Final Technical Report

AIACC AS07

Southeast Asia Regional Vulnerability to Changing Water Resource and Extreme Hydrological Events due to Climate Change

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Part 1: Project Information and brief summary

1 Project Information

1.1 Project title and AIACC reference number

- Southeast Asia Regional Vulnerability to Changing Water Resource and Extreme Hydrological Events due to Climate Change
- AIACC Regional Study AS07

1.2 Abstract

This research studied the impact of climate change on hydrological condition and rain-fed agriculture in Southeast Asia with focus on the lower Mekong River basin as well as assessed vulnerability and adaptation of rain-fed farmer to climate change impact. In this study, future climate scenarios were developed using climate model with given condition of increasing atmospheric CO_2 concentration from the baseline of 360ppm to 540ppm and 720ppm (in other words, 1.5 and 2 times of baseline). The result from the simulation suggests that average temperature in the region tends to be slightly cooler under climate condition at CO_2 concentration of 540ppm but will be slightly warmer than baseline condition under climate condition at CO_2 concentration of 720ppm. The range of temperature change is 1-2ºC. The hot period of the year will extend longer and the cool period will be significantly shorter while the length of rainy season would remain the same, but with higher rainfall intensity. These changes in climate pattern will result in higher discharge of most of the Mekong River tributaries, which is higher proportion to the increasing in precipitation. Agriculture sector, especially rain-fed system will also be affected from change in climate pattern. The result from simulation using crop modeling technique shows that yield of rice productivity in the study site in Thailand will increase by 3-6%; but on the contrary, may reduce by almost 10% in the study site in Lao PDR. The rice production in the Mekong River delta in Viet Nam tends to have severe impact from climate change, especially summer-autumn crop production, of which the yield may reduce by over 40%. Change in rice productivity was used as proxy of climate change impact to assess risk and vulnerability of rain-fed farmer. The assessment shows that vulnerability to climate change impact of the farmers in the lower Mekong River region

vary from place to place, according to degree of climate impact as well as socio-economical and physical condition in each location. Result from farmer survey in selected communities in Lao PDR, Thailand and Vietnam shows adaptation strategy that is shaped by the socio-economic condition of their surrounding community. Farmers in communities with less developed socio-economic conditions, such as Lao PDR, tend to pursue simple strategies targeted at increasing coping capacity and sustaining basic needs that can be implemented at the household or community level with limited financial and other resources. Farmers in communities with more developed socio-economic conditions, as the case study in Thailand, tend to pursue strategies targeted at reducing the variability of income and at improving the productivity and resilience of their farms. The measures that they adopt tend to depend more on market and other institutions, improved technologies and financial resources than is the case for farmers in less developed communities.

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1.5 Project funding and in-kind support

AIACC	158,000USD + 15,000USD
APN (under CAPaBLE program)	58,085USD

Southeast Asia START Regional Center provides in-kind support in facilities, administrative support, equipments and tools.

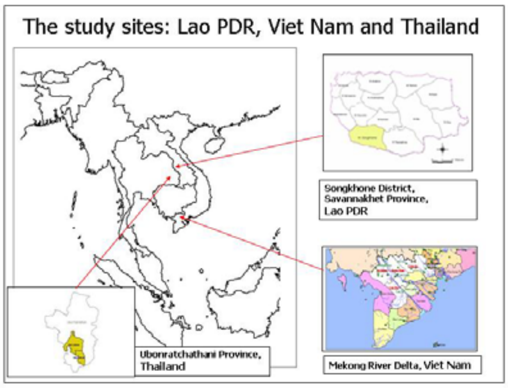
1.6 Countries of Primary Focus

Thailand, Lao PDR, Viet Nam

1.7 Case Study Areas

The 3 study sites selected for the vulnerability and adaptation assessment are as follows,

1. Ubon Ratchathani Province, Thailand
2. Savannakhet Province, Lao PDR
3. Mekong River delta, Viet Nam



1.8 Sectors Studied

Water resources

Agriculture - rain-fed system

1.9 Systems Studied

Water resources

Agriculture - rain-fed rice cultivation

1.10 Groups Studied

Livelihood groups - rain-fed farmer

1.11 Sources of Stress and Change

Change in climate pattern and extreme climate event.

2 Executive Summary

2.1 Research problems and objectives

Research problems:

- What are impacts of climate change on the hydrological regime and fresh water resources in Mekong River Basin?
- What are impacts of climate change on rain-fed rice productivity in Mekong River Basin?
- How would rain-fed farmer in the region be vulnerable to the impact of climate change?
- How would rain-fed farmer in the region adapt to impact of climate change?

Objectives:

- To develop high resolution climate scenario - in terms of geographical and temporal
- To understand the impact of climate change on regional hydrological regime and rain-fed agriculture in the Mekong River basin.
- To develop and test framework and method to measure vulnerability of household in the community to climate impact.
- To understand coping capacity and adaptation to climate impact of the rain-fed farmer in the lower Mekong River region.

2.2 Approach

This study can be divided into 2 parts, which used different approaches in the study.

- The study on climate change and its impact on biophysical systems are based on the modeling approach. This area of study was focused on changes in climate pattern and its first order impact on hydrological condition and agriculture, particularly the rain-fed system, in the region. Climate model was used to simulate high resolution future climate scenario. Climate change impact was analyzed by using future climate data from the simulation as input to hydrological model and crop model for further simulation on hydrological regime of the Mekong River sub-basins and potential crop productivity yield in the study sites.

- Assessment of vulnerability and adaptation to climate impact were based on field survey by individual households interviewing and focus group meeting. The analysis on field interview data was based on quantitative analysis and multi-criteria method, which used multiple criteria and indicators developed for this case study.

2.2.1 The study on climate change and its impact on biophysical systems: modeling approach

- Study of climate change in Lower Mekong River Basin.

  The study of the climate change under this study is based on high-resolution regional climate scenario, which was simulated for the Southeast Asia region by regional climate modeling technique as the downscaling technique has been proven to be unable to give accurate result for the region. The Conformal Cubic Atmospheric Model (CCAM), which is the second-generation regional climate model developed specifically for Australasian region and developed by CSIRO Division of Atmospheric Research in Australia, was used and the output resolution was set at 0.1 degree (approximately 10 km). The model uses the principle of stretched coordinate of a global model instead of uniform latitude-longitude gridding system and runs for 18 vertical levels including the stratosphere. CCAM has also been evaluated in several international model inter-comparison exercises to be among the best climate model for Asian region (McGregor et al, 1998). The condition used for the simulation of climate change scenarios was the increasing of atmospheric CO_2 concentration from 360ppm, which was used as baseline in the analysis, to 540ppm and 720ppm.

- Study of impact of climate change on hydrological regime in Lower Mekong River basin.

  The study of the climate change impact on hydrological regime was based on the Variable Infiltration Capacity (VIC) hydrological model. VIC is a macro-scale hydrologic model that solves full water and energy balances, originally developed by Xu Liang at the University of Washington.(Liang, et al, 1994) It is a semi-distributed grid-based hydrological model that parameterizes the dominant hydro meteorological processes taking place at the land surface - atmosphere interface. A mosaic representation of land surface cover, and sub grid parameterizations for infiltration and the spatial variability of precipitation, account for sub-grid scale heterogeneities in key hydrological processes. The model uses two soil layers and a vegetation layer with energy and moisture fluxes exchanged between the layers. Vegetation and soil characteristics associated with each grid cell are reflected in sets of vegetation and soil parameters. Parameters for vegetation types are specified in a user defined library of vegetation classes (usually derived from standard, national classification schemes), while their distribution over the gridded land surface area is specified in a vegetation parameter file. Soil characteristics (e.g. sand and clay percents, bulk density) can be represented for a user-defined number of vertical soil layers - usually two or three, divided into a thin upper layer and a secondary set of layers that extend several meters into the soil column (Lohman, et al, 1998).

- Study of impact of climate change on rain-fed agriculture in Lower Mekong River Basin

  Crop model was used to simulate future potential yield of rice productivity in the region under different climate conditions from the scenarios simulated by climate model. Decision Support System for Agro Technology Transfers (DSSAT version 4.0) crop modeling software (Hoogenboom et al, 1998) was selected as simulation tool in this. The crop modeling software used daily climate data from the climate simulation, including maximum and minimum temperature, precipitation, solar radiation, etc., coupled with crop management scheme and soil property to calculate potential yield of rice in the study area. By using daily climate data for the simulation process, this study is able to capture the impact of climate change on rain-fed rice production not only in terms of the change in degree of intensity of each climate parameter, e.g. increase or decrease in rainfall or temperature, but also change in temporal aspect too, e.g. shifting of the onset or changing on the length of raining season or change in the pattern of mid-season dry spell period, etc.

2.2.2 Assessment of vulnerability and adaptation to climate impact: field survey approach

The assessment on risk and vulnerability of rain-fed farmer to climate impact in this study was based on field survey to collect data for the analysis of baseline livelihood of rain-fed farmers in the selected study sites, and also for multi-criteria analysis in measuring risk to climate impact. The three criteria used in this study in the assessing farmer's risk to climate impact are as follows;

- Household economic condition, which was used to measure the sensitivity of the farmer household to climate impact.
- Dependency on on-farm production, which was used to measure the exposure of the farmer household to climate impact.
- Coping capacity to climate impact.

Change in rice productivity under influence of climate change and extreme climate event was used as proxy of threat from climate impact in the analysis process. Adaptation to climate change was also assessed by field interview and local stakeholders meeting, which mainly focus on the opinion of the farmers in the study sites.

2.3 Scientific findings

2.3.1 Future climate change in Southeast Asia: lower Mekong River basin

The climate scenario simulation in this study was conducted for the whole region of Southeast Asia and also southern part of People Republic of China for the period of 10 years at each atmospheric CO_2 concentration level. However, the analysis and verification/adjusting process was focused on the Lower Mekong River basin in Lao PDR, Thailand and Vietnam only. This is due to the limited availability of the observed climate date which is required for adjusting process.

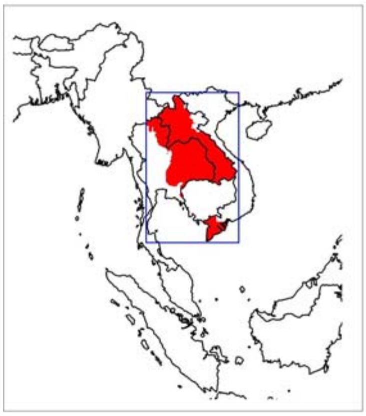


Figure 1: Focus area of climate change scenario analysis

The climate scenario shows that the region tends to get slightly cooler under climate condition at CO_2 concentration of 540ppm but will be warmer under climate condition at CO_2 concentration of 720ppm. However, change in temperature under this set of climate scenario will be within range of 1-2 ºC, but the change in number of annual hot and cool days will be prominent. Hot day, which defined as the day with maximum temperature over 33ºC, will increase by 2-3 weeks and the cool days, which defined as the day with minimum temperature under 15ºC, will reduce also by 2-3 weeks throughout the region. In other words, summer time in the region will be significantly longer in the future.

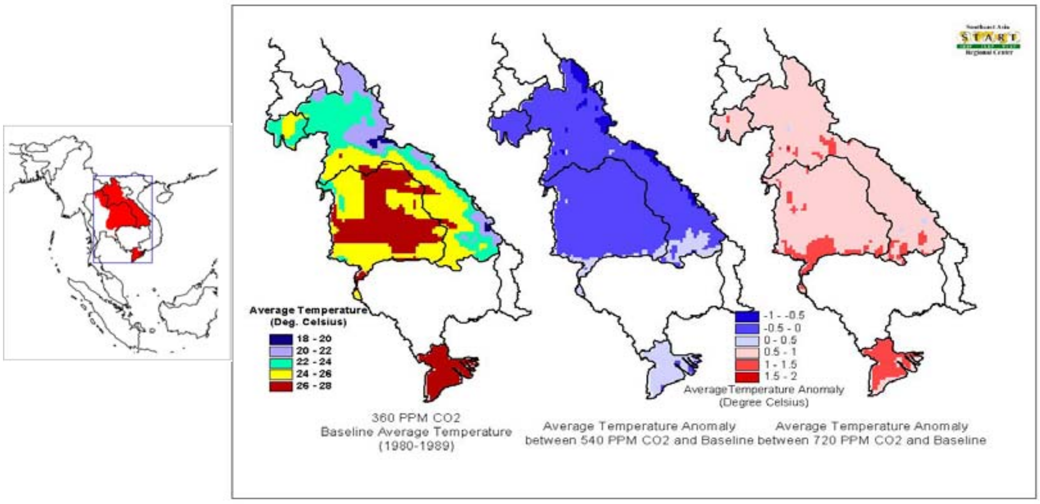


Figure 2: Average temperature in the lower Mekong River basin (baseline simulation) and comparison analysis to show future change

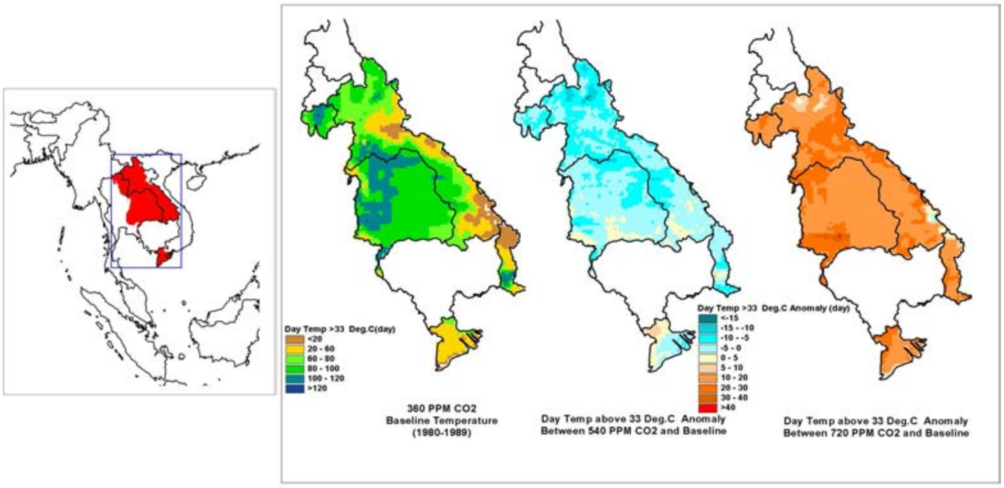


Figure 3: Number of annual "hot day" in the lower Mekong River basin (baseline simulation) and comparison analysis to show future change

