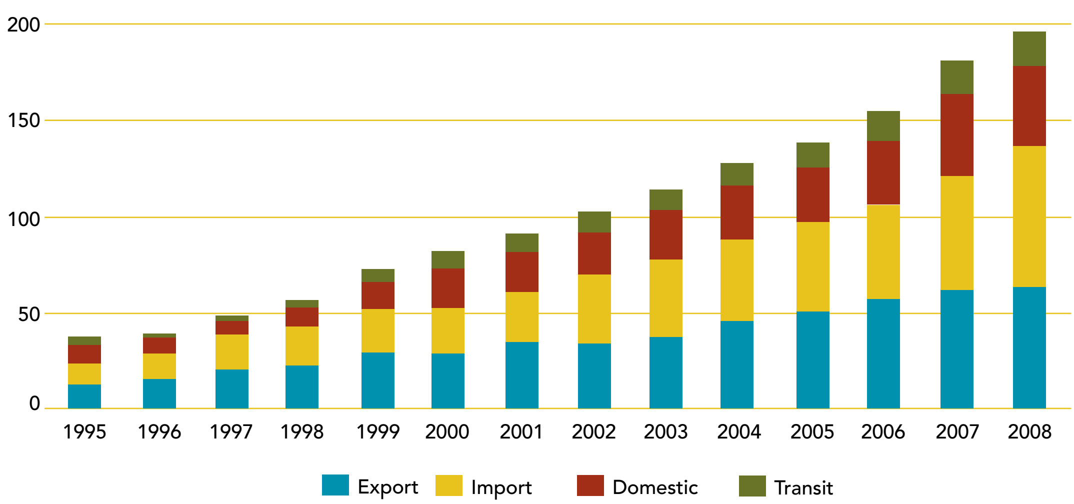


**TABLE 37 DRIVERS AND IMPACTS OF CLIMATE CHANGE ON COASTAL PORTS**

| *Drivers* | *Potential impact on ports* |
|---|---|
| Increase in the magnitude, extent, and duration of storm surges, coastal flooding, spray zone, and erosion patterns | Degradation, failure, and replacement<br>Changed dredging requirements<br>Lowland flooding |
| Wave attack at higher water level reducing the energy loss of breaking | Increased vulnerability of structures |
| Changes in frequency duration and intensity of storms | Loss of sand offshore and onshore<br>Degradation of structures<br>Loss of viable industrial land for port enlargements<br>Problem in maneuvering |
| Change in the sea level range (and other sea state parameters) | Degradation of materials over time<br>Corrosion of wharfs and jetties |

ports, a further 26 will begin to suffer from flooding by 2050, and 19 in the period 2050–2100.

## Adaptation Costs and Options

In order to maintain the operation of ports at their existing levels (number of operating days per year), the options for adaptation that were examined included (a) redevelopment and/or raising quay walls and fendering systems, (b) improvements in the surface drainage system to overcome any increase in the frequency of overtopping and lowland flooding, and (c) increasing the maintenance and replacement of port infrastructure.

These adaptation options were examined in case studies for three ports—Hai Phong, Cai Lan, and Hai Thinh—taking into consideration each port's length of quay walls and land surface (yards and stores). The case studies allow for the cost of adaptation to accommodate the projected rise in sea level up to 2100. These costs were estimated at approximately $48 million for Hai Phong, $3 million for Cai Lan, and $2 million for Hai Thinh. The difference in costs reflects the much larger size of Hai Phong.

Extrapolating the cost of adaptation from these case studies to all of Vietnam's coastal ports can only be a very approximate exercise, since each port requires specific technical studies to assess the feasibility and cost of various adaptation options. Subject to this qualification, the total cost of adapting ports to cope with the effects of climate change up to 2100 is likely to fall in the range $400–$500 million, or about $12 million per year if the investments are made before 2050. Many of the ports will receive substantial investment to expand capacity, while some may be replaced by new ports in more suitable locations. This means that the actual cost of adaptation is likely to be considerably lower than the maximum figure, because adaptation will be undertaken as part of more general projects to expand and modernize existing ports.

A final point concerns the importance of allowing for a combination of future sea level rise and storm surges when designing and constructing either new ports or port upgrades. The choice of a time horizon that should be built into planning decisions involves a tradeoff between a higher initial investment and the risk of needing to spend significant sums to upgrade and adapt ports in the future. Since the marginal cost of buying insurance against future sea level rise is relatively low—for example, by constructing higher quay walls and providing more surface drainage—it is likely to be appropriate to design new ports and port upgrades with a time horizon of at least 2100.

