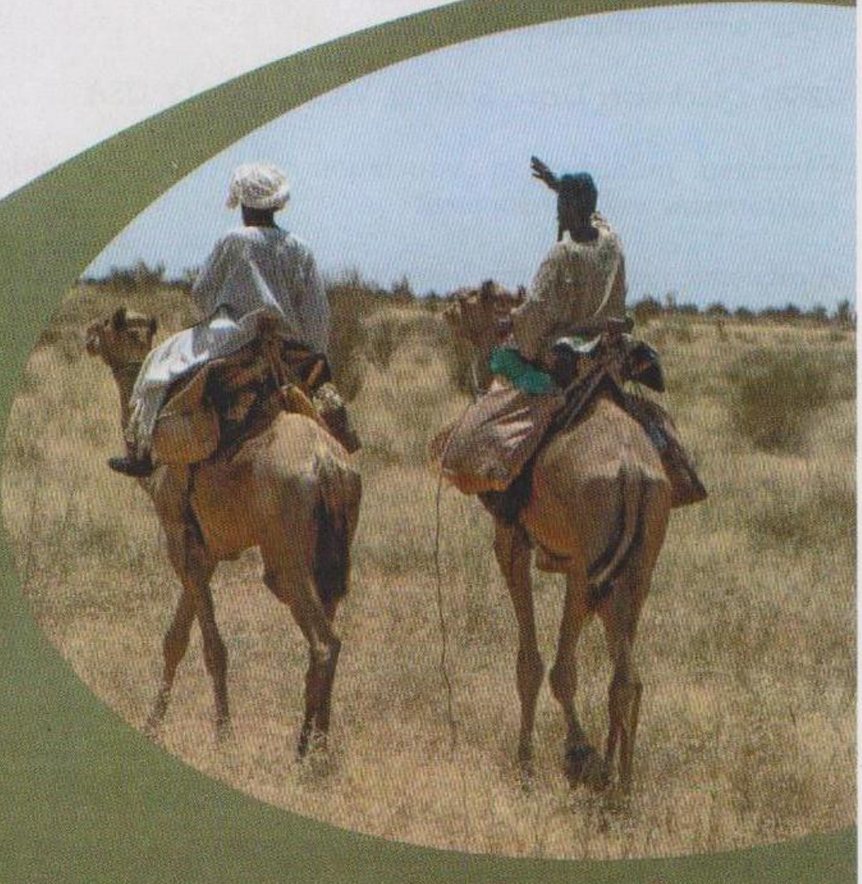
Climate Change and Vulnerability



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Climate Risks and Rice Farming in the Lower Mekong River Basin

Suppakorn Chinvanno, Somkhith Boulidam, Thavone Inthavong, Soulideth Souvannalath, Boontium Lersupavithnapa, Vichien Kerdsuk and Nguyen Thi Hien Thuan

Introduction

Agriculture is one of the most important activities in the lower Mekong river basin. It is a source of livelihood for a large portion of the population and a significant contributor to national incomes. For example, in Lao PDR, agriculture employs 76.3 per cent of the country's 5.7 million people (UNESCAP, undated) and agricultural products contributed 44.8 per cent of Lao PDR's gross domestic product (GDP) of US$2.9 billion in 2005 (World Bank, 2007). In Thailand, agriculture contributed a much smaller 9.9 per cent of total GDP (US$176.6 billion) (World Bank, 2007), yet the sector employs 44.9 per cent of Thailand's 63.1 million people (UNESCAP, undated).

Rice is the most important agricultural product of the region in terms of the proportion of land area used, the quantity and value of output, and contribution to diet. In Thailand, rice is cultivated on 88 per cent of land used for cereal production and represents 43 per cent of the per capita daily caloric intake (FAO, 2004a). Rice is even more predominant in Lao PDR, where 94 per cent of cereal lands is planted in rice and 64 per cent of daily caloric intake is provided by it (FAO, 2004b). Most rice and other cereals are grown under rain-fed conditions as the irrigated land area is limited, accounting for 19 and 30 per cent of total harvested area in Lao PDR and Thailand respectively (Barker and Molle, 2004).

Because of the high dependence on rain-fed rice cultivation, and the sensitivity of rain-fed rice yields to rainfall amounts and other climate conditions, the region is strongly affected by variations or changes in climate that adversely affect rice cultivation. Farmers of rain-fed rice are among the most vulnerable groups in the lower Mekong basin as their livelihood depends heavily on their annual production of rice, which is directly exposed to climate risk. In addition, most of these farmers are poor and have limited resources and other capacity with which to cope with the impacts of climate variability and change. The risk profile and vulnerability of rice farmers of the Mekong basin vary from place to place due to differences in the changes in climate to which they will be exposed, the sensitivity of the production systems to climate change, the socioeconomic condition and lifestyle of each community, and the condition of the surrounding natural environment (IPCC, 2001a).

As part of a larger study of climate change in the lower Mekong basin, we investigated the existing climate risks faced by rice farmers in selected villages in Lao PDR and Thailand and how their risks may change with climate change (see Snidvongs, 2006). This chapter presents the results of our investigations. Our approach, which follows the Adaptation Policy Framework of the United Nations Development Programme (Lim et al, 2004), is outlined in Figure 16.1. The analysis includes development of climate change scenarios for the region, estimation of climate change impacts on rice yields, and assessment of the vulnerability of farm households to climate variations and change as a function of their sensitivity to climate risk, exposure and coping capacity. Strategies for adapting to climate change were also examined and are evaluated in Chinvanno et al (2008).