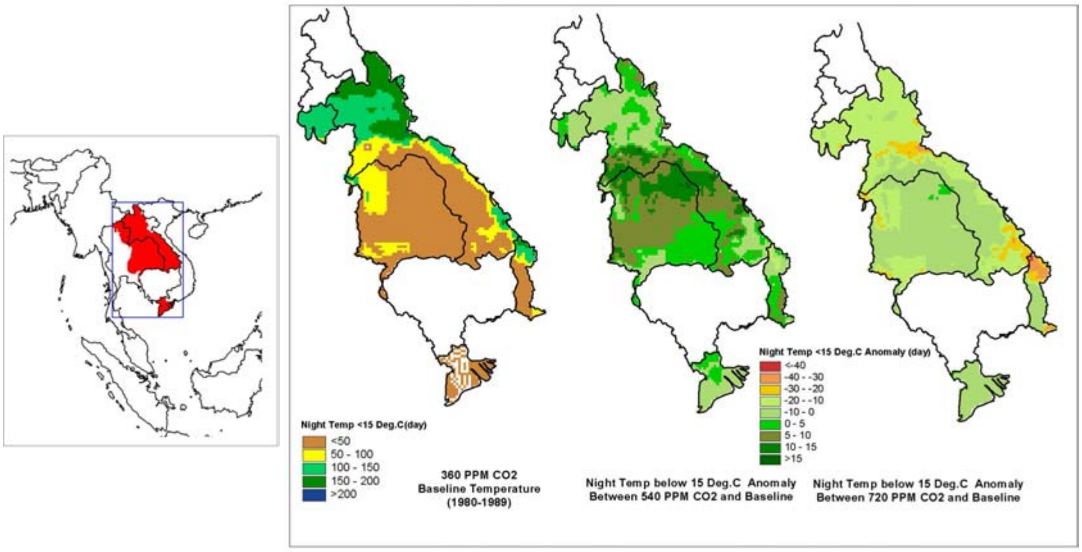


Figure 4: Number of annual "cool day" in the lower Mekong River basin (baseline simulation) and comparison analysis to show future change

The simulation result shows trend of increasing precipitation by 10-30% throughout the region under future climate condition at CO_2 concentration of 540ppm and 720ppm, especially in the eastern and southern part of Lao PDR (see Figure 5).

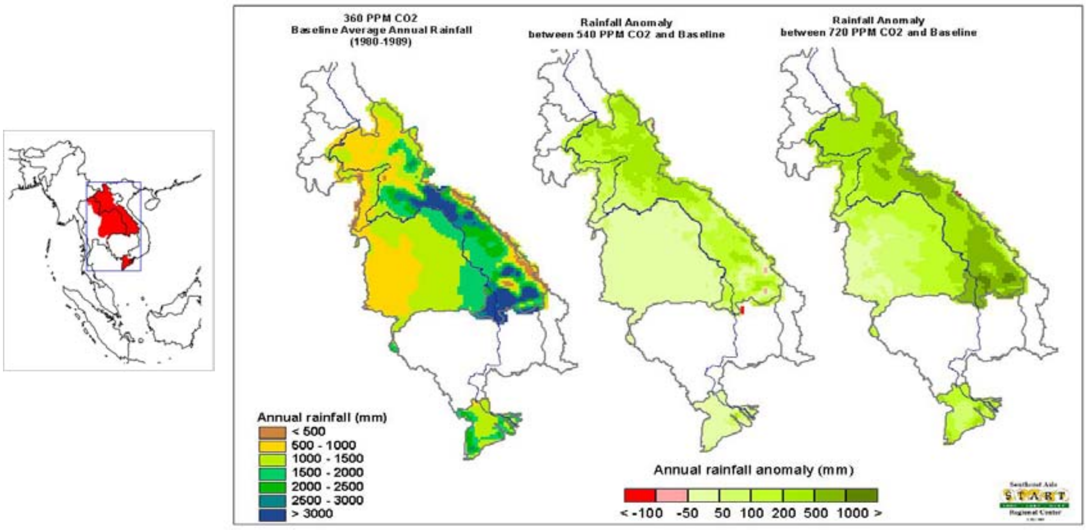
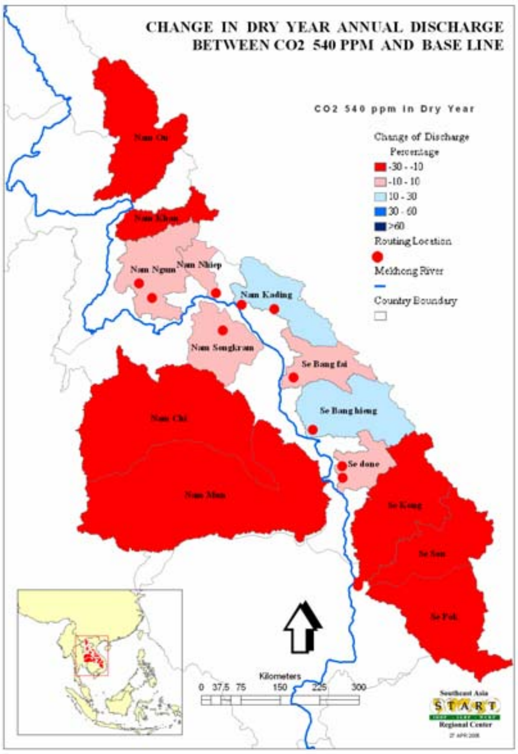
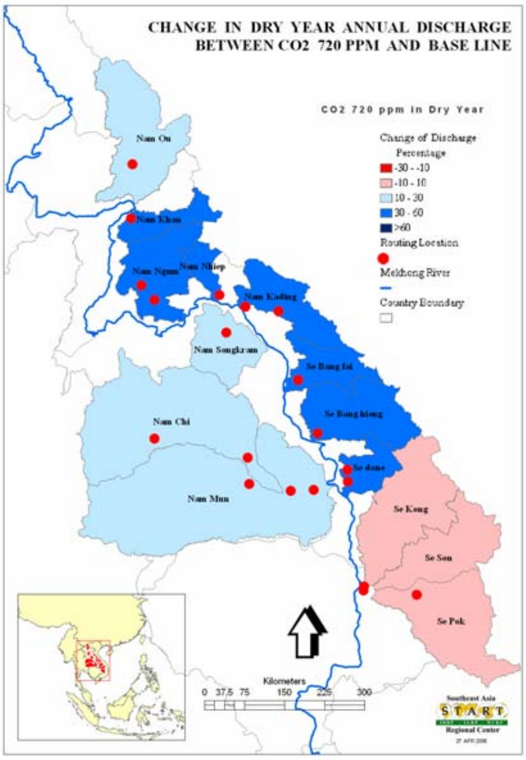


Figure 5: Average rainfall in the lower Mekong River basin (baseline simulation) and comparison analysis to show future change

2.3.2 Impact of climate change on hydrological regime: Mekong River’s tributaries

As CCAM climate model generated a snap shot of one decade climate condition under different CO_2 concentration conditions, data on wettest year and driest year of the decade were used for hydrological regime simulation, in order to analyze plausible range of hydrological change under future climate condition. The simulation result from VIC hydrological model, which focused on major Mekong River tributaries in Lao PDR and Thailand, shows that most of the sub-basins tend to have higher discharge under impact of climate change.





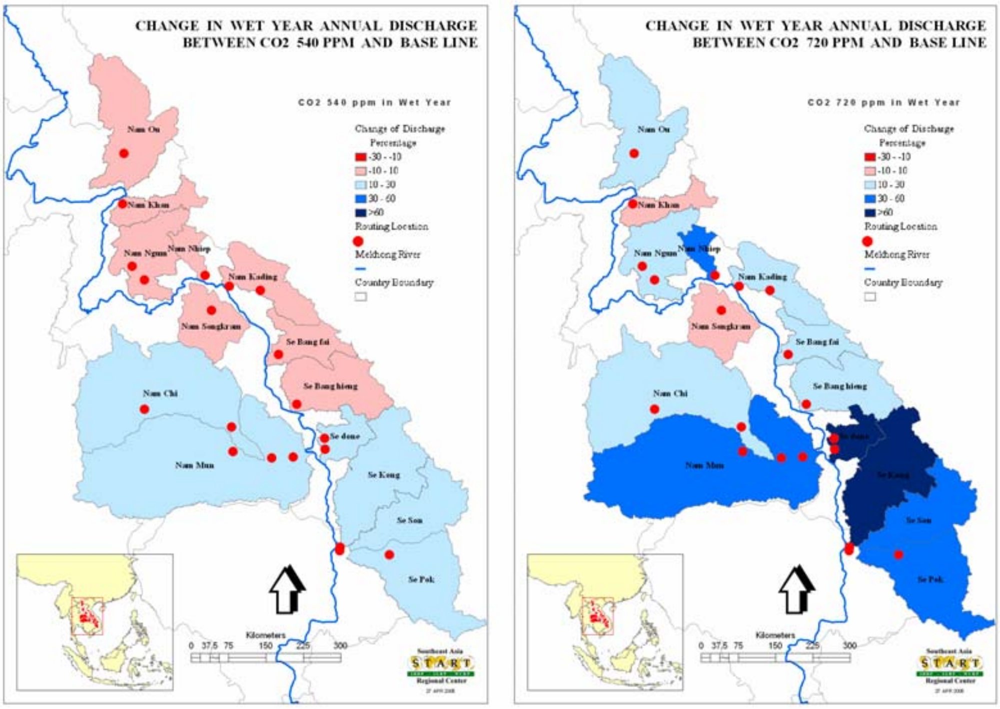


Figure 6: Change in discharge of Mekong River tributaries in Lao PDR and Thailand under different climate scenarios

2.3.3 Impact of climate change on rain-fed agriculture: rice cultivation

The study of impact of climate change on rice productivity in Southeast Asia was conducted in 3 study sites selected in Lao PDR, Thailand and in the Mekong River delta in Vietnam.

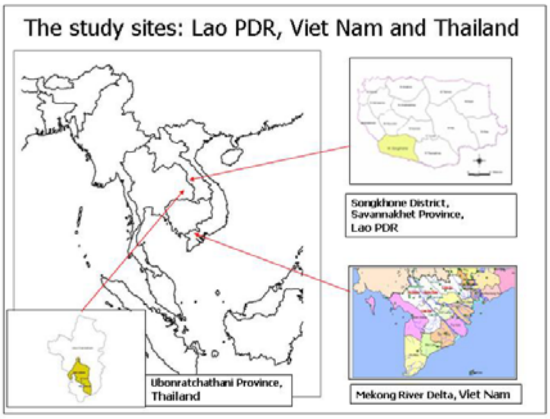


Figure 7: Selected study sites on impact of climate change on rice productivity in Southeast Asia

From the mathematic model simulation using DSSAT crop model, the result shows that future climate condition, according to the climate scenario from CCAM climate model, may have slight negative impact on the rain-fed rice production in the study site in Lao PDR, Savannakhet province. The yield of rice productivity in Savannakhet province would reduced by almost 10% under climate condition at CO_2 concentration of 540 ppm, but will be back to almost the same as baseline condition under the climate condition at CO_2 concentration of 720 ppm.

For the case study in Thailand, the simulation result shows that climate change has positive impact on the rice productivity in the study area in Ubonratchathani province. The simulation shows trend of increasing in yield of rice productivity under future climate condition. The increase in productivity yield could be as high as 10-15% in some areas.

In Viet Nam, where farmer grows 2 crop cycles in a year, the simulation result shows different climate impacts on yield of rice productivity in each crop cycle. The winter-spring crop will get slight impact from climate change as the yield will increase slightly from baseline year under climate condition at atmospheric CO_2 concentration of 540 ppm, but will drop slightly from baseline year under climate condition at CO_2 concentration of 720 ppm. However, the summer-autumn crop tends to get severe impact from climate change. The simulation shows significant decline in summer-autumn crop productivity by approximately 8-12% under climate condition at CO_2 concentration of 540 ppm and would sharply drop up to almost 50% in some areas under climate condition at CO_2 concentration of 720 ppm.

The study sites and analysis result from crop model calculation that shows impact of climate change on rain-fed rice cultivation are as follows:

Impact of climate change on rice productivity

Remark: Rice yield shown in kg/ha

Location	**Climate condition under different atmospheric CO_2 concentration**			**Change in % compare to baseline period**	
	360 ppm	**540 ppm**	**720 ppm**	**540ppm**	**720ppm**
Lao PDR					
Savannakhet Province					
Songkhone District	2,534.90	2,303.20	2,470.10	-9.14	-2.56
Thailand					
Ubonratchathani Province					
Zone 1	1,154.39	1,235.14	1,330.85	7.00	15.29
Zone 2	1,919.61	2,002.15	2,072.04	4.30	7.94
Zone 3	2,363.70	2,407.62	2,438.92	1.86	3.18
Zone 4	2,542.32	2,575.03	2,591.89	1.29	1.95
Zone 5	3,024.18	3,051.44	3,068.82	0.90	1.48
Viet Nam					
An Giang Province					
Winter-Spring crop	5,592.00	5,741.33	5,357.00	2.67	-4.20
Summer-Autumn crop	4,830.33	4,439.33	2,858.00	-8.09	-40.83
Can Tho Province					
Winter-Spring crop	5,799.67	5,971.00	5,361.33	2.95	-7.56
Summer-Autumn crop	6,778.67	6,783.33	5,627.00	0.07	-16.99
Dong Thap					
Winter-Spring crop	5,578.00	5,877.33	5,153.33	5.37	-7.61
Summer-Autumn crop	4,830.33	4,214.67	2,545.67	-12.75	-47.30
Long An Province					
Winter-Spring crop	5,601.33	5,855.00	5,128.67	4.53	-8.44
Summer-Autumn crop	6,646.67	6,535.00	5,301.67	-1.68	-20.24

Table 1: Simulated yield of rice productivity at the 3 study sites under different climate scenarios

2.3.4 Risk and vulnerability of rain-fed farmer in Southeast Asia to climate change

The countries of the lower Mekong River region, being agriculture base country, have vast population of the rain-fed farmer, whose livelihood relies on the rice production and could seriously be affected from impact of climate change. The assessment on household risk to climate change impact was based on change in rice productivity of each household according to climate impact scenarios, which derived from the simulation and also coupled with influence of climate variability based on farmers' perspective. The analysis of surveyed data, which focused on change in rice productivity under different climate scenarios and its impact on farmers' livelihood condition, showed that vulnerability is site-specific condition, which depends upon the degree of climate impact and socio-economic condition as well as physical condition of each site. The profile of risk to climate change impact would differ from community to community.