EIGHT

# Lessons Learned

Climate change will have a significant impact on some regions and sectors of Vietnam's rural economy. Still, in macroeconomic terms the impacts of climate change on agriculture and related sectors, even with no adaptation, appear to be relatively modest, reducing the projected growth of consumption over the next 40 years from 4.1 percent per year to 3.95 percent per year. In practice, there will be substantial autonomous adaptation even without active government intervention, since farmers will change the crops and crop varieties that they grow and their methods of farming.

The limited impact of climate change is a consequence of the dynamism and prospects for economic growth driven by industrial development and the growth of services. For this reason it is important not to neglect those who continue to depend on farming and other rural occupations for their employment and incomes.

The major concern is the extent to which climate change will hit poor households in general, partly because of the decline in agricultural incomes and partly because of an increase in food prices relative to the general cost of living. The lowest 20 percent of households arranged by household expenditure per person, both in rural and urban areas, will experience larger reductions in real standards of living due to climate change than those in the top 20 percent of households. The effects will also be quite uneven across regions: households living in the Central Highlands region will be the hardest hit because of a decline in agricultural value-added of up to 30 percent.

Thus, the driving purpose of policies to adapt to climate change should be to protect the poor, the vulnerable, and those least able to respond to changing climatic stresses. In large part the focus of planned adaptation should be on providing farmers and others with the tools and resources that will enable them to respond to climate change itself and to the new risks that will accompany climate change. Fortunately, this can be done at a moderate cost by building on programs and policies that are recognized as being essential for future development. The key elements of an adaptation strategy, at least for the sectors looked at under the EACC studies, are:

- Increased expenditures on research, development, and extension for crop production, aquaculture, and forestry to develop new crop varieties that are more tolerant to drought, salinity, higher temperatures early in the growing season, etc.

- Investment in expanding irrigation infrastructure, especially in the central regions where

the opportunities for irrigation expansion are greatest.

- Increased spending on the maintenance and extension of coastal and flood defenses to minimize the impacts of sea inundations, salinity intrusion, and river flooding, especially in the Mekong River and Red River Deltas.

Much of this spending would be justified even without climate change, so adaptation to climate change is primarily a matter of building on no regrets measures. Under the intermediate MoNRE climate scenario, the program of agricultural adaptation outlined in this study would increase agricultural incomes relative to the baseline, especially in the Central Highlands region, illustrating the general benefits of the strategy. If the program of adaptation were to be implemented, the adverse impacts of climate change on poorer households would largely be avoided. There would still be a net loss of agricultural value-added and aggregate consumption in the Wet and Dry climate scenarios, but the magnitude of the losses would be significantly smaller and the skewed impact on the distribution of income would be corrected. In addition, any strategy would be adjusted to respond to the specific features of climate change as more is learned about it, so the residual impacts of climate change could, in practice, be offset by a more focused allocation of resources in response to different challenges.

A related point is that the nature of climate change and adaptation is an area of great uncertainty. The three climate scenarios used for this study give a sense of the range of possible outcomes of climate change. The biggest uncertainties concern changes in the level and seasonal pattern of precipitation at a regional level. The essence of any well-designed policy to adapt to climate change must be flexibility, so that the policies can be modified as more information about the direction of climate change is collected. That is an important reason for making a strong commitment to research, development, and extension activities, since the focus of such efforts can be shifted as more is learned about the extent and impacts of climate change.

Climate change should not be seen simply as a story of doom and despondency. For agriculture, aquaculture, and forestry, there will be new opportunities that can be built on as well as a loss of income from existing activities. Again, the key element is flexibility and a willingness to facilitate change—that is, to resist pressures to protect activities whose future is threatened by a changing climate and to redirect resources to activities that should benefit. Such change is rarely easy, but the government should ensure that it designs and implements policies that smooth the path of autonomous adaptation wherever this is possible.

Climate change is the long-term face of weather variability. Policies and systems that can effectively cope with existing weather variability will be more successful in adapting to future climate change than those that cannot. Hence, it is important to enhance the capacities of agricultural and water systems in Vietnam to cope with current weather variability and build resilience into such systems.