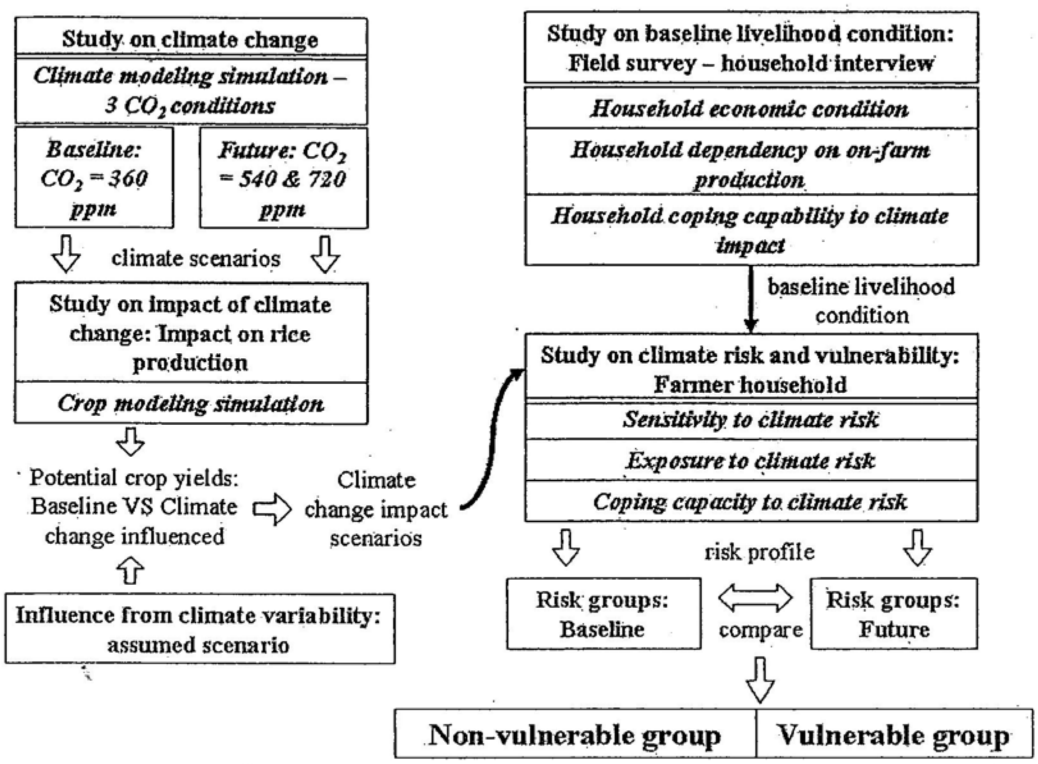


Figure 16.1 *Framework for climate risk and vulnerability assessment*

The Study Sites

Our study encompassed three countries of the lower Mekong basin: Lao PDR, Thailand and Vietnam. In this chapter, we focus on study sites in Savannakhet Province in Lao PDR and Ubon Ratchathani Province in Thailand. These two countries of Southeast Asia represent opposite ends of the scale of socioeconomic development, resulting in very different conditions that lead to differences in their farmers' vulnerability to climate hazards and climate change. Thailand is far more economically developed than Lao PDR, as reflected by the per capita gross national income levels in 2005 of US$2720 in Thailand and US$430 in Lao PDR (The World Bank, 2007), and has a higher population and population density. The different level of development and socioeconomic conditions are reflected in different livelihoods (commercial farming vs subsistence), structure of household expenses, resources for coping and adapting to stresses, institutional support, and agricultural practices. But despite the differences, farmers of rain-fed rice in the two countries share the same cultural roots and are among the poorest members of their respective societies; in both countries their well-being is highly dependent on climatic conditions.

We selected four villages for study in Lao PDR: Seboungnuantay, Lahakhoke, Khouthee and Dongkhamphou. The villages, all located within the Songkhone district of Savannakhet Province, have a total land area of 1851ha and a population of 2490 living in 434 households. Savannakhet Province is in the central to southern part of Lao PDR, has a land area of 21,774km^2 and consists of 15 districts. The topography of the province is lowland with a slight slope from east to west towards the Mekong river. Savannakhet Province has the largest area of rice fields in the country, nearly 140,000ha or 19 per cent of all rice fields in Lao PDR (Committee for Planning and Cooperation, 2003). It is also the most populated province of the country, with a total population of 811,400, or approximately 15 per cent of the population of Lao PDR.

Songkhone district, where the study villages are located, is in the southwest of Savannakhet Province. It is the largest district of the province, with a total area of 1406km^2. The district consists of 142 villages with 13,919 households and a total population of 86,855. Most of the inhabitants are subsistence farmers who grow rice mainly for their own consumption and sell only a small amount of their farm output in markets. Rice farming is rain-fed and a single crop is grown each year. Households supplement their food supply and livelihoods by harvesting natural products from surrounding natural ecosystems, which are relatively intact.

Eighteen villages were selected for study in Thailand, all located in Ubon Ratchathani Province in the lower northeastern region of Thailand. The province covers an area of 16,112km^2. Most of the land area consists of highlands, averaging 68 metres above sea level, with mixed sandy soils of low fertility. The Mekong river and mountains form the border between the province and Lao PDR to the east and high mountains form the border between the province and the Democratic Republic of Cambodia to the south. Major rivers include the Chi river, which merges with the Mun river and flows through Ubon Ratchathani Province from west to east before joining the Mekong in Khong Chiam district. In 2005, Ubon Ratchathani maintained a total population of 1,774,808 in 432,923 households, which are mostly in the agricultural sector (Department of Provincial Administration, undated).

The study area is part of the Ubon Ratchathani Land Reform Area (ULRA), which covers 55,000ha on the east bank of the Dome Yai river. This area has three slope classes: level to gently sloping, sloping to undulating, and undulating to rolling. Soils are generally sandy and of low fertility. Korat series is the major soil type in this area; these soils are fairly well drained and strongly acidic.

Most of the area is cultivated for paddy rice, with some areas cultivated for upland crops. There are small patches of degraded forests. Water is plentiful in the wet season, but severe shortage occurs in the dry season. Average rainfall is about 1600mm, 90 per cent of which falls in the period May to October. Average monthly temperature ranges from a minimum of 17.0°C in December and January to a maximum of 35.9°C in March and April. There is very limited irrigation and cropping is mainly a wet season activity (Ubon Ratchathani Province Administration, undated). Farmers are mostly commercial farmers who grow a single rice crop each year on farms of moderate size and using mechanized farming methods. The study area is divided into five zones, which are characterized in Table 16.1.