The case study in Lao PDR shows that livelihood condition of farmer in Lao PDR is low risk to climate impact, even though large number of population may be vulnerable under certain conditions. Under climate condition at CO_2 concentration of 540ppm, over 80% of surveyed population in Lao PDR is classified under low risk category, while approximately 10% is in moderate risk and only slightly over 5% is in high risk categories. There is no substantial different between the situation under normal condition and extreme climate event situation. When compare to the baseline condition, the impact of climate change under normal condition would cause almost one-fifth of surveyed population in Lao PDR to be vulnerable and more than half of the population would be vulnerable in situation of extreme climate event coupled with climate change impact.

In the case study sites in Thailand, baseline risk assessment shows that approximately one-third of survey population is low risk to climate impact, while the moderate risk group is the largest group, which account for approximately 40-50% of the surveyed population. Climate change has favorable impact on rice cultivation, but it cannot cover the influence extreme climate event and cause large portion of population to be vulnerable. In this case, many of those households in moderate risk group moved to high risk group.

The impact of climate change under climate condition at atmospheric CO_2 concentration of 720 ppm causes only slightly change in rice productivity from the condition under climate condition when CO_2 concentration is 540 ppm, therefore, has little effect to the risk grouping in both case studies in Lao PDR and Thailand.

2.3.5 Adaptation of rain-fed farmer in Southeast Asia to climate change

Rice farmers in the Southeast Asia region are experienced in managing climate risks and employ a variety of measures to reduce their vulnerability that are highly place and time specific. The measures used differ according to the specific climate hazards faced, physical and environmental constraints, available technologies, social and economic condition of the farm household and community, vitality of community institutions, degree of engagement in the market economy, market conditions, and the priorities and objectives of the farm households. Results from surveys of farmers in selected communities of Lao PDR, Thailand and Vietnam suggest a pattern that is shaped by the socio-economic condition of their surrounding community. Surveyed farmers identified numerous practices currently in use in their communities in Lao PDR, Thailand and that in their consideration lessen their vulnerability to present day climate variability and hazards. Some of the measures are motivated primarily by climate risks, while others are motivated by other concerns yet nonetheless reduce climate risks by increasing the resilience of farmers' livelihoods to multiple sources of stress. They include measures that are implemented at the individual farm-level, the community-level, and the national-level.

Farmers of the Lao PDR study sites tend to rely mostly on farm level measures for adapting to climate hazards and to a lesser degree on collective actions at the community level. Measures at the national level are very limited. Consequently, the capacity of the individual farm household to adapt is a key limiting factor at present for managing climate risks. Their responses to climate hazards aim mainly at basic household needs, primarily food security of the household. Common measures implemented by rice farmers include seasonal changes in seed variety, cultivation methods, and timing of farm management tasks based upon seasonal climate forecasts made with indigenous knowledge. Also common are raising livestock~~,~~ and harvesting natural products for additional food and income.

Farmers at the study sites in Thailand tend to rely on household and national level measures for reducing climate risks, while the role of community level measures has declined or been neglected. The household level measures focus on income diversification, primarily from off-farm sources that are not as sensitive to climate variations as income from rice. The main practice is seasonal migration to work in the cities, which can lead to the permanent migration of some members of the family in order to secure fixed income for the household. Wage income from city employment is less sensitive to climate and helps to insulate the farm household from climate driven variations in farm income. Seasonal and permanent migration to diversify and supplement household incomes are more common in the Thai study sites than in Lao PDR and Vietnam and are made possible by close links between the rural villages an urban areas where there is demand for labor.

The rain-fed rice farmer in Vietnam tends to rely on measures implemented at the household level and aimed mainly toward on-farm actions to protect against climate hazards. Community and national level measures play very limited role in reducing their climate risks. The farm-level solutions include efforts and investments to increase and sustain the productivity of their farms such as construction and maintenance of small scale irrigation systems or embankments to protect their farmland from flood. But investment costs and limited financial capacity of farmers limit wider use of these measures. Using an alternative strategy, some farmers in the study sites have adapted to flood by accepting floods as part of the ecosystem~~s~~ of their farmland, adjusting their the crop calendar accordingly and allowing their lands to be flooded, thereby gaining advantages from nutrients being deposited that enhance soil fertility and pollutants being washed from their farmland. In addition, use of alternate crops and seed varieties are also common adaptation measures of the farmer in the Mekong River delta in Vietnam.

2.4 Capacity building outcomes and remaining needs

The research capacity in climate change study is limited in the Southeast Asian countries, particularly in the vulnerability and adaptation to climate change. The activities under this research had contributed in helping to bring these countries, particularly Lao PDR and Thailand, up to speed in the study and assessment on the impacts, vulnerability and adaptation to climate change. The activities under this research served as hand-on exercise for the researchers to conduct study on the climate change related issues.

More than 20 researchers and research assistants from 3 countries, who had actively participated in this research, are from the following institutes:

- Chulalongkorn University, Thailand
- Chiang Mai University, Thailand
- Mahidol University, Thailand

- Khon Kaen University, Thailand
- Ubonratchathani University, Thailand
- Meteorological Department, Ministry of Science, Thailand
- Department of Agriculture, Ministry of Agriculture, Thailand
- Land Development Department, Ministry of Agriculture, Thailand
- National University of Laos, Lao PDR
- National Agriculture and Forestry Research Institute, Ministry of Agriculture, Lao PDR
- Environmental Research Institute, Science Technology and Environment Agency, Lao PDR
- Water Resource Coordinating Committee, Office of the Prime Minister, Lao PDR
- Sub-institute of Hydrometeorology of South Vietnam, Vietnam

The researchers from these institutes had formed up a network, which was initiated from their involvement in various processes in this pilot study. The study on climate change and its impact as well as vulnerability and adaptation of various systems and sectors still need to be further developed and expanded to wider range of research network in the Southeast Asia region. More local research capacity needs to be developed, which include the capacity of researcher itself as well as the network of collaboration among the institutions and also forum to exchange research results and develop further joint activity that may lead to further policy implementation.

In addition, tools, dataset, methodology, and approaches, which were developed and used in this study, are made available to academic society and may be used as foundation for other climate change research in the future. However, tools and data which are vital for future study in climate change are still very much needed or be further improved. Among various tools and data needed are climate model to generate high resolution climate scenarios, which should be implemented locally within the region, in order to create diversity for robustness on climate impact analysis.

2.5 National Communications, Science-Policy Linkages and Stakeholder Engagement

The next Second National Communications to UNFCCC would emphasize substantially more on the impacts of climate change on natural system and human society than its first generation, yet expertise and know-how to assess and formulate adaptive strategy in systematic ways are still much lacking in the Mekong River countries. The activities under this research had helped in develop research capacity of both personnel as well as network among institutions in Lao PDR, Thailand and Viet Nam to be able to assist or responsible in the preparation of the next National Communications to UNFCCC.

In addition, the result from the activities under this research, which includes tool, data, methodology, analysis summary, etc., such as model and dataset, high resolution regional climate scenario, analysis on impact of climate change on hydrological regime and crop productivity, etc., would be summarized and disseminated to relevant policy makers as well as other stakeholders in the Southeast Asia region for further study in wider scale as well as be used in future policy consideration.

However, as the preparation of the second National Communications to UNFCCC of the countries where this research had focused upon (Lao PDR, Viet Nam and Thailand) has not yet started, therefore, there has been no direct involvement or contribution from this research to the National Communications yet. But as far as the science-policy linkage is concerned, the principle investigator of this research, Dr.Anond Snidvongs, was appointed a member of National Climate Change Committee of Thailand and an associate investigator, Mr.Suppakorn Chinvanno, was also appointed a member of working group in developing national climate change strategy for Thailand.

2.6 Policy implications and future directions

This pilot study project has raised awareness among policy maker and public sectors in the region regarding the climate change issues; however, in developing the climate change policy, the policy maker still requires more explicit answer regarding climate change impact, vulnerability and adaptation on various key systems, which need more study to confirm. In addition, the study on climate change impact under this regional study is base on long timescale, which is too long for the policy planning scope of any country in the region. Future study may need to focus on the issue of climate change impact in shorter timescale or address more on the climate variability that may change its pattern from climate change influence. Furthermore, more involvement from the policy maker and policy implementing agency should also be planned for the future activity. Pilot implementation, which may help building resilience to climate impact that has immediate as well as long-term benefit, such as seasonal climate forecast, may be further explored and pilot test be implemented.

The climate change has impact on both bio-physical systems as well as socio-economic aspects, and in many cases, need to be considered in regional scale as it may impact large geographic coverage and may have consequences that are trans-boundary. Furthermore, the efforts to cope with climate change impact in one location may cause side effect the other locations or systems or sectors, which could also be trans-boundary issue. This call for regional collaboration to jointly look into the issues together in order to establish and share common understanding on the impact and adaptation in bigger picture at regional scale, of which would ultimately lead to the adaptation strategy that could be implemented collectively under holistic approach to achieve better efficiency and effectiveness in coping with the climate stress and also help avoid conflict that may arise from discreet planning and implementation.

Part 2: Details Report

3 Introduction

This research studied the impact of climate change on hydrological regime and rain-fed agriculture in Southeast Asia, which focused on lower Mekong River basin region. In addition to study impact of climate change on bio-physical systems, this research also assessed risk, vulnerability and adaptation of rain-fed farmer in the region to climate change and variability.

The objectives of this research are not only to find the answers to the research problems, but also to serve as pilot project to build research capacity in this discipline. The coverage of the activities under this research, which spanned across 3 countries in the lower Mekong River region - Lao PDR, Thailand and Vietnam, had established a network of researchers that may initiate more collaboration in the future for benefit of the region.

In addition, this research also aimed to develop framework of study, methodology, tool and dataset that can be used for other study in the future. Among various outcomes of this research, high resolution future climate scenario of the region is an important deliverable that can be used for the study of climate change impact on various sectors and systems in the future. Risk and vulnerability assessment method, which was developed under this research, may also be used as guideline in the future assessment, even though they still need to be further improved. The activities under this research also serve as the demonstration on the scenario-based approach study. In addition, it also points out that the study on impact of climate change need to be conducted with site specific or place-based approach, therefore, the national or regional assessment would need to be conducted in wide scale with the issue of trans-boundary impact well aware.

This research also aimed to raise awareness of climate change issues among the policy makers and public sectors through series of workshop, meetings and published articles as well as to stimulate more studies in the future.

4 Characterization of Current Climate and Scenarios of Future Climate Change

4.1 Activities Conducted: Development of high resolution regional climate scenario for the lower Mekong River region

4.2 Description of Scientific Methods and Data

This research had developed high resolution climate scenario for Southeast Asia region. The simulated climate scenario provides high resolution daily climate data at the resolution of 0.1 degree (approx. 10km), which would then be used as input for hydrological and crop model.

The climate model used for this simulation is Conformal Cubic Atmospheric Model (CCAM), which is the second-generation regional climate model developed specifically for Australasian region by the CSIRO Division of Atmospheric Research in Australia. (McGregor et al, 1998) CCAM has also been evaluates in several international model inter-comparison exercises to be among the best climate model for Asian region. The model uses the principle of stretched coordinate of a global model instead of uniform latitude-longitude grid system, which helps minimizing 'bouncing' effect at the boundary. This technique has advantage over the downscaling technique, which has been proven to be unable to give accurate result for the region. The simulation process in this "stretched grid technique" will make calculation for the specific area at high resolution while calculate the area further away at lower resolution in order to save computing time. Such technique has an important advantage that it can produce very high-resolution climate projections for the target study area, the output resolution was set at 0.1 degree (about 10 km). The CCAM model runs for 18 vertical levels including the stratosphere. It also allows for other features, such as land and sea surfaces surface land form and land cover be varied and climate be simulated under different combinations of atmospheric and land surface

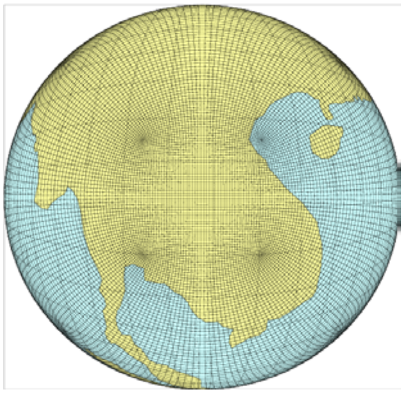


Figure 8: Stretched-grid with controlled boundary in the study area

forcing. It also addresses both climate change and climate variability and the most important feature is that it generates daily climate output which is necessary for downstream impact study, e.g. for use in the modeling of hydrological regime and crop production.

The driving force that was used for generating this set of climate scenarios was the increasing of atmospheric CO_2 concentration, as CO_2 is the largest contributor to anthropogenic radiative forcing of the atmosphere (SRES, 2000). The future climate scenarios were simulated based on the condition of different atmospheric CO_2 concentration levels. The atmospheric CO_2 concentration of 360 ppm, which is the CO_2 concentration level approximately at present time (or to be more precise such condition was around the decade of the 1980s), was used for simulating baseline climate scenario. The climate scenarios for future were simulated at CO_2 concentration of 540 ppm and 720 ppm (or at 1.5 time and double of baseline condition).