This study has concentrated on Vietnam's rural economy, but climate change—including sea level rise—will affect the country's infrastructure and require expenditures on adaptation. The case study of coastal ports reinforces the lesson that the costs of adaptation are likely to be modest. The total cost of protecting existing ports that are exposed to flooding as a result of a higher sea level combined with greater storm surges is estimated as no more than $500 million over 40 years, or about 1 percent of planned investment in ports over the period 2010–30. The EACC studies did not look at other infrastructure areas.

An equally important lesson from the case study is that it is essential to plan ahead for climate change. Ports that are built over the next 10–20 years should be designed to cope with sea levels and storms to which they may be exposed 50 or more years from now. It is much cheaper to build margins of resilience and safety into new infrastructure than to upgrade assets during the course of their life. The same lesson emerges from the analyses for infrastructure and coastal protection undertaken as part of the EACC global study. The total cost of adaptation for these sectors amounts to about 2 percent of total investment for the Global Wet scenario and about 1.3 percent of total investment for the Global Dry scenario, on the assumption that adaptation measures are combined with new investments anticipating climate change up to 2100.

# *References*


2WE Associates Consulting Ltd. 2000. "Aquaculture and climate change in Canada: A discussion paper." *Seafood Sustainability in a Changing Climate: A participatory workshop to develop solutions for the Northeast Pacific Ocean and Coastal Zones.* Victoria, BC: Canadian Institute for Climate Studies (CICS), University of Victoria.

Adams. P., J. Giesecke, and N. Tran. 2010. "The Economics of Adaptation to Climate Change: Macro Level Assessment for Vietnam." Victoria: Monash University Centre of Policy Studies.

Adger, WN. 1999a. "Evolution of economy and environment: an application to land use in lowland Vietnam." *Ecological Economics* 31 (3): 365–379.

Adger, W.N. 1999b. "Social vulnerability to climate change and extremes in coastal Vietnam." *World Development* 27: 249–269.

Adger, W.N. 2000. "Institutional adaptation to environmental risk under the transition in Vietnam." *Annals of the Association of American Geographers* (2000): 738–758.

Adger, W.N. 2003. "Social capital, collective action and adaptation to climate change." *Economic Geography* 79: 387–404.

Adger, W.N., M. Kelly, A. Winkels, Luong Quang Huy, and C. Locke. 2002. "Migration, remittances, livelihood trajectories, and social resilience." *Ambio: A Journal of the Human Environment* 31 (4): 358–366.

Agrawal, A. 2008. "The role of local institutions in adaptation to climate change." Paper prepared for the meeting on Social Dimensions of Climate Change, Social Development Department, The World Bank, Washington DC, March 5–6, 2008.

Almeida, A., C. Beadle, K. Paul, A. Siggins. 2010. "Economics of Adaptation to Climate Change (EACC) Project's Vietnamese Forestry-Sector Study." Commonwealth Scientific and Industrial Research Organisation (CSIRO).

Asian Development Bank (ADB). 2005. *Viet Nam: Gender Situation Analysis*. Manila: ADB.

Asian Development Bank (ADB). 2009. *The Economics of Climate Change in Southeast Asia: A Regional Review*. Manila: ADB.

Asian Disaster Reduction Center (ADRC). 2003. "The Role Of Local Institutions In Reducing Vulnerability To Recurrent Natural Disasters. In *Sustainable Livelihoods Development Case Study: Vietnam*. Rome: FAO and Asian Disaster Reduction Center.Ayres, P.G., and M.J. Lombadero. 2000. "Assessing the consequences of global climate change for forest disturbance from herbivores and pathogens." *The Science of the Total Environment* 262: 263–286.

Badjeck, M-C., E.H. Allison, A.S. Halls, N.K. Dulvy. 2009. "Impacts of climate variability and change on fishery-based livelihoods." *Marine Policy* 34: 375-383.

Battaglia, M., J. Bruce, C.L. Brack, and T. Baker. 2009. *Climate change and Australia's plantation estate: analysis of vulnerability and investigation of adaptation options*. Hobart, Australia: CSIRO.

Be Minh Chau et al. 2008. "Assessment of climate change impacts to the risk of forest fires." Hanoi: Forest Ecology and Environment Research Center.

Bolay, Jean-Claude, Sophie Cartoux, Antonio Cunha, Thai Thi Ngoc Du and Michel Bassand. 1997. "Sustainable development and urban growth: Precarious habitat and water management in Ho Chi Minh City, Vietnam." *Habitat International* 21(2): 185–197.