Table 16.1 *Villages by zone in Thailand*

Zone	Characteristics of zone	Villages studied
#1	Deep sandy soils. Cropping patterns are rice plus plantation and forest. The forest trees are eucalyptus and cashew nut.	1. Ban Mak Mai 2. Ban Mek Yai 3. Ban Khok Pattana
#2	This area lies along the Lam Dom Yai river. Soil has high fertility. It is a wet area. The dominant cropping system is rice and upland crops such as vegetables, cassava or kenaf.	1. Ban Fung Pa 2. Ban Muang 3. Ban Bung Kham 4. Ban Bua Thaim
#3	The area is partly upland rice. The cropping system is an encroached forest area.	1. Ban Nong Sanom 2. Ban Udom Chart 3. Ban Pa Rai 4. Ban Non Sawang
#4	This area has an intensive rice system. Mostly commercial farming practice. There is low tree density.	1. Ban Bua Ngam 2. Ban Nong Waeng 3. Ban Rat Samakee 4. Ban Non Yai
#5	This area is similar to zone # 3 but has more lowland characteristics. Rice cultivation encroaches into forest areas.	1. Ban Pa Pok 2. Ban Sok Seang 3. Ban Non Deang

Projected Climate Change in the Lower Mekong Basin

Our analyses of potential impacts of climate change on rice production are based on climate change scenarios constructed for our study areas from projections of the conformal cubic atmospheric model (CCAM), a high- resolution regional climate model. The CCAM is a second-generation regional climate model developed for the Australasian region by the Commonwealth Science and Industrial Research Organization (McGregor and Dix, 2001). Evaluations of the model in several international model inter-comparison exercises have shown it to be among the best climate models for reproducing key features of the climate of the Southeast Asian region (Wang et al, 2004).

The baseline climate for the analysis is developed using a steady state simulation of the CCAM with an atmospheric concentration of carbon dioxide (CO_2) of 360ppm, which corresponds to the CO_2 concentration during the 1980s. Scenarios of future climate are developed using steady state simulations for CO_2 concentrations of 540ppm and 720ppm, which correspond to 1.5 times and double the baseline level. These concentrations would be reached by roughly the 2040s and 2070s, respectively, for the IPCC's A1FI scenario of greenhouse emissions, the highest of the IPCC emission scenarios (IPCC, 2001b).

Figures 16.2 and 16.3 display baseline temperatures and precipitation for the region and the changes projected by the CCAM for CO_2 concentrations of 540ppm and 720ppm. The CCAM simulations have a spatial resolution of 0.1 degree, or approximately 10km². No results are shown for Cambodia due to insufficient observational data. For the 540ppm scenario, the CCAM projects that the region would get slightly cooler. For the 720ppm scenario, warming of less than 1°C is projected over most of Thailand and Lao PDR. Annual precipitation is projected to increase throughout the region for both climate change scenarios, with greater precipitation projected for the 720ppm CO_2 concentration scenario than for the 540ppm scenario. The increases are greatest in the eastern and southern part of Lao PDR.

Climate change in the study areas

To create climate scenarios for our study sites, the outputs of the CCAM model must be adjusted to match local climate conditions. The adjustment focused on precipitation and used observed data from weather stations throughout the region. The statistical procedure used to adjust the model output is based on cumulative rainfall using a non-linear log–log function to exponentially increase the daily variability. An arbitrary rainfall threshold of 3mm/day was applied to reduce the number of rainy days.

In Savannakhet Province in Lao PDR, the rainy season is extended slightly for the 540ppm CO_2 scenario as the onset of the rainy season is projected to shift approximately 10 days earlier. Total annual rainfall increases roughly 10 per cent from the baseline average of 1624mm to 1780mm. In comparison, the rainy season length would settle back to the same condition as the baseline when the CO_2 concentration rises to 720ppm. However, total rainfall increas-

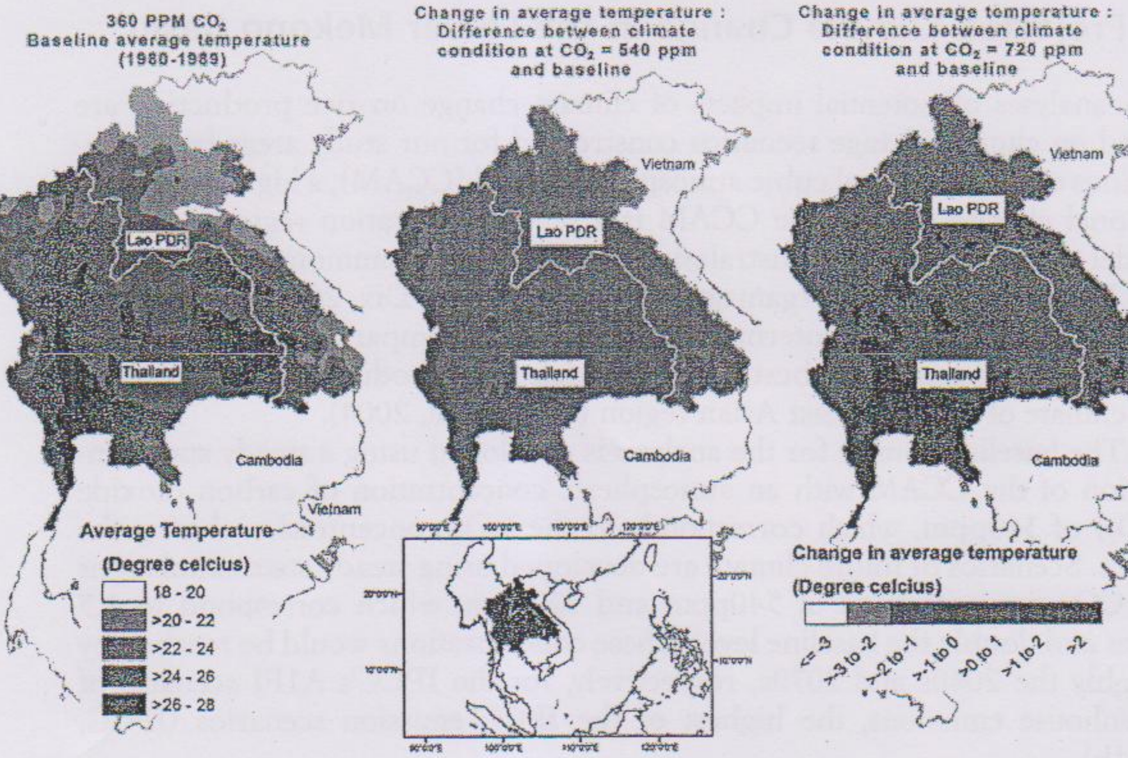


Figure 16.2 *Average temperature in the lower Mekong river basin: Baseline and projected changes*

es by a larger amount, about 20 per cent above the projection for 540ppm, to 2120mm. Projected temperatures for Savannakhet only change within the range of +/-1 degree C as more cloud cover locally dampens the global warming trend.