The coverage of climate simulation under this study is as per illustration below:

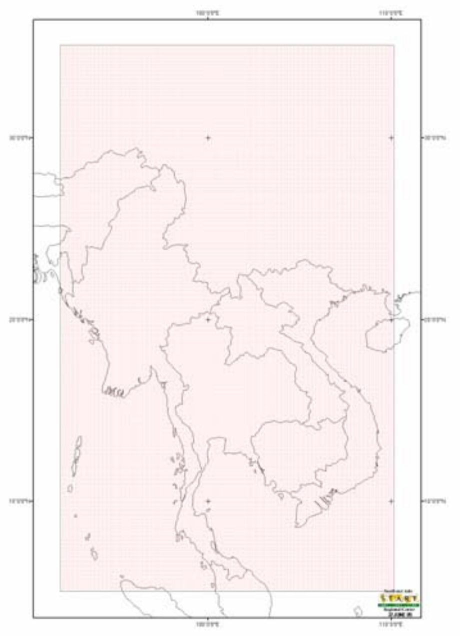


Figure 9: Geographical coverage of the CCAM simulation – Southeast Asia and southern region of People Republic of China

The result from climate simulation still require further analysis and adjusting based on observed climate data during the baseline period. Even though, the climate model simulation was conducted for the whole region of Southeast Asia and also southern part of People Republic of China, but the analysis and adjusting were performed only on the lower region of Mekong River basin in Lao PDR, Thailand and Vietnam only due to the limited availability of the observed climate date which is required for adjusting process. The analysis of climate scenario in Cambodia area was also excluded under this study due to insufficient data from Cambodia. The focused area of study, which covers most part of Lao PDR, northeastern part of Thailand and Mekong River delta in Viet Nam, is shown in the illustration below:

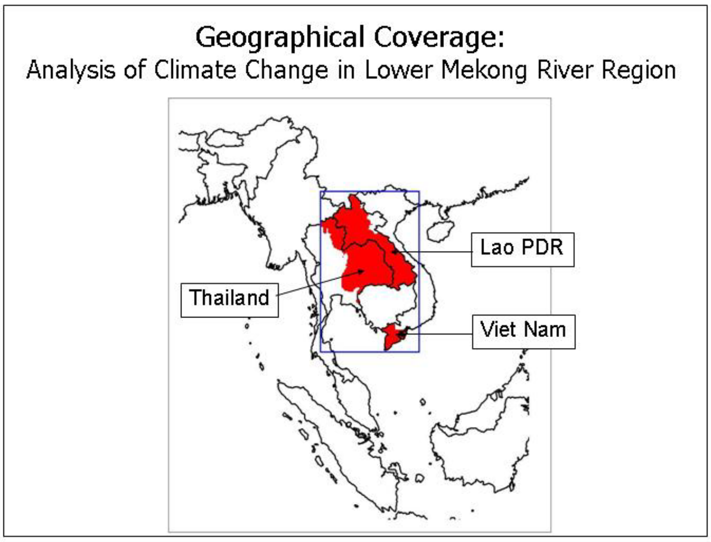


Figure 10: Geographic coverage of the analysis on climate change – Mekong River basin in Lao PDR, Thailand and Viet Nam

The statistical adjustment process is based on cumulative rainfall using a non-linear function (log-log regression) to exponentially increase the daily variability. An arbitrary rainfall threshold of 3 mm/day was applied to reduce number of rain days. The observed data used for the adjusting of future climate information are from:

- Meteorology and Hydrology Department, Ministry of Agriculture and Forestry, Lao PDR
- Meteorological Department, Ministry of Science and Technology, Thailand
- Sub-institute of Hydrometeorology of South Vietnam, Vietnam

Observed rainfall data from 23 meteorological observation stations from 3 countries during the period of 1980s was used for climate scenario adjusting. The name and location of those stations are as shown in the illustration below:

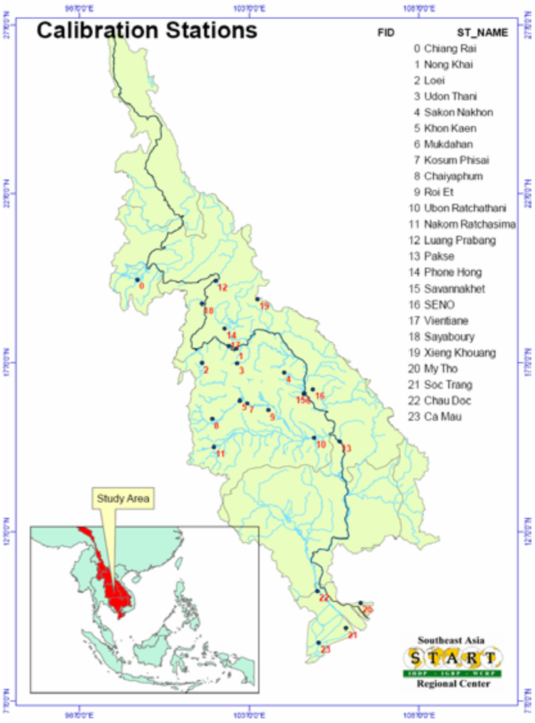


Figure 11: Location of meteorological stations that provide observed data for rainfall calibration process

4.3 Results: Climate change in lower Mekong River basin

The result of the climate simulation is the daily climate data for the period of 10 years of climate condition at atmospheric CO_2 concentrations of 360ppm/540ppm/720ppm. The climate parameters from the simulation include:

- Daily maximum, minimum and average temperature (^oC)
- Specific humidity (kg/kg)
- Heat flux (W/m^2)
- Pressure (hPa)
- Cloud cover (%)

- Rainfall (mm/d)
- Wind speed (m/s) and direction
- Radiation (W/m^2)

The summary on future climate change focuses on 2 primary parameters: temperature and precipitation.

4.3.1 Change in future temperature in lower Mekong River basin

The result from simulation shows that the region tends to get slightly cooler under climate condition at CO_2 concentration of 540ppm and will change to be warmer under climate condition at CO_2 concentration of 720ppm. The illustrations below show the 10-year average temperature in the study area under climate condition at each different CO_2 concentration level (360/540/720 ppm).

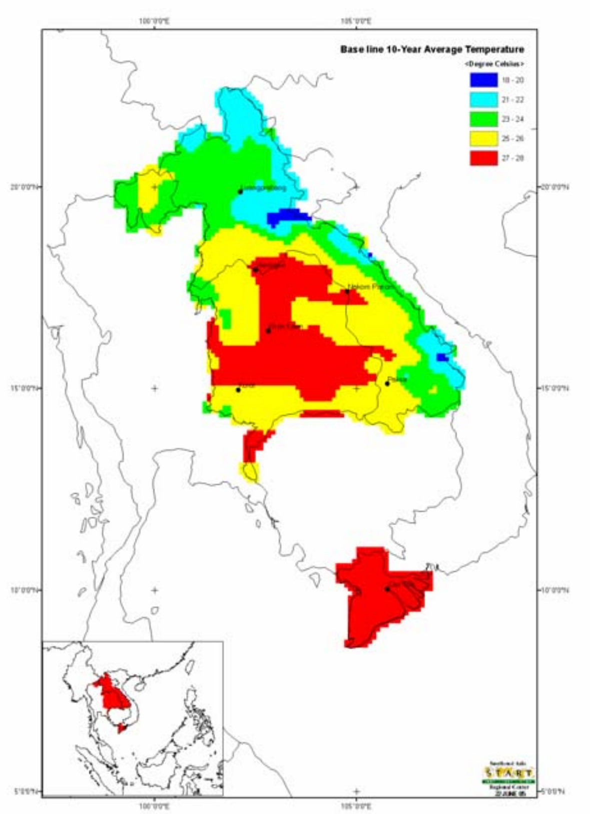


Figure 12: Baseline average temperature in the study area under climate condition at CO_2 concentration of 360 ppm

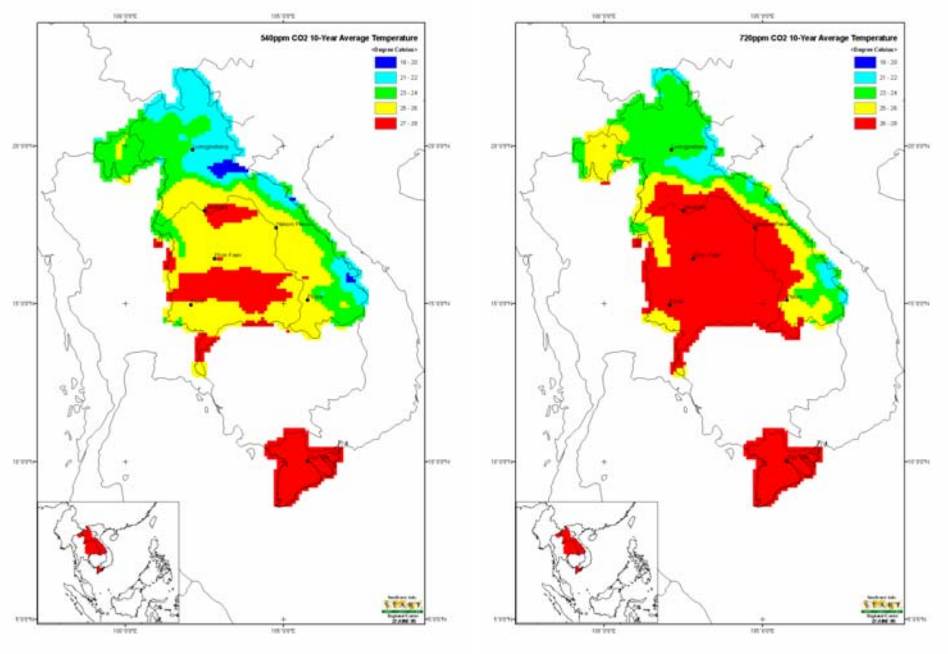


Figure 13: Future temperature in the study area –
Average temperature under climate condition at CO_2 concentration of 540ppm and 720ppm

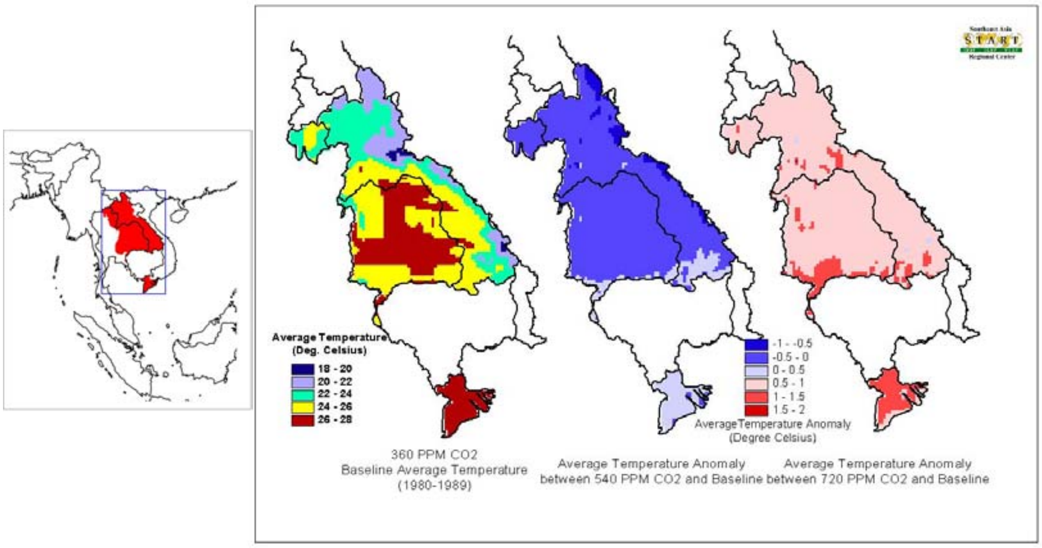


Figure 14: Baseline average temperature lower Mekong River basin and future change

According to the simulation result, temperature change in the future will vary from baseline condition within the range of 1-2ºC. This will occur during the dry period of the year, which can be seen by looking at the 10-year average daily temperature at different time of the year. The tables below is the summary on average minimum and maximum temperature, which is extracted for demonstration at 7 major cities in the region, was prepared for the month of January, which is winter or cool period of the year, April, which is summertime and July/Oct, which represent the beginning and end of rainy season.

Figure 15: Locations of major cities selected to illustrate the impact of climate change on temperature in different seasons

According to the simulation result, change in temperature in the future will occur in the winter and summertime, while the temperature during rainy season would remain almost unchanged, see Table 2 and Table 3.

10-year Averaged Minimum Temperature

UNIT: Degree Celsius

Country	City	Lat.	Long.	Climate scenario: CO_2 level	Jan	Apr	Jul	Oct
Vietnam	Can Tho	10.05	105.75	360	20.1	23.5	23.4	22.6
				540	20.2	23.3	23.7	22.9
				720	21.4	24.5	24.6	23.7
Lao PDR	LuangPrabang	19.85	102.15	360	8.6	18.5	18.1	14.5
				540	7.8	19.5	18.5	14.4
				720	9.7	20.0	19.5	15.1
	Vientiane	18.05	102.55	360	14.5	25.0	22.2	20.2
				540	13.8	24.5	22.4	19.9
				720	15.8	27.0	23.2	20.5
	Pakse	15.15	105.75	360	17.1	23.6	20.9	20.4
				540	16.6	23.6	21.3	20.6
				720	18.4	24.9	22.0	21.0
Thailand	Nakhon Ratchasima	14.95	102.05	360	14.0	22.9	22.1	19.1
	(Korat)			540	13.3	23.0	22.4	18.8
				720	15.3	24.3	23.4	19.4
	Khon Kaen	16.45	102.85	360	15.5	26.4	22.3	20.3
				540	14.9	26.2	22.4	20.1
				720	16.9	27.7	23.3	20.6
	Nakhon Phanom	17.45	104.75	360	15.7	25.7	22.0	20.7
				540	14.8	25.6	22.2	20.6
				720	16.9	27.2	22.9	21.1

Table 2: Average minimum temperature in major cities at different seasons under climate condition at CO_2 concentration of 360ppm, 540ppm and 720ppm.

10-year Averaged Maximum Temperature								
								UNIT: Degree Celsius
Country	**City**	**Lat.**	**Long.**	**Climate scenario: CO_2 level**	**Jan**	**Apr**	**Jul**	**Oct**
Vietnam	Can Tho	10.05	105.75	360	28.6	34.6	29.0	29.9
				540	28.6	34.4	29.5	30.2
				720	30.0	35.8	30.2	30.6
Lao PDR	LuangPrabang	19.85	102.15	360	23.4	33.6	28.4	27.6
				540	22.6	33.9	28.0	26.4
				720	24.3	35.0	28.4	26.7
	Vientiane	18.05	102.55	360	28.5	39.4	31.6	29.1
				540	27.8	39.6	31.4	29.0
				720	29.6	41.1	32.0	29.4
	Pakse	15.15	105.75	360	28.4	35.8	27.3	28.4
				540	28.3	36.0	27.6	28.8
				720	30.0	37.5	28.1	28.7
Thailand	Nakhon Ratchasima	14.95	102.05	360	28.0	36.6	31.0	29.4
	(Korat)			540	27.0	37.0	31.3	29.4
				720	29.0	37.9	32.3	29.7
	Khon Kaen	16.45	102.85	360	27.8	38.6	29.6	28.8
				540	27.0	38.8	29.4	28.8
				720	28.9	40.1	30.1	28.9
	Nakhon Phanom	17.45	104.75	360	28.0	38.4	28.4	28.4
				540	27.3	38.7	28.5	28.6
				720	29.4	40.1	29.1	29.0

Table 3: Average maximum temperature in major cities at different seasons under climate condition at CO_2 concentration of 360ppm, 540ppm and 720ppm.