Carew-Reid, J. 2008. *Rapid assessment of the extent and impact of sea level rise in Vietnam.* Hanoi: International Centre for Environmental Management (ICEM).

Chan, L. M., and V.V Dung. 1992. *Forest Tree Text Book.* Xuan Mai: Vietnam Forestry University.

Christensen, J.H., B. Hewitson, and A. Busuioc, et al. 2007. "Regional Climate Projections." In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller, eds. *Climate Change 2007: The Physical Science Basis.* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge, UK, and New York: Cambridge University Press.

Cupples, J. 2007. "Gender and Hurricane Mitch: reconstructing subjectivities after disaster." *Disasters* 31(2): 155–175.

Dalvia, R. S., A. K. Pala, L. R. Tiwarib, T. Dasa, and K. Baruahc. 2009. "Thermal tolerance and oxygen consumption rates of the catfish *Horabagrus brachysoma* (Günther) acclimated to different temperatures." *Aquaculture* 295:116–119.

Dang Nguyen Anh. 2005. "Viet Nam Internal Migration: Opportunities And Challenges for Development." Regional Conference On Migration And Development In Asia, Lanzhou, China, March 14–16, 2005 .

Dasgupta, S., B. Laplante, C. Meisner, D. Wheeler, and C. Yo. 2009. "The impacts of sea-level rise on developing countries: A comparative analysis." *Climatic Change* 93 (3): 379–388.

Desai, Jaikeshan. 1995. *Viet Nam through the Lens of Gender: An Empirical Analysis using Household Survey Data.* Hanoi: UNDP.

De Sherbinin, Alex., Andrew Schiller, and Alex Pulsipher. 2007. "The vulnerability of global cities to climate hazards." *Environment & Urbanization* 19 (1): 39–64.

DFID. 2004. *The impact of climate change on the vulnerability of the poor.* London: Department for International Development.

Dun, O. 2009. "Viet Nam Case Study Report." EACH-FOR *Environmental Change and Forced Migration Scenarios.* European Commission, SERI (Austria) and ATLAS Innoglobe (Hungary). Available at: www.each-for.eu.

Duong, N.D. 2006. "Applying GAP in shrimp culture in Ca Mau province." Master Thesis, Can Tho University.

Eastham, J., F. Mpelasoka, M. Mainuddin, C. Ticehurst, P. Dyce, G. Hodgson, R. Ali, and M. Kirby. 2008. *Mekong River Basin Water Resources Assessment: Impacts of Climate Change.* Collingwood, Victoria, Australia. CSIRO, Water for a Healthy Country National Research Flagship.

Evans, Martin, Ian Gough, Susan Harkness, Andrew McKay, Huyen Dao Thanh, and Ngoc Do Le Thu. 2007. *How Progressive is Social Security in Vietnam?* Hanoi: UNDP Policy Dialogue Paper.

Fan, S., P. L. Huong, and T. Q. Long. 2004. "Government spending and poverty reduction in Vietnam." Report prepared for the World Bank. Washington, DC: World Bank.

Few, R., and G.T. Pham. 2010. *Climatic hazards, health and poverty: exploring the connections in Vietnam.* Working Paper 19, DEV Working Paper Series. Norwich, UK: The School of International Development, University of East Anglia.

Fordham, E. 1998. "Making women visible in disasters: Problematizing the private domain." *Disasters* 22 (2): 126–143.

General Statistics Office (GSO). 2009. *Agriculture, Forestry and Fishery.* Available at: http://www.gso.gov.vn/default_en.aspx?tabid=469&idmid=3.

Gilman, E.L.,J. Ellison, N.C. Duke, and C. Filed. 2007. "Threats to mangroves from climate change and adaptation options: a review." *Aquatic Botany* 89: 237–250.

Government of Vietnam (GoV). 1994. *Biodiversity action plan for Vietnam.* Hanoi: GoV and the Global Environment Facility.

Hang, P.T., and T. Lennaerts. 2008. "Joint basin development planning to foster IWRM in the Lower Mekong Basin." Paper presented at a Symposium entitled Mekong Management at a Watershed – IWRM in the Global Crisis? Gothenburg University, Sweden, September 29-October 1, 2008. Available at: http://www.mrcmekong.org/programmes/bdp/bdp-publication.htm.