In Ubon Ratchathani Province of Thailand, the onset of the rainy season is projected to start much earlier, by about 20 days, for both the 540 and 720ppm CO_2 scenarios. The simulated 10-year average annual rainfall is 1688mm during the baseline period and it rises to 1734mm and 1901mm for the 540 and 720ppm scenarios, respectively. However, despite the increased rainfall, the mid-season dry spell becomes more prominent for the 540ppm simulation. The temperature in the area would change within a narrow range of +/-1°C, which is also projected for the study site in Lao PDR, again because more cloud cover in the region dampens the warming trend.

Comparison to other projections of climate change for Southeast Asia

To put the CCAM-derived scenarios in context, it is useful to compare them to the range of climate projections from other models. The projections of future temperature increases in Southeast Asia that are assessed in the IPCC's most recent report range from 1.5 to 3.7°C average annual warming over the 100-

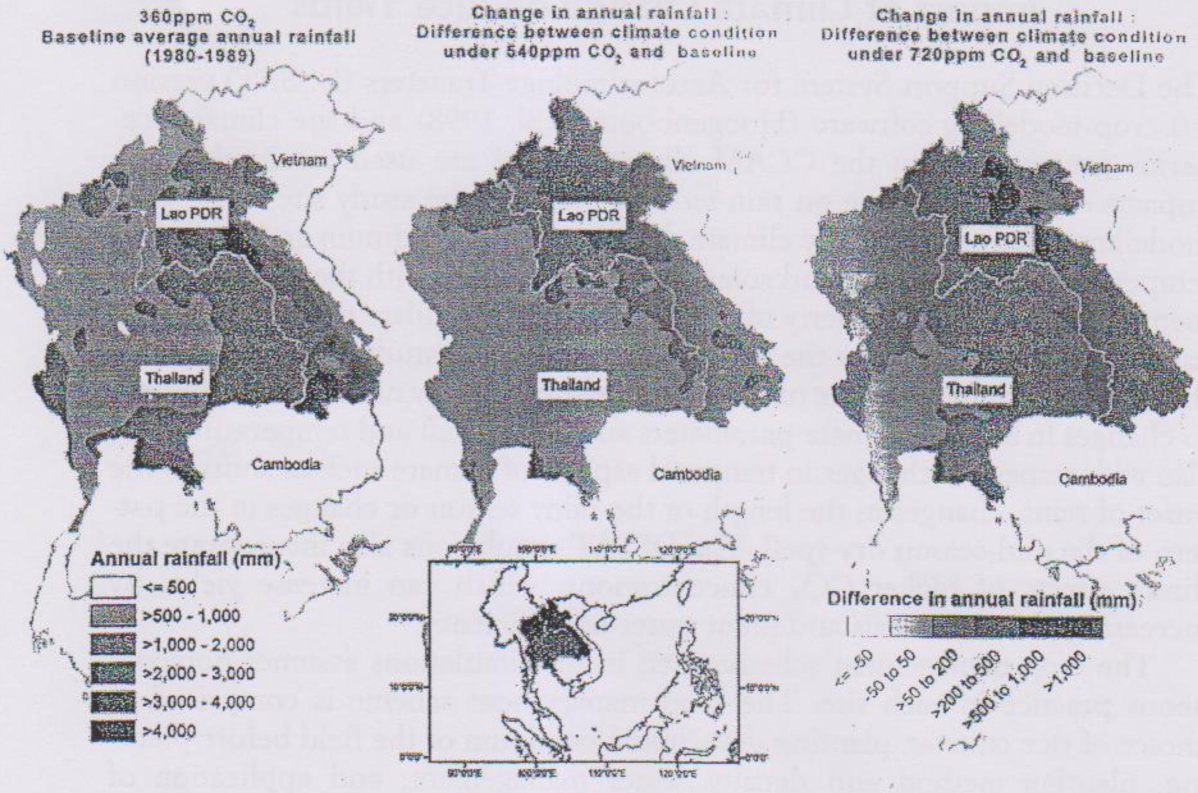


Figure 16.3 *Average rainfall in the lower Mekong river basin: Baseline and projected changes*

year period from 1980–1999 to 2080–2099 (Christensen et al, 2007). Seasonal warming is roughly the same for each season as the projected change in average annual temperature. The median projected warming for the region is 2.5°C, similar to the global average, while the 25th and 75th percentile projections span a range of 2.2 to 3.0°C. Somewhat greater warming is projected over Indochina and the larger land masses of the archipelago. Note that none of the projections assessed in the new IPCC report indicate cooling for the region and that the CCAM projection of temperature changes for 720ppm is below the range projected by other models. So, our analyses are based on scenarios that are significantly cooler than other models have projected.

The projected increase in precipitation from the CCAM is consistent with other model projections for the region. Most of the models reviewed by the IPCC project increases in precipitation averaged over all Southeast Asia, with a median increase of about 7 per cent in all seasons (Christensen et al, 2007). But there is potential for substantial local variations in precipitation changes, as demonstrated by McGregor and Dix (2001). For example, precipitation decreases are often projected in areas away from the Intertropical Convergence Zone (ITCZ) (Christensen et al, 2007). In areas where mean precipitation is projected to increase there is also the potential for more intense daily extreme precipitation.

Impact of Climate Change on Rice Yields

The Decision Support System for Agrotechnology Transfers (DSSAT) version 4.0 crop modelling software (Hoogenboom et al, 1998) and the climate scenarios generated from the CCAM climate model are used to simulate the impacts of climate change on rain-fed rice yields at the study sites. The crop modelling software uses daily climate data, including maximum and minimum temperature, precipitation and solar radiation, coupled with the crop management scheme and soil property of the study sites, to calculate the rice yields. By using daily climate data for the simulation process, our study is able to capture the impact of climate change on rain-fed rice productivity not only with respect to changes in average climate parameters such as rainfall and temperature, but also with respect to changes in temporal aspects of climate such as shifts in the onset of rains, changes in the length of the rainy season or changes in the pattern of the mid-season dry spell. The DSSAT simulations also incorporate the direct effects of higher CO_2 concentrations, which can increase yields by increasing photosynthesis and plant water-use efficiency.