In addition to the change in minimum and maximum temperature, another indicator that shows change in regional temperature is the number of hot and cool days in a year. Even though the average temperature may change within the range of 2ºC, however, number of hot days will increase and number of cool days will reduce significantly. In other words, the summer tends to get longer and winter time will be shorter. The "hot day" in this study is defined as the day that maximum temperature is over 33ºC and the "cool day" is the day that minimum temperature is below 15ºC. Under the climate condition of CO_2 concentration at 540 ppm, the number of annual hot day will slightly reduce from baseline as the region tend to be slightly cooler, but the hot period will expand by 3-4 weeks throughout the region under the climate condition when the level of CO_2 rises to 720 ppm as per illustration below.

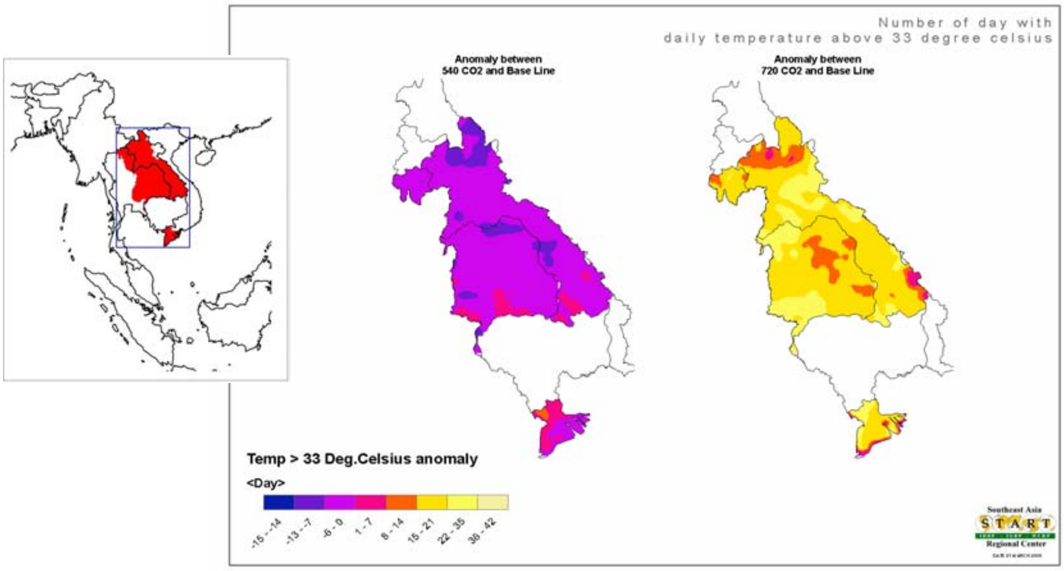


Figure 16: Change in number of annual "hot day" in the study area

The table below shows change in number of annual hot day at the major cites in the region.

Number of annual hot day at different cities in the region				
	**Location**	**Climate scenario: CO_2 = 360 ppm**	**Climate scenario: CO_2 = 540 ppm**	**Climate scenario: CO_2 = 720 ppm**
	Vietnam			
	Can Tho	79	71	108
	Lao PDR			
	Luangphrabang	68	52	77
	Vientiane	148	116	157
	Pakse	86	81	110
	Thailand			
	Nakhon Ratchasima (Korat)	121	116	159
	Khon Kaen	126	115	144
	Nakhon Phanom	112	103	142

Table 4: Number of annual hot day at selected cities in the region under climate condition at different levels of atmospheric CO_2 concentration

On the other hand, the climate change scenario shows trend of decreasing cool day in the future throughout the region, of which the cool period would be shorten by 3-4 weeks in many locations as per illustration below.

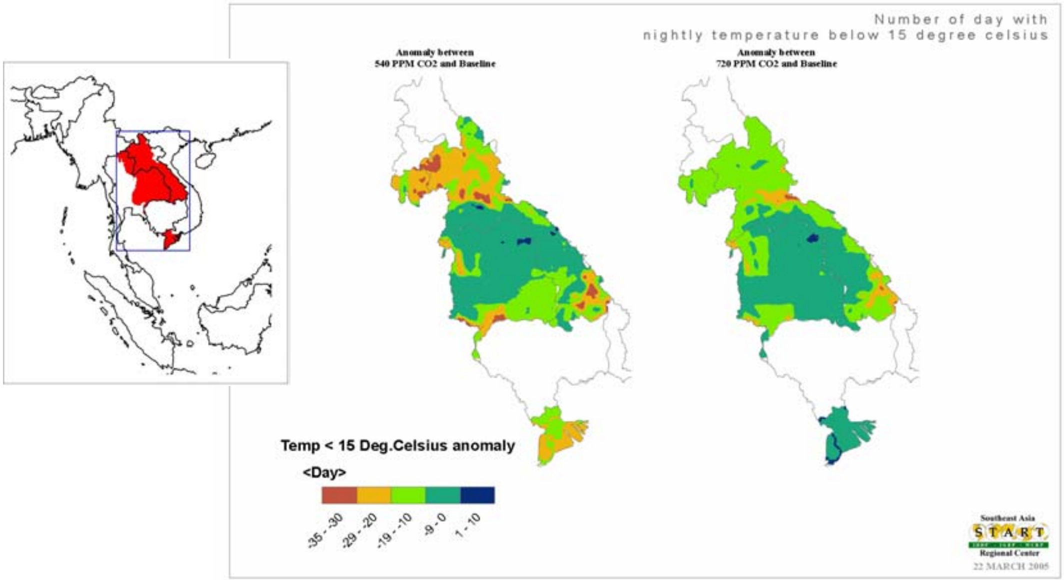


Figure 17: Change in number of annual "cool day" in the study area

The table below shows change in number of annual cool day at the major cites in the region.

Number of annual cool day at different cities in the region				
	**Location**	**Climate scenario: CO_2 = 360 ppm**	**Climate scenario: CO_2 = 540 ppm**	**Climate scenario: CO_2 = 720 ppm**
	Vietnam			
	Can Tho	0	0	0
	Lao PDR			
	Luangphrabang	147	147	141
	Vientiane	66	72	37
	Pakse	30	33	0
	Thailand			
	Nakhon Ratchasima (Korat)	77	78	30
	Khon Kaen	57	54	19
	Nakhon Phanom	60	57	21

Table 5: Number of annual cool day in the selected cities in the region under climate condition at different levels of atmospheric CO_2 concentration

4.3.2 Change in future precipitation in lower Mekong River basin

The result from the simulation shows trend of increasing precipitation throughout the region in the future. The increasing in precipitation will be prominent in Lao PDR as well as Mekong River delta in Viet Nam. However, the length of rainy season seems to be unchanged (see Appendix 1: Rainy Season Pattern at Selected Cities in lower Mekong River Basin under Influence of Climate Change). The illustration below shows 10-year average precipitation of the baseline condition and the future change under climate condition at atmospheric CO_2 of 540ppm and 720ppm.

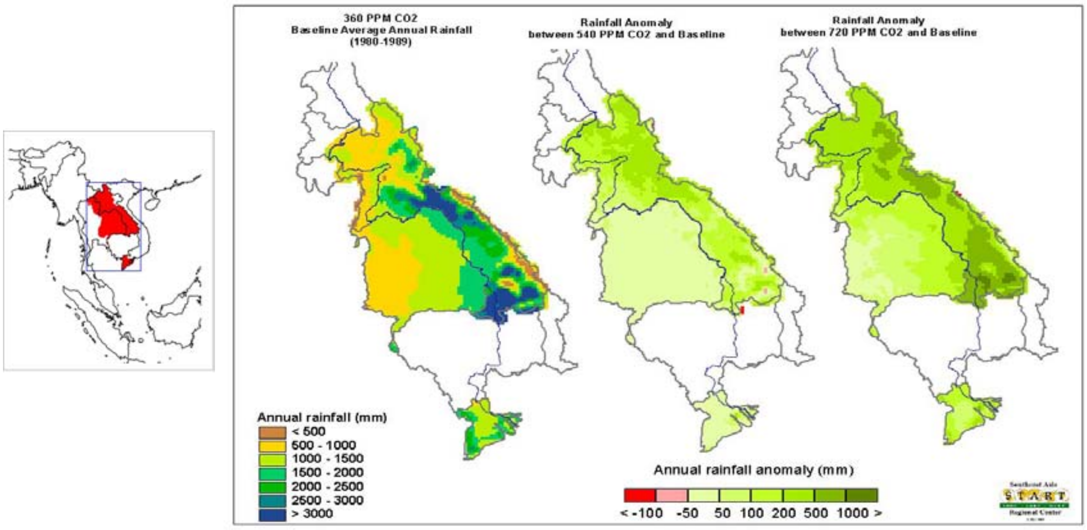


Figure 18: Average annual rainfall in the lower Mekong River region – Baseline condition and future change.

The change in regional precipitation will vary from year to year under influence of climate variability. In the wettest year of the decade, precipitation in Lao PDR will increase by slightly over 10% under climate condition at atmospheric CO_2 of 540ppm and almost 30% under climate condition at atmospheric CO_2 of 720ppm. The Mekong River delta will also have higher annual rainfall by approximately 10%. However, on the contrary, there seems to be almost no change on annual precipitation in Thailand throughout the future under wet year scenario.

Range of change in annual rainfall in Mekong River basin			
Wet year scenario			
Zone	Climate scenario: CO_2 = 360 ppm	Climate scenario: CO_2 = 540 ppm	Climate scenario: CO_2 = 720 ppm
Unit: Millimeter/100km^2			
Thailand	1,384	1,257	1,384
Lao PDR	1,981	2,222	2,549
Vietnam	1,743	1,939	1,983

Table 6: Annual precipitation in Mekong River basin in Lao PDR, Thailand and Vietnam – Wet year scenario

The condition is different in the driest year of the decade; annual precipitation in Mekong River delta in Viet Nam will remain unchanged but Thailand will have higher rainfall by almost 10%. Annual rainfall will remain almost unchanged in Lao PDR under climate condition at atmospheric CO_2 of 540ppm but will increase by 25% under climate condition at atmospheric CO_2 of 720ppm.

Range of change in annual rainfall in Mekong River basin			
Dry year scenario			
Zone	Climate scenario: CO_2 = 360 ppm	Climate scenario: CO_2 = 540 ppm	Climate scenario: CO_2 = 720 ppm
Unit: Millimeter/100km^2			
Thailand	1,069	1,105	1,168
Lao PDR	1,504	1,529	1,888
Vietnam	1,457	1,424	1,434

Table 7: Annual precipitation in Mekong River basin in Lao PDR, Thailand and Vietnam – Dry year scenario

4.4 Conclusions

The major change in climate pattern in the lower Mekong River basin is mainly on the precipitation and prolonged summertime. The result from simulation shows that precipitation will increase throughout the region in the future, especially in Lao PDR. Climate variability tends to be more extreme as the range of precipitation between dry and wet years will be wider in the future. Among the sub-regions in the focused area of study, it seems that Lao PDR would affect from impact of climate change most, in term of increasing precipitation.

The higher precipitation while the length of rainy season will remain unchanged may lead to higher flood risk in the future, which may also increase in its magnitude as well as frequency. In addition to flood risk, higher intensity precipitation may also cause higher risk of landslide, especially in the mountainous area. Wider range of precipitation fluctuation between dry and wet year may also raise concerns in the water utilization and water allocation in dryer year. This could lead to the improvement on the infrastructure or other water policy in the region.

As far as the temperature is concerned, the range of hot and cool weather in the region may only slightly change, but the region will have longer summer with shorter winter time. This phenomenon may have impact on various ecosystems, e.g. problem with pest and vector borne disease may also arise; however, this was not covered under the study of this research.

5 Impacts and Vulnerability

5.1 Activities Conducted

- Study of impact of climate change on hydrological regime in lower Mekong River region.
- Study of impact of climate change on rain-fed rice productivity in lower Mekong River region.
- Assessment on vulnerability and adaptation of rain-fed farmer in the lower Mekong River region to impact of climate change.

5.2 Study of impact of climate change on hydrological regime in lower Mekong River region

5.2.1 Description of Scientific Methods and Data

This research focus the study of impact of climate change on hydrological regime on Mekong River's tributaries in Lao PDR and Thailand by using climate data from the climate scenario, which was simulated by CCAM climate model, as input into Variable Infiltration Capacity (VIC) hydrological model to conduct high resolution hydrological simulation.

The tributaries of Mekong River under this study are as follows: (also see Figure 19)

- Lao PDR: Nam Ou, Nam Khan, Nam Nhiep, Nam Ngum, Nam Theun, Nam Kading, Se Bang Fai, Se Bang Hieng, Se Done and Se Kong
- Thailand: Nam Songkram, Nam Chi and Nam Mun

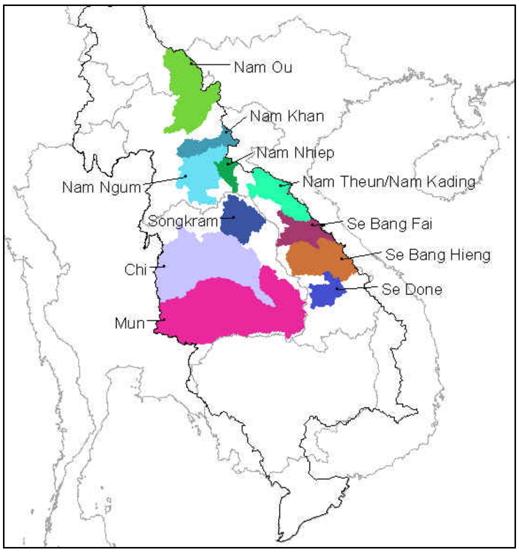


Figure 19: Selected Mekong River tributary watersheds for the study of climate change impact on hydrological regime

Variable Infiltration Capacity (VIC) is a macro-scale hydrologic model that solves full water and energy balances, originally developed by Xu Liang at the University of Washington.(Liang, et al, 1994) It is a semi-distributed grid-based hydrological model that parameterizes the dominant hydro meteorological processes taking place at the land surface - atmosphere interface. A mosaic representation of land surface cover, and sub grid parameterizations for infiltration and the spatial variability of precipitation, account for sub-grid scale heterogeneities in key hydrological processes. The model uses two soil layers and a vegetation layer with energy and moisture fluxes exchanged between the layers.(Lohman, et al, 1998) Vegetation and soil characteristics associated with each grid cell are reflected in sets of vegetation and soil parameters. Parameters for vegetation types are specified in a user defined library of vegetation classes (usually derived from standard, national classification schemes), while their distribution over the gridded land surface area is specified in a vegetation parameter file. Soil characteristics (e.g., sand and clay percents, bulk density) can be represented for a user-defined number of vertical soil layers - usually two or three, divided into a thin upper layer and a secondary set of layers that extend several meters into the soil column. (Richey, et al, 2000)