Hoang Cong Dung, Tran Van Doai, Pham Anh Duc, and Pamela McElwee. 2006. *Access by Ethnic Minorities to Financial Services in the Northern Mountainous Region of Vietnam.* Hanoi: Institute for Ethnic Minority Affairs and the World Bank.

Hoang Xuan Huy and Le Van Chinh. 2007. "Health Impacts of Climate Variability and Change in Vietnam." Paper prepared for the Workshop on Climate Change and Health in South-East and East Asian Countries, Kuala Lumpur, Malaysia, July 2–5, 2007.

Hoanh, C. T., H. Guttman, P. Droogers, and J. Aerts. 2003. *ADAPT. Water, Climate, Food and Environment under Climate Change. The Mekong basin in Southeast Asia.* Colombo, Phnom-Penh, and Wageningen: International Water Management Institute, Mekong River Commission, Future Water, Institute of Environmental Studies.

Hung, N. D. 1996. "The flora and fauna resource in the forests of Vietnam." In M. L. Quang, ed. *Vietnamese Studies.* Hanoi.

International Labor Organization (ILO). 2008. *Economically Active Population Estimates and Projections.* 5th edition, revision 2008. Geneva: International Labor Organization. Available at: http://laborsta.ilo.org/applv8/data/EAPEP/eapep_E.html.

International Monetary Fund (IMF). 2009a. *World Economic Outlook Update: Contractionary Forces Receding But Weak Recovery Ahead.* Washngton, DC: International Monetary Fund. Available at: http://www.imf.org/external/pubs/ft/weo/2009/update/02/index.htm.

International Monetary Fund (IMF). 2009b. *World Economic Outlook: Crisis and Recovery.* Washington, DC: International Monetary Fund. Available at: http://www.imf.org/external/pubs/ft/weo/2009/01/index.htm.

Intergovernmental Panel on Climate Change (IPCC). 2007. *Emissions Scenarios 2000, Fourth Assessment Report, Climate Change 2007: Synthesis Report.* Geneva: IPCC.

Kam S.P., M-C. Badjeck , L. Teh , V.T. Be Nam, T.T. Hein, N.T. Hue, M. Phillips, R. Pomeroy, L.X. Sinh. 2010. "Economics of Adaptation to Climate Change in Vietnam's Aquaculture Sector: A case study." Report to the World Bank.

Kim, H., P.V. Bien, and R.H. Howeler. 2001. "Status of cassava in Vietnam: Implications for future research and development." In *A Review of cassava in Asia with country case studies on Thailand and Viet Nam.* Proceedings of the Validation Forum on the Global Cassava Development Strategy, Rome, April 26–28, 2000.

Kirby, M., and M. Mainuddin. 2009. "Water and agricultural productivity in the Lower Mekong Basin: trends and future prospects." *Water International* 34(1): 134–143.

Knutson, T.R., and R.E. Tuleya. 2004. "Impacts of CO2 induced warming on simulated hurricane intensities and precipitation: Sensitivity to the choice of climate model and convective parameterization." *Journal of Climate* 17: 3477–3495.

Kyoto University and Oxfam. 2007. *Drought-Management Considerations for Climate- Change Adaptation: Focus on the Mekong Region.* Kyoto: Graduate School of Global Environmental Studies of Kyoto University.


Lacombe, G. 2009. "Analysis of possible rainfall and temperature change in the greater Mekong subregion over the period 1960-2049." In R. Johnston, S.P. Kam, C.T. Hoanh, G. Lacombe, A. Noble, V. Smakhtin, and D. Suhardiman, eds. *Scoping study on natural resources and climate change in Southeast Asia with a focus on agriculture.* Report prepared for the Swedish International Development Cooperation Agency. Battaramulla, Sri Lanka, and Penang, Malaysia: International Water Management Institute, Southeast Asia and WorldFish Center.

Lambro, Y., and G. Piana. 2006. *Gender: The Missing Component of the Response to Climate Change.* Rome : Food and Agriculture Organization of the United Nations.

Lan Anh Hoang, Jean-Christophe Castella, and Paul Novosad.2006. "Social networks and information access: Implications for agricultural extension in a rice farming community in northern Vietnam." *Agriculture and Human Values* 23 (4): 513–527.

Le Ngoc Thanh, Pamela McElwee, Thach Muni, and Hong Thai. 2006. *Final Report: Living Standard Analysis For Socio-Economic Development Of The Ethnic Khmer In The Mekong Delta 2006-2010.* Hanoi: Institute for Ethnic Minority Affairs and the World Bank.