The crop management scheme used in the simulations assumes homogeneous practice in each site. The crop management scheme is comprised of choice of rice cultivar, planting date, initial condition of the field before planting, planting method and density, water management, and application of organic and inorganic fertilizers. Results of the simulations are shown in Table 16.2. Simulation results for the baseline case differ somewhat from actual yields as recorded from field interviews. Differences in yields are due, in part, to differences between modelled and actual farm management practices and differences between the dataset used for the simulations and actual field conditions, particularly for soil properties. However, the simulations provide useful indicators of the future trend and potential impacts of climate change on rice productivity in the study areas.

Table 16.2 *Simulated rice yields under different climate scenarios*

Climate Scenario	Rice Yields (kg/ha)			Change from Baseline	
	360ppm CO_2 (Baseline)	Average Climate for 540ppm CO_2	Average Climate for 720ppm CO_2	540ppm CO_2	720ppm CO_2
Lao PDR					
Savannakhet Province					
Songkhone District	2535	2303	2470	–9.1%	–2.6%
Thailand					
Ubon Ratchathani Province					
Zone 1	1154	1235	1331	7.0%	15.3%
Zone 2	1920	2002	2072	4.3%	7.9%
Zone 3	2364	2408	2439	1.9%	3.2%
Zone 4	2542	2575	2592	1.3%	2.0%
Zone 5	3024	3051	3069	0.9%	1.5%

According to the climate change scenarios simulated by the CCAM, climate change has a slight negative impact on rain-fed rice production in Savannakhet Province in Lao PDR. The simulated rice yield is reduced by nearly 10 per cent under climate conditions corresponding to a CO_2 concentration of 540ppm, but for the 720ppm CO_2 scenario, yields rise back to almost the same level as the baseline scenario. The simulated rice yields at the study sites in Ubon Ratchathani Province in Thailand show positive impacts from climate change. The increase in rice yield varies from zone to zone and is greater for the 720ppm CO_2 scenario than for the 540ppm scenario. The increases range from roughly 1 to 7 per cent for the CO_2 concentration of 540ppm and 1.5 to 15 per cent for the 720ppm climate.

The mild impact of climate change on rice yields in the Lao PDR sites and the positive impacts at the Thai sites are due primarily to three factors: the beneficial effects of carbon dioxide and increased rainfall for rice cultivation and the relatively modest temperature changes of the climate scenarios used in the analysis. Scenarios with greater warming would likely result in less beneficial outcomes or even negative outcomes. It is also worth noting that the simulations do not take account of the potential effects of more intense rainfall, flooding and changes in the timing of rainfall, which are discussed in the following section.

Farmers' Concerns and Extreme Events

Interviews with farmers in the study areas revealed that farmers are already threatened by climate variability. Farmers are highly concerned about extreme climate events that can cause substantial losses of farm output and threaten their livelihoods. Extreme events identified by farmers as threats to rice cultivation in the study areas include prolonged mid-season dry spells, floods and late-ending rainy seasons. Farmers of rain-fed rice sow their rice at the start of the rainy season, typically in May, or transplant seedlings into their fields in mid-June to mid-July, and harvest their crop in October or November after the end of the rainy season. A mid-season dry spell after sowing or transplanting rice is common to the region. The dry spell can damage young rice plants or impose additional costs on farmers for water procurement to sustain the rice plants while waiting for the rains to resume. If plants are lost but the resumption of rains does not come too late, the farmer can replant to salvage his harvest, but again incurring additional expenses. In the worst case, the mid-season dry spell is prolonged and rains resume too late for replanted rice to mature before the rainy season ends. When very prolonged dry spells occur, farmers are at risk of losing a substantial portion of their crop and income.

Floods are also a significant threat to rice cultivation in the lower Mekong basin. Floods commonly occur near the end of the rainy season, around the months of October and November, when water flow is at its highest in the Mekong river and its tributaries. This period of frequent flooding coincides with the middle to end of the crop season. Late season floods have caused severe damage to rice production, and recovery is difficult as it is too late in the rainy season to replant. Another source of risk is a late end to the rainy season. Rains during and after harvest can damage the harvest or result in higher costs for drying the rice.

Our simulations of the impacts of climate change on rice productivity do not take into account potential changes in the timing, duration or severity of events such as dry spells, heavy rains and floods. But the greatest climate risks to farmers are currently from extreme events and it is changes in extremes that are of greatest concern to farmers. Thus, a complete assessment of climate change risks and vulnerability needs to consider potential changes in the distribution frequencies of extreme events. However, this requires climate scenario simulations for longer time periods than the 10-year time slices constructed for our study.

In order to gauge the sensitivity of farmers to the occurrence of extreme climate events, we examine the impacts of a hypothetical extreme event on farm household risk profiles. Group discussions with farmers and community leaders in the study sites indicate that an event causing a loss of approximately one third of rice production or higher would be a severe situation that would significantly affect a farmer's livelihood. Therefore, a loss of 30 per cent of rice production is used as a proxy for an extreme climate event in our analysis.

Baseline Climate Risk

The level of climate risk faced by farm households is a function of three broad determinants: the sensitivity of the household to stresses in climate variations and changes, the exposure of the household to climate stresses, and the capacity of the household to cope with climate impacts. A variety of indicators are used to measure these three determinants of risk (see Table 16.3).

Indicators of household economic condition are used to measure the sensitivity of the farmer household to climate stresses. Households with current consumption that is sustainable within the limits of household income, land ownership and farm size, allowing self-sufficient food production, have low sensitivity to climate stresses. The degree of dependency on farm production and rice production are used to measure the exposure of the farmer household, with low levels of dependency indicating low exposure. Coping capacity is measured by the diversity and amount of resources available to the farmer household for responding to and recovering from climate impacts. Within this conceptual framework, farmer households are at high risk if they have an unstable or unsustainable household economic condition, are highly reliant on rice production for their livelihood, and have few resources for coping with climate impacts.

Data on the indicators was collected through field interviews of 560 farmer households in Thailand and 160 farmer households in Lao PDR. The field assessment activity in Thailand was conducted by researchers from the Faculty of Agriculture of Ubon Ratchathani University during May–July 2004. The assessment in Lao PDR was conducted by researchers from the National University of Laos during September 2004.