Data description and data source that were used for the simulation are as follows:

- Forcing data: CCAM climate scenario data set at 0.1 degree resolution

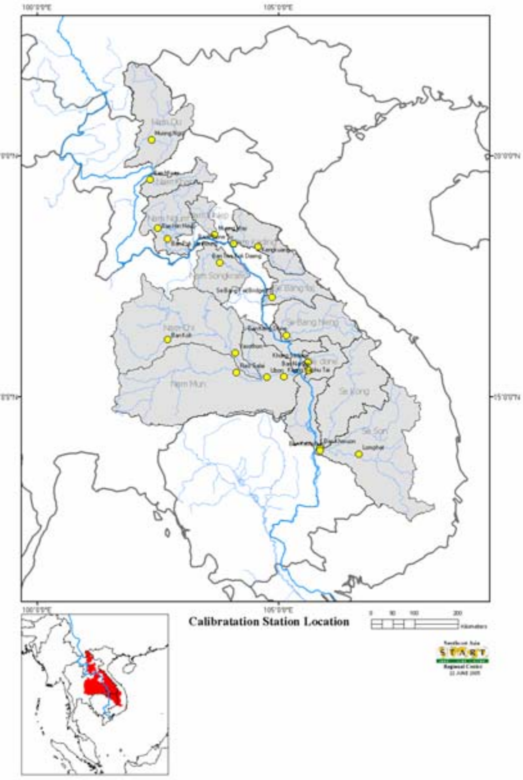
- Vegetation data: UMD 1km Global Land Cover dataset - year 1994
- Soil data: Global Soil Data Task 2000 - Global Soil data product (IGBP-DIS) 0.5 minute resolution
- Elevation data: Shuttle Radar Topography Mission 3-arc second (SRTM-90M) compiled by Consortium for Spatial Information of the Consultative Group for International Agricultural Research (CGIAR-CSI)
- River network: The Digital Chart of the World (DCW), which is the Environmental Systems Research Institute, Inc. (ESRI)'s product originally developed for the US Defense Mapping Agency (DMA) using DMA data. The dataset used was the DCW 1993 version, at 1:1,000,000 scale
- Watershed boundaries: River basin boundaries are based on the EROS Data Center HYDRO1k basin boundaries developed at the U.S. Geological Survey (http://edcdaac.usgs.gov/gtopo30/hydro/)

All data sets were re-calculated by GIS technique to 5 km resolution for operational model resolution.

Baseline hydrological condition: Model calibration

The baseline hydrological regime for further analysis was simulated by VIC hydrological model. This is also part of model calibration process, of which the result from the simulation was compared against the observed data during the 1980s. The simulation was performed to calculate tributaries run-off at various key locations where observation stations are located and model calibration was performed by using the observed data from these stations. The calibrated hydrological simulation result is shown in the Appendix 2: Hydrology Calibrating Result. The result shows that VIC model is able to simulate total discharge reasonable well in most of the sub-basis under this study. However, the model still has limitation in simulating the month-to-month discharge, this may due to the model limitation in handling the soil property, particularly the soil moisture. In addition, the model still has limitation in handling back water effect from the main stream into the tributary.

The locations selected for the baseline simulation and calibration are as shown in the illustration and table below:



Sub-Basin: Nam Ou - Lao PDR
Station: Muong Ngoy (N20.702 E102.335)

Sub-Basin: Nam Khan - Lao PDR
Station: Ban Mixay (N19.787 E102.177)

Sub-Basin: Nam Ngum - Lao PDR
Station: Ban Hin Heup (N18.663 E102.355)

Sub-Basin: Nam Ngum - Lao PDR
Station: Ban Pak Kanhoung (N18.417 E102.575)

Sub-Basin: Nam Nhiep - Lao PDR
Station: Muong May (N18.505 E103.662)

Sub-Basin: Nam Theun - Lao PDR
Station: Bang Signo (N17.850 E105.067)

Sub-Basin: Nam Songkhram – Thailand
Station: Ban Tha Kok Daeng (N17.867 E103.783)

Sub-Basin: Se Bang Fai - Lao PDR
Station: Se Bang Fai Bridge-13 (N17.072 E104.985)

Sub-Basin: Se Bang Hieng - Lao PDR
Station: Ban Keng Done (N16.185 E105.815)

Sub-Basin: Nam Chi - Thailand
Station: Ban Chot

Sub-Basin: Nam Mun - Thailand
Station: Kaeng Saphu Tai (N15.240 E105.250)

Sub-Basin: Se Done - Lao PDR
Station: Souvanakhili (N15.383 E105.817)

Sub-Basin: Se Kong - Lao PDR
Station: Attapeu (N14.800 E106.833)

Figure 20: Selected locations in Mekong River tributaries for calculating baseline hydrological condition and model calibrating process

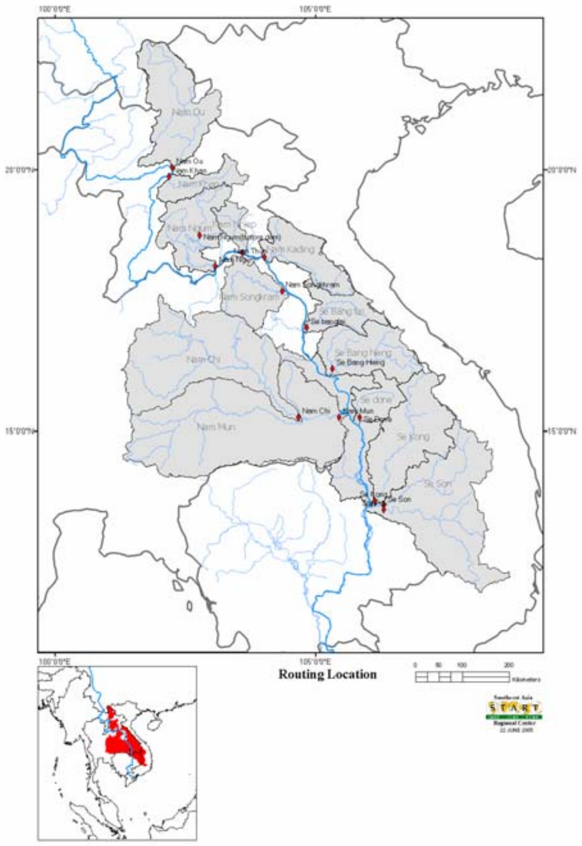
For result of baseline simulation and model calibration, see Appendix 2: Result of Hydrological Regime Baseline Calculation and Model Calibration.

5.2.2 Results: Impact of climate change on discharge of Mekong River's tributaries in Lao PDR and Thailand

After the VIC hydrological model had been calibrated, the future climate data from climate scenario, which was simulated from CCAM climate model, was used as input to simulate future tributary's run-off under influence of climate change. As CCAM climate model generates 10 years climate data at each atmospheric CO_2 concentration condition (360ppm, 540ppm and 720ppm), climate data from the wettest year and driest year of the decade were used in the hydrological simulation, in order to understand the range of change in future hydrological condition in these watersheds.

The VIC model runs one grid cell at a time over a desired period (any subset of the period spanned by the model forcing data), to produce time series of runoff, base flow, evaporation, and other physical variables for each grid cell. These time series are then routed by the VIC routing model to produce stream flow at points of interest in the watershed. The simulation of tributary discharge was based on the calculation of run-off at the river mouth before it flows into Mekong River main stem. The locations of the routing are as per Figure 21 below:

(For the result of simulation of each sub-basin, see Appendix 3: Simulation Result of Hydrological Regime of major Sub-basins of Mekong River in Lao PDR and Thailand under Different Climate Scenarios).



Sub-Basin: Nam Ou - Lao PDR
Station: Tributary mouth (N20.05 E102.24)

Sub-Basin: Nam Khan - Lao PDR
Station: Tributary mouth (N19.87 E102.18)

Sub-Basin: Upper Nam Ngum - Lao PDR
Station: Before dam entry (N18.75 E102.77)

Sub-Basin: Nam Ngum - Lao PDR
Station: Tributary mouth (N18.16 E103.07)

Sub-Basin: Nam Nhiep - Lao PDR
Station: Tributary mouth (N18.41 E103.59)

Sub-Basin: Nam Theun - Lao PDR
Station: Tributary mouth (N18.33 E104.01)

Sub-Basin: Se Bang Fai - Lao PDR
Station: Tributary mouth (N16.98 E104.83)

Sub-Basin: Se Bang Hieng - Lao PDR
Station: Tributary mouth (N16.19 E105.32)

Sub-Basin: Se Done - Lao PDR
Station: Tributary mouth (N15.26 E105.84)

Sub-Basin: Se Kong - Lao PDR
Station: Tributary mouth (N13.67 E106.13)

Sub-Basin: Se Son - Lao PDR
Station: Tributary mouth (N13.58 E106.30)

Sub-Basin: Se Pok - Lao PDR
Station: Tributary mouth (N13.50 E106.30)

Sub-Basin: Nam Songkhram - Thailand
Station: Tributary mouth (N17.68 E104.35)

Sub-Basin: Nam Chi - Thailand
Station: Tributary mouth (N15.26 E104.66)

Sub-Basin: Nam Mun - Thailand
Station: Tributary mouth (N15.26 E105.45)

Figure 21: Routing locations for analysis of climate change impact on hydrological regime of the Mekong River's tributaries

The result from the simulation shows that most of the tributaries of Mekong River in Lao PDR and Thailand tend to have more water in the future due to higher precipitation. For the wet year scenario, almost every watershed will have higher discharge under the climate condition at CO_2 concentration of 540 ppm and increase further under the climate condition at CO_2 concentration of 720 ppm. However, in the dry year scenario, many sub-basins will have slightly less water under climate condition at CO_2 concentration of 540 ppm, but the discharge will increase under the climate condition at CO_2 concentration of 720 ppm.

Change in the discharge of Mekong River's tributary under influence of climate change is summarized in the table below:

Impact of Climate Change on Water Resource in Mekong River's tributaries in Lao PDR and Thailand						
Mekong River's tributary	Wet Year Scenario: Tributary catchment's discharge under climate condition at different CO_2 concentration			Dry Year Scenario: Tributary catchment's discharge under climate condition at CO_2 different concentration		
	Baseline: 360 ppm (million m^3)	540 ppm (% change from baseline)	720 ppm (% change from baseline)	Baseline: 360 ppm (million m^3)	540 ppm (% change from baseline)	720 ppm (% change from baseline)
Lao PDR						
Nam Ou	11,458	+7.23%	+16.78%	9,035	-15.56%	+24.38%
Nam Khan	1,293	+6.65%	+6.93%	946	-11.17%	+44.80%
Upper Nam Ngum (before dam)	3,820	+14.77%	+8.44%	2,891	-12.30%	+51.49%
Nam Ngum	14,837	+6.83%	+11.79%	11,837	+4.70%	+46.63%
Nam Nhiep	4,796	+4.70%	+46.63%	3,902	-4.00%	+33.28%
Nam Theun	39,427	-5.86%	+18.75%	31,483	+11.03%	+30.47%
Se Bang Fai	8,330	-4.54%	+14.92%	6,412	+1.40%	+32.69%
Se Bang Hieng	10,057	+0.04%	+27.95%	6,784	+10.60%	+51.21%
Se Done	2,574	+13.30%	+100.05%	1,829	+2.91%	+53.43%
Se Kong	37,506	+20.20%	+63.21%	35,138	-13.64%	+5.57%
Se Son	14,279	+24.74%	+51.75%	13,303	-11.60%	+1.84%
Se Pok	13,050	+22.39%	+51.26%	12,382	-15.29%	-3.53%
Thailand						
Nam Songkram	12,270	+6.34%	+7.41%	11,750	+7.18	+24.98
Nam Chi	6,423	+12.73%	+21.27%	7,788	-10.24	+14.43
Nam Mun	18,645	+10.02%	+34.06%	21,232	-15.01	+15.39

Table 8: Impact of climate change on discharge of Mekong River's tributaries in Lao PDR and Thailand

The illustrations below show the summary result Impact of climate change on hydrological condition in tributaries of Mekong River in Lao PDR and Thailand.

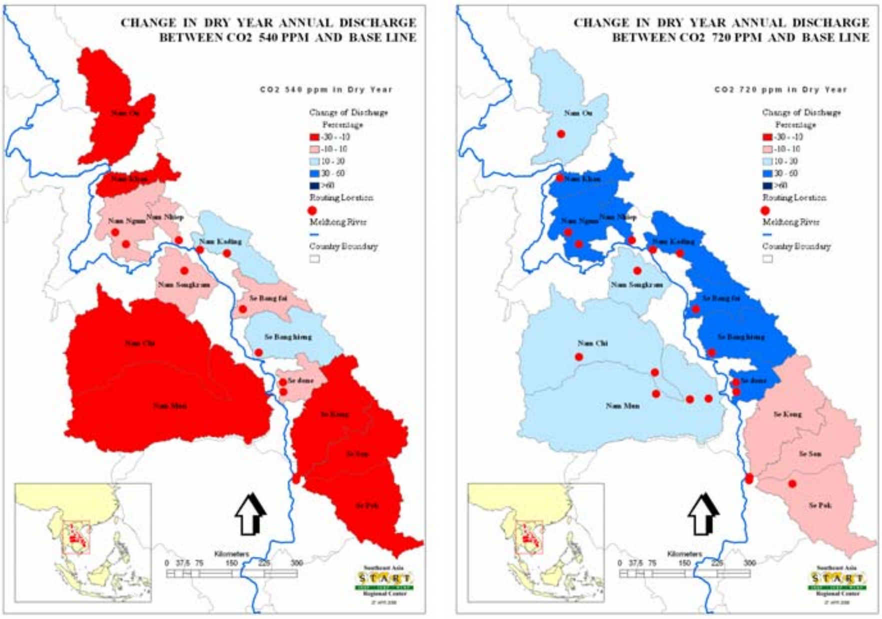


Figure 22: Change in discharge of Mekong River tributaries in Lao PDR and Thailand under dry year scenario of climate condition at CO2 concentration of 540ppm and 720ppm

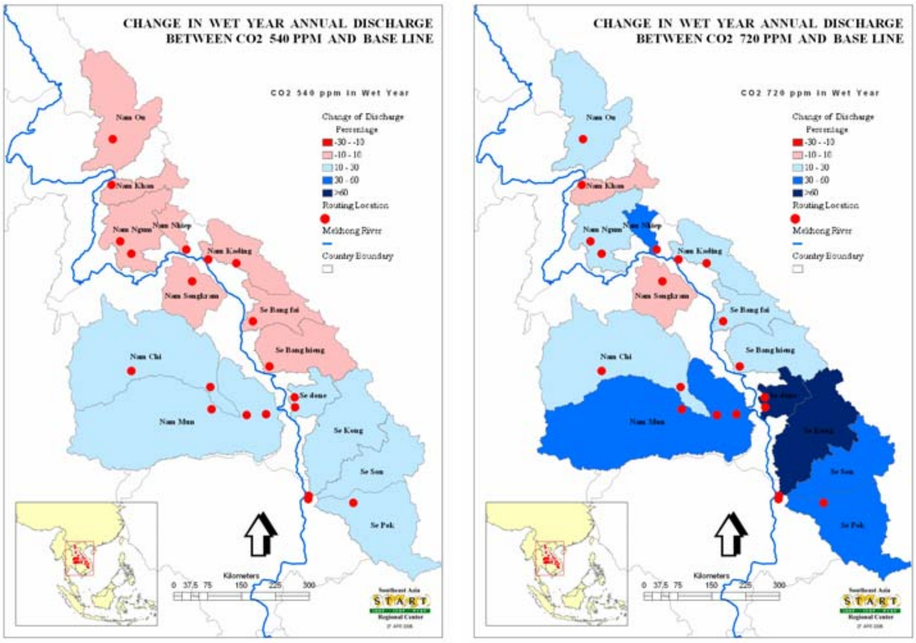


Figure 23: Change in discharge of Mekong River tributaries in Lao PDR and Thailand under wet year scenario of climate condition at CO2 concentration of 540ppm and 720ppm

5.2.3 Conclusion

The change in tributary's run-off is not in proportion of to the change in precipitation. Increasing in tributary's discharge is higher than the increasing of precipitation in the catchments. The increased discharge is excess water as the current water condition is sufficient to maintain the ecosystem of the watershed, e.g. evapotransporation of plant in the watershed, soil moisture, etc.