Le Van Thanh Thanh. 2002. "Population and urbanization in Ho Chi Minh City (Vietnam): towards new policies on migration and urban development." Poster paper prepared for the IUSSP Regional Population Conference, Siam City Hotel, Bangkok, Thailand, June 10–13, 2002.

Linh V.B. 1996. "Dry open Dipterocarpus in Vietnam." In M.L.Quang, ed. *Vietnamese Studies.* Hanoi.

Macintosh, D.J., and E.C. Ashton. 2002. *A review of mangrove biodiversity conservation and management.* Denmark: Centre for Tropical Ecosystems Research.

McElrone, A.J., C.D. Reid, K.A. Hoye, E. Hart, and R.B. Jackson. 2005. "Elevated CO2 reduces disease incidence and severity of a red maple fungal pathogen via changes in host physiology and leaf chemistry." *Global Change Biology* 11: 1828–36.

McElwee, P. 2007. "From the Moral Economy to the World Economy: Revisiting Vietnamese Peasants in a Globalizing Era." *Journal of Vietnamese Studies* 2(2): 57–107.

McElwee, P. 2008. "Forest environmental income in Vietnam: household socioeconomic factors influencing forest use." *Environmental Conservation* 35 (2): 147–159.

McLeod, E., and R.V. Salm. 2006. "Managing mangroves for resilience to climate change." IUCN Resilience Science Group Working Paper No. 2.

Miller, F. 2006. "Risks, Responses and Rights: Gender Dimensions of Water Excess and Water Scarcity in the Mekong Delta, Vietnam." In *Fluid Bonds: Views on Gender and Water.* Kolkata: Stree Press.

Ministry of Agriculture and Rural Development (MARD). 2006. "Forest Ecological Programme." In: *Forestry Sector Manual.* Hanoi: Transport Publishing House.

Ministry of Agricultural and Rural Development (MARD). 2007. *Vietnam Forestry Development Strategy* 2006-2020. Hanoi: Agriculture Publisher

Ministry of Agriculture and Rural Development (MARD). 2009. *Draft Fisheries Development Strategy in Vietnam until 2010 and Vision 2020.* Hanoi: Ministry of Agriculture and Rural Development (In Vietnamese).

Ministry of Natural Resources and Environment (MONRE). 2009. *Climate Change, Sea Level Rise Scenarios for Vietnam.* Hanoi. Ministry of Natural Resources and Environment.

MoLISA and UNDP. 2004. *Taking Stock, Planning Ahead: Evaluation Of The National Targeted Programme On Hunger Eradication And Poverty Reduction And Programme 135.* Hanoi.

Nelson, V., K. Meadows, T. Cannon, J. Morton, and A. Martin. 2002. "Uncertain predictions, invisible impacts, and the need to mainstream gender in climate change adaptations." *Gender and Development* 10(2): 51–59.

Oxfam. 2008. *Viet Nam: Climate Change, Adaptation and Poor People.* Oxford, UK: Oxfam.

Paul, K.I., and P.J. Polglase. 2004. "Prediction of decomposition of litter under eucalypts and pines using the FullCAM model." *Forest Ecology and Management* 191:73–92.

Phon N.H, N. H. Dung, and V.V. Dung. 2001. "The limestone forests in Vietnam – Strategy for management, protection and development. *Journal of Agriculture and Rural Development* 8: 577–579.

Phong Tran,Fausto Marincioni, Rajib Shaw, Massimo Sarti, and Le Van An. 2008. "Flood risk management in Central Viet Nam: challenges and potentials." *Natural Hazards* 46:119–138.

Pincus, J., and J. Sender. 2008. "Quantifying Poverty in Viet Nam: Who Counts?" *Journal of Vietnamese Studies* 3(1): 108–150.

Pinkard, E.A.,M. Battaglia, et al. 2010. *Adaptation to climate change in Australia's plantation industry.* Hobart, Australia: CSIRO.

Poverty Task Force. 2002. "Reducing vulnerability and providing social protection." *Localizing MDGs for Poverty Reduction in Vietnam Project.* Hanoi. Ministry of Labor, Invalids, and Social Affairs.

Sam, D. D, N. N. Binh, N. D. Que, and V. T. Phuong. 2005. *Overview of mangrove forests in Vietnam.* Hanoi: Agriculture Publishing House.