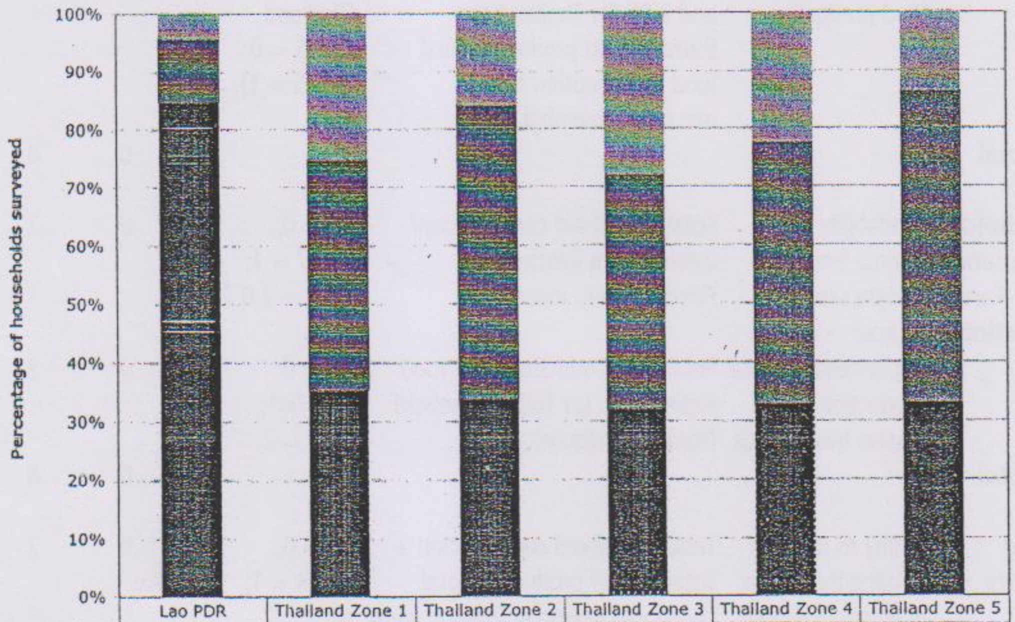
Table 16.3 *Indicators used in evaluating farmers' risk from climate impact*

Criteria	Indicator	Measurement	Scoring	Min score	Max score
Household Economic Condition	Sustainability of household consumption	Total household production (or income)/total household consumption (or expenditure)	>1 = 0; 1–0.7 = 1; <0.7 = 2	0	2
	Stability of household production	Farmland: own or rent	Own = 0, Rent = 1	0	1
	Self-sufficiency of household food production	Farmland/capita 0.8ha/capita for Lao PDR and 0.65 for Thailand are thresholds to produce annual food consumption for one family member	≥0.8 = 0; <0.8 = 1 (Thailand ≥0.65 = 0; <0.65 = 1)	0	1
Sub-total				**0**	**4**
Household Dependency on On-Farm Production	Availability of income from non-climate sensitive sources	Total household consumption/ income from livestock + Fixed off-farm income	>1 = 0; 1–0.7 = 1; <0.7 = 2 0 2	0	2
	Dependency on rice production to sustain basic needs	Total rice production/total food expenditure (or Total household fixed expenditure)	>1 = 0; 1–0.7=1; <0.7 = 2	0	2
Sub-total				**0**	**4**
Coping Capacity	Ability to use non-farming income to maintain livelihood	Total household consumption + Total cost of production/total household saving + Total off-farm income + Income from livestock + Extra income	≤1 = 0; 1–1.3 = 1; >1.3 = 2	0	2
	Ability to use non-farming income to maintain household basic needs	Total food expenditure (or Total fixed expenditure)/total household saving + Total off-farm income + Income from livestock + Extra income	≤1 = 0; –1.3 = 1; 1>1.3 = 2	0	2
Sub-total				**0**	**4**
			Total	**0**	**12**

The collected indicator data were combined into an index of climate risk using the scoring system outlined in Table 16.3. Farm households are grouped into three risk categories according to their scores as follows:

- Low risk: households with risk scores in the range 0–4;
- Moderate risk: households with risk scores in the range 5–8; and
- High risk: households with risk scores in the range 9–12.

The pròportions of farm households classified as having low, moderate and high risk in the current climate for each of the study sites are shown in Figure 16.4. Farm communities in Savannakhet Province in Lao PDR are found to be highly resilient to climate stresses relative to the farm communities of Ubon Ratchathani Province in Thailand. More than 80 per cent of the households in the Laotian villages are classified as low risk and less than 5 per cent are classified as high risk. In comparison, farmers at the study sites in Thailand are at greater risk from climate impacts. Only about a third of the surveyed population are classified as low risk, while approximately 15–25 per cent are in the high risk category. The moderate risk group is the largest group of the population, in some study sites accounting for as many as half of the total surveyed population.



	Lao PDR	Thailand Zone 1	Thailand Zone 2	Thailand Zone 3	Thailand Zone 4	Thailand Zone 5
High Risk	4.4	25	15.7	27.9	22.3	13.6
Moderate Risk	11.3	39.6	50.4	39.9	44.6	53.4
Low Risk	84.3	35.4	33.9	32.2	33.1	33

Figure 16.4 *Climate risk levels of farm households under current climate conditions*

The contributions of exposure, sensitivity and coping capacity to household risk scores are displayed in the risk profiles in Figure 16.5. The low risk groups in every location have risk profiles that differ substantially from the moderate and high risk groups. Their risk scores are low in every criterion. In most cases the biggest difference between the low risk and higher risk groups is that the higher risk groups have much less coping capacity. Greater exposure to climate stresses is also a significant contributor to the greater risks faced by households classified as moderate and high risk. The total risk scores of the low risk groups in Lao PDR and Thailand range roughly from 1 to 2 points, while the total risk scores of the moderate and high risk groups average close to 7 and 10 points respectively.