5.3 Study of impact of climate change on rain-fed rice productivity in lower Mekong River region

Change in climate pattern will affect agriculture system directly, especially the rain-fed system. This study focused the study of climate change impact on rain-fed rice cultivation as it is considered as the most important food crop of the Southeast Asia region with focus on 3 selected study sites in Lao PDR, Thailand and Viet Nam.

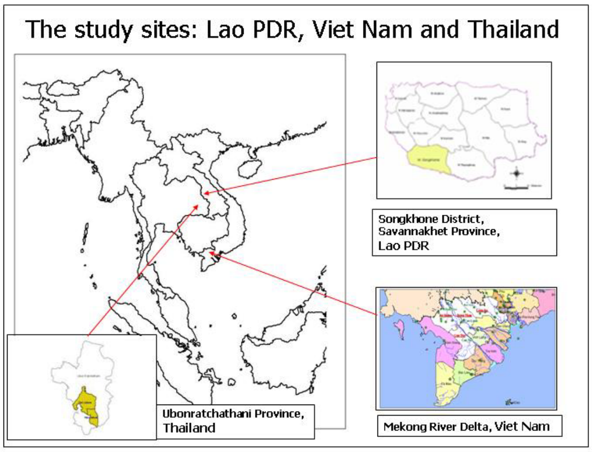


Figure 24: Selected study sites on impact of climate change on rain-fed rice productivity

5.3.1 Description of Scientific Methods and Data

This study analyzed the impact of climate change by using crop model to simulate potential future yield of rice productivity in the region under different climate scenarios. The crop model used is Decision Support System for Agro Technology Transfers (DSSAT version 4.0) crop modeling software (Hoogenboom et al, 1998) with daily climate data from climate scenario, which was generated by CCAM climate model, as input, which include maximum and minimum temperature, precipitation, solar radiation, etc. and coupled with crop management scheme and soil property to calculate the yield of rice productivity. By using daily climate data for the simulation process, this study is able to capture the impact of climate change on rain-fed rice production not only in terms of the change in degree of intensity of each climate parameter, e.g. increase or decrease in rainfall or temperature, but also change in temporal aspect too, e.g. shifting of the onset or changing on the length of rainy season or change in the pattern of mid-season dry spell period, etc.

The crop management scheme used in the simulation process was based on assumed homogeneous practice at each site to simplify the calculation process. Crop managements comprised of crop cultivars, planting field, initial condition of the field before planting, planting detail (method and plat density), water management, and both organic and inorganic fertilizer application.

5.3.2 Results: Impact of climate change on rice productivity in lower Mekong River basin

Farming systems in Lao PDR and Thailand are single crop cycle per year due to the length of the rainy season. Viet Nam farming system adopt dual crop as the rainy season is longer in the Mekong River delta area. The climate change from the CCAM climate model shows slight negative impact on the rain-fed rice productivity in Lao PDR. The simulated yield of rice productivity in Savannakhet province would reduce by 10% under climate condition at CO_2 concentration of 540 ppm but will increase back to almost baseline condition under the climate condition at CO_2 concentration of 720 ppm.

The simulation of rice productivity at the study site in Ubonratchathani province, Thailand, shows that climate change has positive impact on the rice production in the area. The simulation result shows trend of increasing yield of rice productivity under future climate condition. The increase in productivity yield could be as high as 10-15% in some areas.

In Viet Nam, the simulation result shows different climate impacts on yield of rice productivity in different crop cycle. The winter-spring crop may get slight positive impact, of which the productivity would slightly increase by approximately 3-5% under climate condition at CO_2 concentration of 540 ppm, however yield would drop by approximately 4-8% from baseline condition under climate condition at CO_2 concentration of 720 ppm. The summer-autumn crop tends to get severe impact from climate change, which the simulation result shows significant drop by approximately 8-12% under climate condition at CO_2 concentration of 540 ppm, and would sharply drop further by approximately 15% to almost 50% in some areas under climate condition at CO_2 concentration of 720 ppm. On average, the simulation result shows that yield of rice production in the Mekong River delta would drop by approximately 18% toward the end of this century (under climate condition at CO_2 concentration of 720 ppm, which according to SRES A1FI, will be around the end of the century).

The result from the simulation is shown in the table below:

Rice productivity under different climate scenarios

Remark: Rice productivity yield shown in kg/ha

Location	**Climate condition under different atmospheric CO_2 concentration**			**Change in % compare to baseline period**	
	360 ppm	**540 ppm**	**720 ppm**	**540ppm**	**720ppm**
Lao PDR - Savannakhet Province					
Songkhone District	2,534.90	2,303.20	2,470.10	-9.14	-2.56
Thailand - Ubonratchathani Province					
Zone 1	1,154.39	1,235.14	1,330.85	7.00	15.29
Zone 2	1,919.61	2,002.15	2,072.04	4.30	7.94
Zone 3	2,363.70	2,407.62	2,438.92	1.86	3.18
Zone 4	2,542.32	2,575.03	2,591.89	1.29	1.95
Zone 5	3,024.18	3,051.44	3,068.82	0.90	1.48
Viet Nam					
An Giang Province					
Winter-Spring crop	5,592.00	5,741.33	5,357.00	2.67	-4.20
Summer-Autumn crop	4,830.33	4,439.33	2,858.00	-8.09	-40.83
Can Tho Province					
Winter-Spring crop	5,799.67	5,971.00	5,361.33	2.95	-7.56
Summer-Autumn crop	6,778.67	6,783.33	5,627.00	0.07	-16.99
Dong Thap					
Winter-Spring crop	5,578.00	5,877.33	5,153.33	5.37	-7.61
Summer-Autumn crop	4,830.33	4,214.67	2,545.67	-12.75	-47.30
Long An Province					
Winter-Spring crop	5,601.33	5,855.00	5,128.67	4.53	-8.44
Summer-Autumn crop	6,646.67	6,535.00	5,301.67	-1.68	-20.24

Table 9: Simulated yield of rice productivity at the 3 study sites under different climate scenarios

5.3.3 Conclusion

Climate change will have both positive and negative to the rice cultivation in the region. However, the result from the simulation is still somewhat differ from the actual yield according to surveyed data from field interview, perhaps due to the assumptions made for crop management and accuracy of other dataset used for the simulation, particularly soil property. Anyhow, these figures may be used as indicator to show future trend of the climate change impact on rice productivity in the Southeast Asia region. However, another significant climate impact on rice production in the study areas is from extreme climate event, such as flood, drought and dry spell, etc, which may increase in terms of frequency and severity as impact of global warming. Based on farmer interview at the study sites, especially in Thailand and Lao PDR, the extreme climatic events may cause loss of rice productivity by average 30-50% from flood in moderate flood year.

Figure 25: Impact of extreme climate event on rice cultivation

5.4 Assessment on vulnerability and adaptation of rain-fed farmer in the lower Mekong River region to climate change

The rain-fed farmer in the lower Mekong River region could be among the most vulnerable group as their livelihood depends heavily on their annual on-farm productivity, particularly the rice cultivation, which is directly exposed to climate risk. In addition, household economic condition of these farmers is also considered to be in the poor group in the society, thus may cause them to have limited resource or other capacity to cope with impact of climate variability and change. Assessment of risk and vulnerability of the rain-fed farmer of the lower Mekong River region in this study was based on field interview to assess baseline livelihood condition and also baseline climate risk, which will be further used in the analysis on vulnerability to climate change impact.

5.4.1 Description of Scientific Methods and Data

The assessment on risk and vulnerability to impact of climate change was based on change in rice productivity under different climate scenarios, which was used as a proxy of stress from future climate change, and analyzes its effect on the household livelihood condition according to the following diagram.

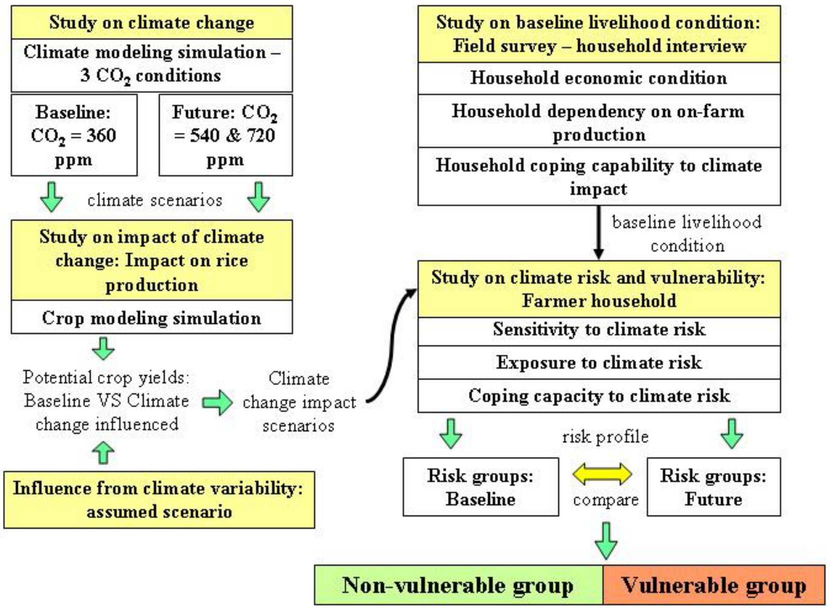


Figure 26: Framework on the assessment of risk and vulnerability of rain-fed farmer to impact of climate change

The main focus of this study covers 3 countries in lower Mekong River countries, the field survey to assess risk and vulnerability to climate impact of rain-fed farmer was focused in Lao PDR, Thailand and Viet Nam.

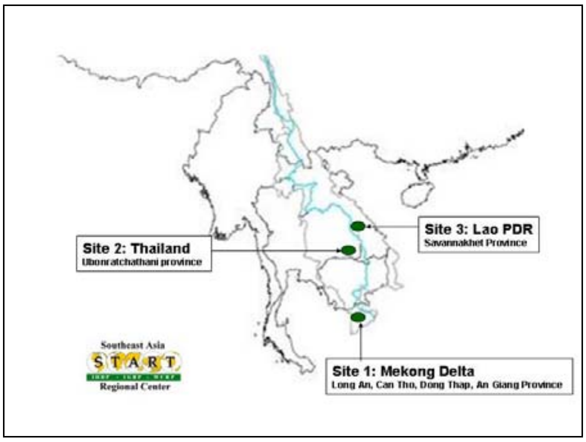


Figure 27: Selected sites on risk and vulnerability of rain-fed farmer to impact of climate change

The assessment in Viet Nam was conducted as pilot activity to test and fine tune the field interview and analysis method. The assessment in Thailand and Lao PDR was conducted to assess and compare risk and vulnerability of farmers in the society that has different socio-economic conditions, which can be indicated by the Gross National Income (GNI) figures of the two countries. In the year 2003, Lao PDR's GNI per capita was $380, while Thailand's GNI per capita was $2,550 in the same year (The World Bank). The field interview covered 560 farmer households in Thailand and 160 farmer households in Lao PDR. This report will focus on the result from the assessment in Lao PDR and Thailand.

Background of Study Site in Thailand: Ubonratchathani Province

Ubonratchathani province is located in the lower North-Eastern region of Thailand. The province covers area of 16,112km^2. Most of the land areas in Ubonratchathani province are highlands, about 68 meters above the sea level, with Mekong River as the border line between the province and People Republic Democracy of Laos, as well as high mountains as the border line between People Republic Democracy of Laos and Democratic Republic of Cambodia. However, the overall areas in Ubonratchathani province are highlands with slopes from eastern part, with mixed sandy soils of low fertility. Also, there is Chi River coming to merge with Mun River, before passing through Ubonratchathani province from the West to the East, and downing into Mekong River at Khong Chiam district. In 2001, Ubonratchathani maintained a total population of 1,779,098 persons, mostly are in the agriculture sector.

The study site is part of the Ubonratchathani Land Reform Area (ULRA), covers 55,000 ha of gently undulating farm land on the right (eastern) bank of the Dome Yai River. This area has three slope classes, namely; 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 in this area. These soils are almost well drained and strongly acidic.

Most of the area is cultivated for paddy, with some areas 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 1,600 mm, 90 percent of which fall in the period May to October. The average temperature is from a minimum of 17.0 °C in December and January to a maximum of 35.9 °C in the March and April. There is no source of irrigation, so cropping is a wet season activity.