Sands, P.J. 2004. 3*PGpjs vsn 2.4 - a User-Friendly Interface to 3-PG, the Landsberg and Waring Model of Forest Productivity.* Technical Report. No. 140. Hobart, Australia: CRC Sustainable Production Forestry.

Sunderlin, W. D., Huynh Thu Ba. 2005. *Poverty alleviation and forests in Vietnam.* Bogor: CIFOR.

Sutherst, R.W., G.F. Maywald, and A.S. Bourne. 2007. "Including species interactions in risk assessments for global change." *Global Change Biology* 13: 1843–1859.

Phuong V.T., D.C Pham, and H.V Anh. 2010. "Economics of Adaptation to Climate Change Forestry Sector of Vietnam." Hanoi: Ministry of Agriculture and Rural Development

Thanh Ha, D., T. Dinh Thao, N. Tri Khiem, M. Xuan Trieu, R.V. Gerpacio, and P.L. Pingali. 2004. *Maize in Vietnam: Production Systems, Constraints, and Research Priorities.* Hanoi: CIMMYT.

Thuc T. 2009. "Climate change in Vietnam and adaptive solutions." Paper for the Conference on the Impact of climate change and sea level rise in Vietnam, Hanoi.

Trong, N.V. 2008. "Vietnam – Working toward the production of safe and high-quality aquaculture foods." In *Eco-friendly fish farm management and safe aquaculture production.* Food & Fertilizer Technology Center for the Asian and Pacific Region. Available at: http://www.agnet.org/library/bc/55005/.

Trung N.V. 1996. "The forest." In M.L.Quang, ed. *Vietnamese Studies.* Hanoi.

UNDP. 2009. *Gender and Climate Change in Vietnam: A Desk Review.* Hanoi: UNDP.

Van de Walle, D. 2004. "Testing Vietnam's public safety net." *Journal of Comparative Economics* 32 (4): 661–679.

VASEP. 2010a. "Sustainable aquaculture development in Southern provinces." VASEP Daily News, January 04, 2010. Available at: http://www.vasep.com.vn/vasep/edailynews.nsf/87abdd0d40924a754725714200323ea3/D2392D022C68D9DF472576AB003263C5?OpenDocument&Start=41.

Vu Tan Phuong et al. 2008. Initial assessment of the vulnerability due to Climate Change to forestry. Research Centre for Forest ecology and Environment, Hanoi.

VIMARU. 2010. "Inception report: Study on The Economics of Adaptation to Climate Change for Coastal Port Infrastructure of Vietnam." Vietnam Maritime University.

Walsh, K.J.E. 2004. "Tropical cyclones and climate change: Unresolved issues." *Climate Research* 27: 77–84.

Wang, B., I.S. Kang, and J.Y. Lee. 2004. "Ensemble Simulations of Asian–Australian Monsoon Variability by 11 AGCMs." *American Meteorological Society* 17: 803–818.

Winkels, A. 2008. "Rural In-migration and Global Trade." *Mountain Research and Development* 28 (1): 32–40.

World Bank. 1999. *Voices of the Poor: Synthesis of Participatory Poverty Assessments.* The World Bank and DFID in Partnership with ActionAid Vietnam, Oxfam (Great Britain), Save the Children (UK) and Vietnam-Sweden MRDP. Washington, DC: World Bank.

World Bank. 2008. *Vietnam Development Report: Social Protection.* Hanoi: Consultative Group.

World Bank. 2009. *Country Social Analysis: Ethnicity and Development in Vietnam.* Washington, DC: Social Development Department, World Bank.

World Bank. 2010. *Climate Resilient Development in Vietnam: Strategic Directions for the World Bank.* Hanoi: Sustainable Development Department, World Bank.

Yu, B., C. Breisinger, and M.H. Nguyen. 2009. "The future of food security in Vietnam: Farmer responses to policy and market." Working Paper. Washington, DC: International Food Policy Research Institute.

Young, K.B., E.J. Wailes, G.L. Cramer, T.K. Nguyen. 2002. *Vietnam's Rice Economy: Developments and Prospects.* University of Arkansas Research Report 968.

Zhu, T., Z.Guo. 2010. "Climate Change Impacts and Adaptation in Vietnam: Agriculture and Water." Washington, DC: International Food Policy Research Institute.

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