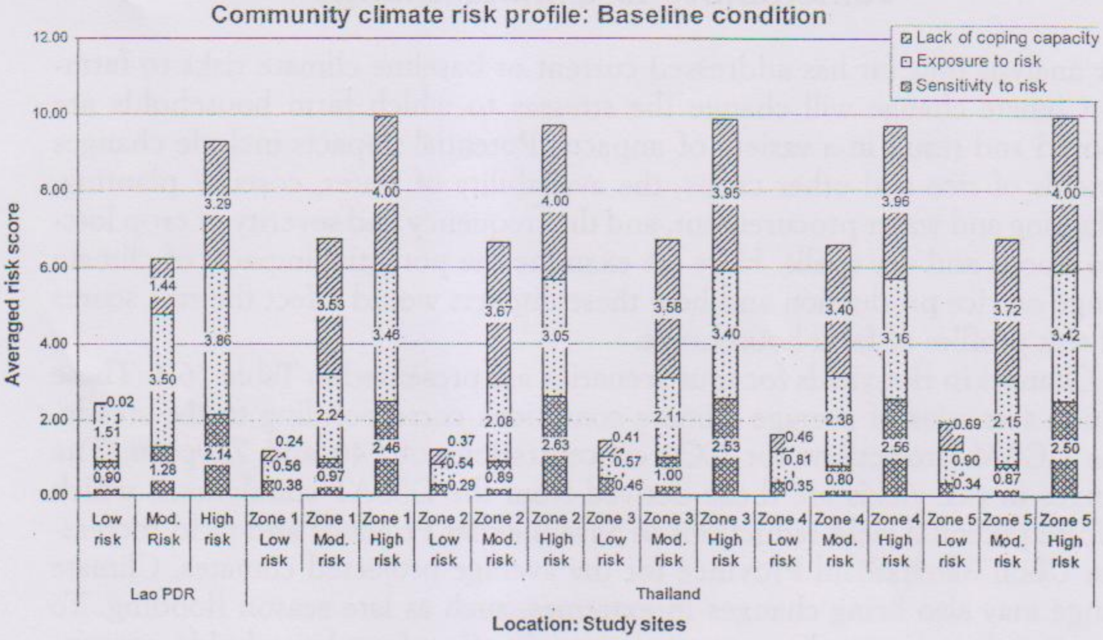


Figure 16.5 *Climate risk profiles under current climate conditions*

The large proportion of rain-fed rice farmers in Lao PDR that are at low risk from climate stresses have high coping capacity relative to other farmers in the study. This is partly because their household production is diversified over various activities, including both on-farm and off-farm sources. Consequently they can accumulate and draw on a wide range of resources with which to cope with climate and other stresses. Rice production for these farmers does not dominate household production and accounts for less than a third of total household output. Another advantage of farmers living in rural areas of Lao PDR is that, due to the low population, natural systems are still able to provide a significant alternate food source and forest products that can be converted or exchanged for other products required for daily use or sold for cash. In addition to relying on natural ecosystems as a coping mechanism, farmers in Lao PDR also have savings in the form of stored rice and cash-convertible livestock to help them cope with impacts from climate stresses, even though cash saving is almost non-existent. In addition, the debt level of farmers in Lao PDR is virtually zero, partly due to the limited availability of loans or other institutional lending mechanisms, but also to social norms that are against indebtedness (Boulidam, 2005).

The majority of surveyed farmers in Thailand are categorized as moderate or high risk. The most important factor contributing to their risk level is very limited coping capacity due to their having few savings and high debts. In addition, the surveyed farmers in Thailand have little diversification in their production and income sources and are highly dependent on income from rice production. Their dependency on rice production creates conditions of high exposure and sensitivity to climate impacts.

Vulnerability to Climate Change

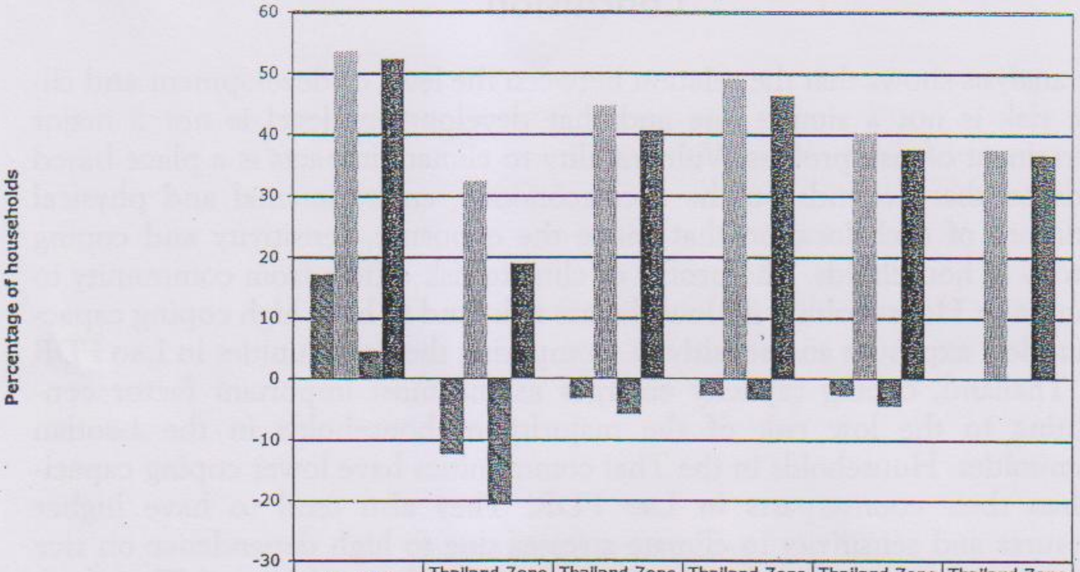
Our analysis thus far has addressed current or baseline climate risks to farmers. Climate change will change the stresses to which farm households are exposed and result in a variety of impacts. Potential impacts include changes in yields of rice and other crops, the availability of water, costs of planting, replanting and water procurement, and the frequency and severity of crop losses to floods and dry spells. Here we examine the potential impacts of climate change on rice production and how these impacts would affect the risk scores and risk profiles of farm households.

Changes in rice yields for four scenarios are presented in Table 16.4. These include scenarios of average climate conditions corresponding to the steady-state CCAM projections for CO_2 concentrations of 540 and 720ppm. The changes in rice yields are those derived from the DSSAT simulations, which indicate potential yield reductions in Savannakhet Province and yield increases in Ubon Ratchathani Province for the average projected climates. Climate change may also bring changes in extremes, such as late season flooding. To investigate how future climate extremes might affect farm households, we construct two scenarios of rice yields that assume that extremes reduce yield by 30 per cent relative to the simulated yields for average climate conditions.

Table 16.4 *Scenarios of changes in rice yields in response to changes in average climate and extreme climate*

	540ppm CO_2		720ppm CO_2	
	Average climate	Extreme climate	Average climate	Extreme climate
Lao PDR:				
Savannakhet Province				
Songkhone district	–9.1%	–39.1%	–2.6%	–32.6%
Thailand:				
Ubon Ratchathani Province				
Zone 1	7.0%	–23.0%	15.3%	–14.7%
Zone 2	4.3%	–25.7%	7.9%	–22.1%
Zone 3	1.9%	–28.1%	3.2%	–26.8%
Zone 4	1.3%	–28.7%	2.0%	–28.1%
Zone 5	0.9%	–29.1%	1.5%	–28.5%

We use these yield changes to recalculate our measures of household economic condition, dependency on rice and coping capacity. New risk scores and risk profiles are then constructed for the climate change scenarios and compared to baseline risks to determine the proportion of households that are vulnerable to climate change. We define households to be vulnerable if the change in climate increases their risk score. Figure 16.6 shows the percentage of households whose risk scores increase or decrease for each scenario.



	Lao PDR	Thailand Zone 1	Thailand Zone 2	Thailand Zone 3	Thailand Zone 4	Thailand Zone 5
540 ppm CO2 Avg climate	17	-12.5	-3.3	-2.8	-2.7	0
540 ppm CO2 Extreme event	53.5	32.3	44.6	49	40.2	37.5
720 ppm CO2 Avg climate	4.4	-20.8	-5.8	-3.5	-4.5	0
720 ppm CO2 Extreme event	52.2	18.8	40.5	46.2	37.5	36.4

Figure 16.6 *Changes in climate risk scores in response to climate change and extremes*

In Lao PDR, there are no substantial changes in the proportion of households classified as low, moderate and high risk for any of the climate change scenarios compared to the baseline case. More than 80 per cent of households are still classified as low risk for each scenario. While the majority of households would still be in the low risk category, however, some households would experience an increase in their risk score. Under average climate conditions, 17.0 and 4.4 per cent of households would face increased risk for the 540ppm and 720ppm CO_2 scenarios, respectively, and are therefore defined as vulnerable. For the scenarios of extreme climate, more than 50 per cent would experience an increase in risk and are thus vulnerable.

In Thailand, there is also no substantial change in the risk groups for the scenarios of changes in average climate, with the moderate risk group still the largest. Because rice yields are projected to increase at the Thai sites for the CCAM-projected changes in average climate, risk scores decrease by 3 to 6 per cent for households in zones 2, 3 and 4 and by 12 to 20 per cent in zone 1. The decrease in climate risk is more pronounced for the 720ppm CO_2 case than for the 540ppm case.

In the extreme climate scenarios, there are noticeable changes in the moderate and high risk group, with some households moving from the moderate to the high risk group. In zone 3, the number of households classified as high risk increases for the extreme climate scenarios and accounts for more than one-third of households. Approximately 18 to 50 per cent of households have higher risk scores for the climate extreme scenarios compared to the baseline case.

Conclusion

Our analysis shows that the relation between the level of development and climate risk is not a simple one and that development level is not a major determinant of risk profiles. Vulnerability to climate impacts is a place-based condition that depends on the socioeconomic, environmental and physical conditions of each location that shape the exposure, sensitivity and coping capacity of households. The profile of climate risk differs from community to community. Households with low climate risk tend to have high coping capacity and low exposure and sensitivity. Comparing the communities in Lao PDR and Thailand, coping capacity emerges as the most important factor contributing to the low risk of the majority of households in the Laotian communities. Households in the Thai communities have lower coping capacity than their counterparts in Lao PDR. They also tend to have higher exposures and sensitivity to climate stresses due to high dependence on rice production for their livelihoods. Consequently, the majority of Thai farm households face moderate to high climate risks.

Changes in average climate conditions are found to have relatively small effects on the degree of climate risk faced by rice farmers in the lower Mekong. For the specific climate change scenarios analysed, average yields would increase in Ubon Ratchathani Province in Thailand, resulting in reductions in climate risks. Vulnerability to changes in climate extremes is potentially greater, as suggested by the increases in climate risk scores for our hypothetical scenario of extreme climate.

Our study is an attempt to develop a quantitative assessment of vulnerability that captures the influences of local context. However, it should be viewed only as a pilot study on the subject in the Southeast Asia region, and there are many gaps in the approach that need to be improved. First of all, we did not cover other non-climate stresses, particularly changes in socioeconomic conditions, which are impacting and changing farmers' livelihoods. Future socioeconomic conditions such as the cost of living, market structure and condition, and national and regional development policy could differ greatly from the current situation, especially in the timescales relevant to the study of climate change. These non-climate factors are important drivers that are likely to have a significant influence on the future vulnerability and risk of any social group. Appropriate scenarios of socioeconomic change should therefore be developed and used in future risk analyses.

Impact on rice production was used as the single proxy of climate stress in the analysis of risk and vulnerability. While changes in rice production are critically important for farmers in the lower Mekong, climate change will have other impacts that also need to be considered. Our categorization of households into risk groups is based on our own judgements; future research should attempt to establish empirical thresholds of farmers' tolerance to climate stresses for delineating low, moderate and high risk households. In addition, the cumulative impact on the household of multi-year or consecutive occurrences of extreme climate event should also be taken into consideration.

The issue of accumulated risk and vulnerability condition may be a serious one, especially in the case of farmers in Thailand, whose coping capacity is low. Most of the Thai farmers have limited resources to buffer climate impacts on their on-farm output and sustain themselves until the next cropping season. In addition, most of the households have debt, which, in many cases, is higher than their annual income. The impact from multi-year climate stresses, especially consecutive years of extreme climate events, may drive them into a very difficult economic state. Such cumulative effects can drain away a household's resources for coping and recovery, and surpass thresholds for the sustainability of their livelihood. For example, they may not be able to repay their debts and end up losing their farmland, which is their most important resource, and be forced to change their way of life or social status from that of an independent farmer to that of a hired farm labourer or leave farming permanently to work in another economic sector. Future study might include annual household cash flow analysis over periods of time under different scenarios in order to understand the effects of multi-year climate stresses on household financial conditions.

Only two projections of climate change were used in this analysis, both from the same climate model and both representing cooler climates for Southeast Asia than are projected by most other models. Future analyses should examine a broader range of future climate projections. Our assessment focused on impacts in a single year for the average climate projected for the future and for artificially constructed extreme climates. But in order to understand climate change vulnerability and adaptation of farmers in the lower Mekong region, it may be necessary to consider the impacts of climate variability over a number of years. Analyses are needed of potential changes in the frequency and magnitude of extreme climate events and their cumulative impacts over multiple-year time horizons.

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