The study site is divided into 5 zones as follows:

Zone	Characteristics of zone	Village selected
# 1	The area is deep sand. Cropping patterns are rice + 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 /upland crop (field crop) such as vegetable, 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. There is low tree density in the area.	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 area is an encroached forest.	1. Ban Pa Pok 2. Ban Sok Seang 3. Ban Non Deang

Table 10: Study site on risk and vulnerability assessment in Thailand - details background of the 5 zones of study

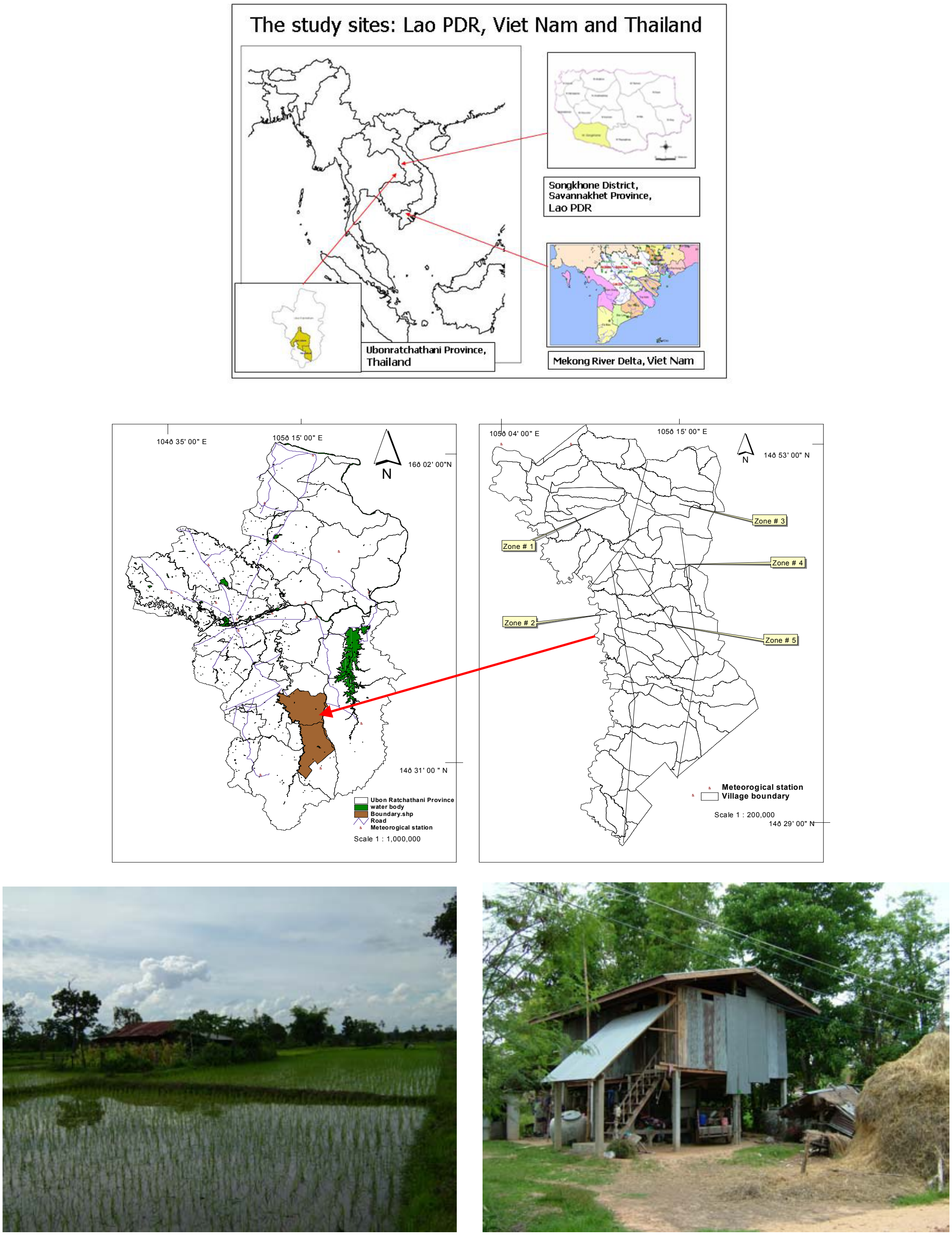


Figure 28: Study site on risk and vulnerability assessment in Thailand and details map of the 5 zones of study

Background of study site in Lao PDR: Savannakhet Province

Lao PDR locates in the center of the Southeast Asian peninsular, between lat. $13^0$54' to $22^0$03' North, and between long. $100^0$05' to $107^0$38' East, with total area of 236,800 km^2. The length from north to south is approximately 1,000 km, and the width from east to west is approximately 470 km.

Savannakhet province locates in the central to southern part of Lao PDR, having a total area of 21,774 km^2, consisting of 15 districts. The topography of Savannakhet province is low land and slope slightly from east to west to Mekong River. Savannakhet province has the largest area of rice fields in the country, 139,582 ha or 19% of total rice fields in Lao PDR (Committee for Planning and Cooperation, 2003). Total population of Savannakhet province is 811,400 people or approximately 15% of the country population, which is the highest populated province in the country and mostly is farmer.

Songkhone district locates in the southwest of Savannakhet province. It is the largest district in the province, with the total area of 1, 406 km^2. The district consists of 142 villages, and 13,919 households, which makes the total population of 86,855 people. Most of the population is farmer and grow rice mostly for own consumption with minor commercial on the excess production. The rice farming system is rain-fed rice farming with single crop cycle per year.

Four villages selected as study area namely, Seboungnuantay, Lahakhoke, Khouthee, and Dongkhamphou villages. The study site has total area of 1,851 ha with the population 2,490 people in 434 households.

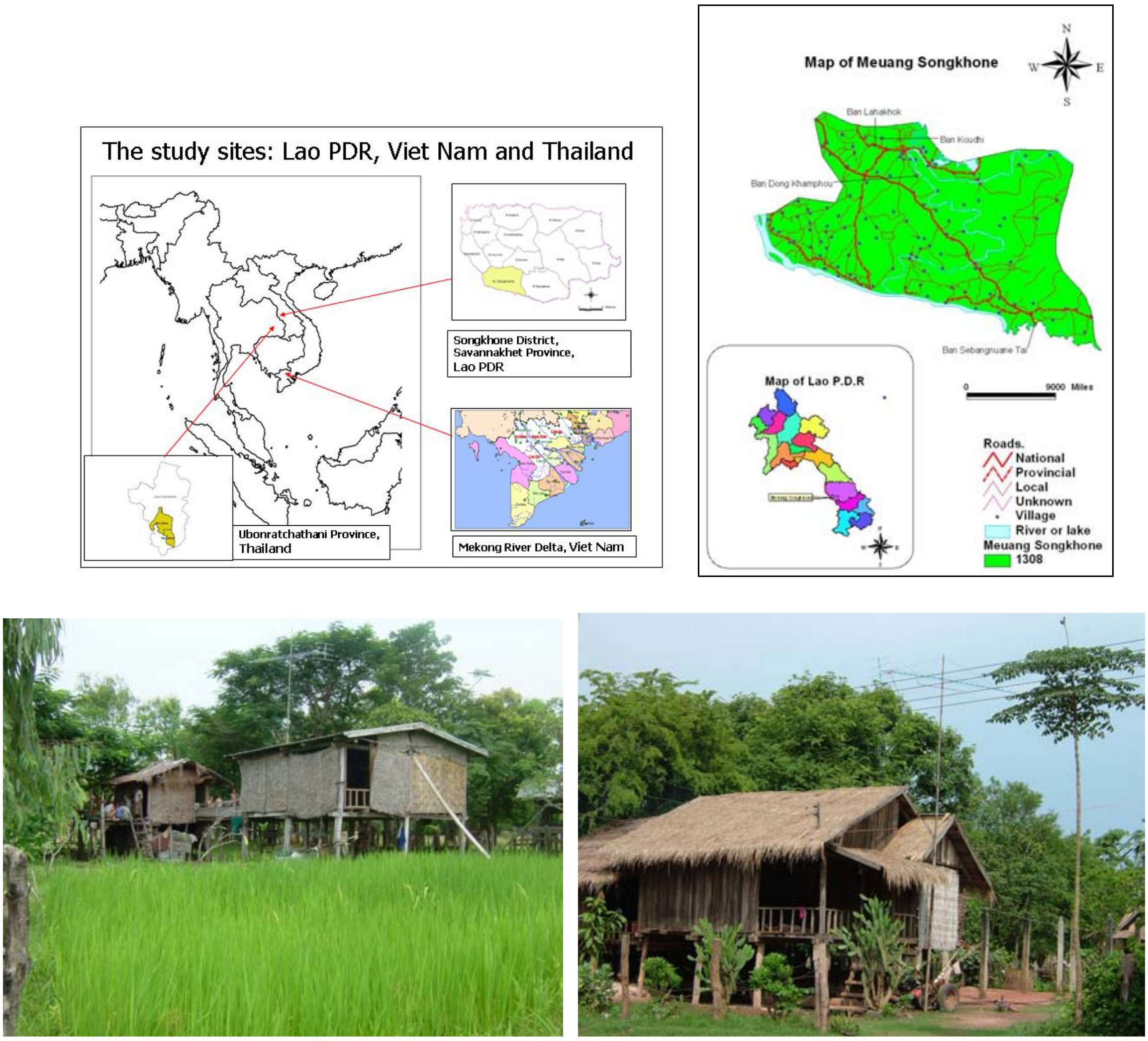


Figure 29: Study site on risk and vulnerability assessment in Lao PDR and details map that shows Songkhone district, Savannakhet province

The analysis on risk and vulnerability to climate impact in this study was based on multiple criteria and each criterion was assessed by using multiple indicators as the nature of risk and condition of livelihood is a complex issue beyond the capacity of any single indicator or criteria to describe. The three criteria selected for this study in the assessing farmer's risk to climate impact are as follows;

- Household economic condition, which was used to measure the sensitivity of the farmer household to climate impact.

- Dependency on on-farm production, which was used to measure the exposure of the farmer household to climate impact.
- Coping capacity of farmer to climate impact.

These criteria when combined together would indicate the degree of risk of rain-fed farmer to climate impact. The concept in evaluating risk profile and risk grouping as well as determining risk group is described in the diagram below;

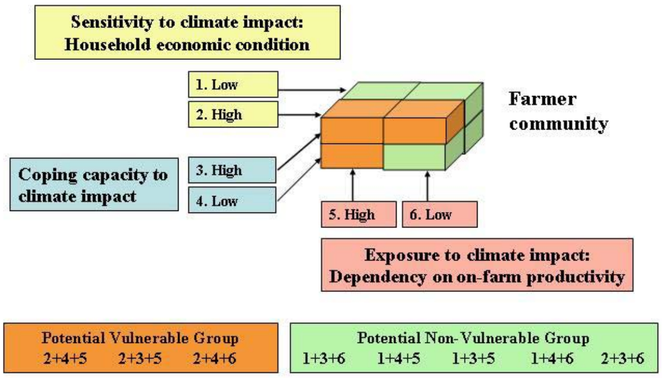


Figure 30: Conceptual framework on the analysis of risk and vulnerability of rain-fed farmers to climate change impact

According to this conceptual framework, the farmer households which may be at risk and has high potential to be vulnerable to impact of climate change / variability are those who are poor or have unstable or non-sustained household economic condition and highly rely on rice production to maintain their livelihood condition, in addition, they may also have limited coping capacity to cope with climate impact too.

In order to determine the risk profile of farmer household from these 3 criteria, a set of indicators was put up to evaluate the condition of each criterion as follow:

Criteria	**Indicator**	**Measurement**	**Scoring**	**Min score**	**Max score**
Household Economic condition	Household sustainability condition	Total household production (or total household income) / Total household consumption (or total household expenditure)	>1=0, 1-0.7=1, <0.7=2	0	2
	Household production resource condition (1)	Farmland own / rent	Own = 0, Rent = 1	0	1
	HH production resource condition (2)	Farmland/capita (ha) - use 0.8ha for Lao PDR and 0.65 for Thailand as threshold in analysis (size of farmland that can produce productivity to support 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	Ability to use non-climate sensitive income to support household livelihood	Total household consumption / Income from livestock + Fixed off-farm income	>1=0, 1-0.7=1, <0.7=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 household fixed expenditure) / Total household saving + Total off-farm income + Income from livestock + Extra income	<=1 = 0, >1-1.3 = 1, >1.3 = 2	0	2
			Sub-total	**0**	**4**
			Total		**12**

Table 11: Indicators used for evaluating farmer's risk to climate impact

This assessment took under consideration the contribution of rice production to the household's livelihood condition into the analysis. The information from household interview would be analyzed according to the table above and farmers would then be grouped together according to their risk scoring, which would be categorized into 3 groups:

- The household which risk score is between 0-4 is classified as low risk category.
- The household which risk score is between 5-8 is classified as moderate risk category.
- The household which risk score is between 9-12 is classified as high risk category.

In this study, change in rice productivity was used to represent climate stress that would affect the household economic condition as well as degree of household dependency on on-farm production to maintain livelihood condition, which would affect the household risk to climate impact at the end. In this study, the vulnerable household is defined as those whose risk score under climate change impact is changed from baseline condition.

The calculation of household risk to climate change impact was based on change in rice productivity of each household according to climate impact scenarios, which derived from the simulation and also coupled with influence of extreme climate event, which is based on farmer's opinion from the field interview that they have been experiencing crop damage by approximately 30%, in most cases from flood.

Changes in rice productivity under climate change impact				
	Climate condition under CO_2 concentration 540 ppm		**Climate condition under CO_2 concentration 720 ppm**	
	Normal condition	**Extreme climate event**	**Normal condition**	**Extreme climate event**
Lao PDR:				
Savannakhet Province				
Songkhone District	-9.14%	-39.14%	-2.56%	-32.56%
Thailand:				
Ubonratchathani Province				
Zone 1	7.00%	-23.00%	15.29%	-14.71%
Zone 2	4.30%	-25.70%	7.94%	-22.06%
Zone 3	1.86%	-28.14%	3.18%	-26.82%
Zone 4	1.29%	-28.71%	1.95%	-28.05%
Zone 5	0.90%	-29.10%	1.48%	-28.52%

Table 12: Scenario on change in rice productivity – proxy used for evaluating farmer's risk and vulnerability to impact of climate change

5.4.2 Result: Risk and vulnerability to climate impact of rain-fed farmer in lower Mekong River basin

Baseline risk of farmer to climate impact

From the assessment, the information from household survey was summarized and analyzed. The analysis shows that farmer in Lao PDR are highly resilience to climate impact as over 80% of the surveyed population is classified in the low risk group, while only less than 5% of the population is high risk to climate impact. However, on the contrary, surveyed farmers in Thailand are riskier to climate impact as about one-third of the surveyed population is classified as low risk and approximately 15%-25% are in the high risk category. The moderate risk group is the largest group of the surveyed farmers in Thailand, which in some study sites is as high as half of the total surveyed population.

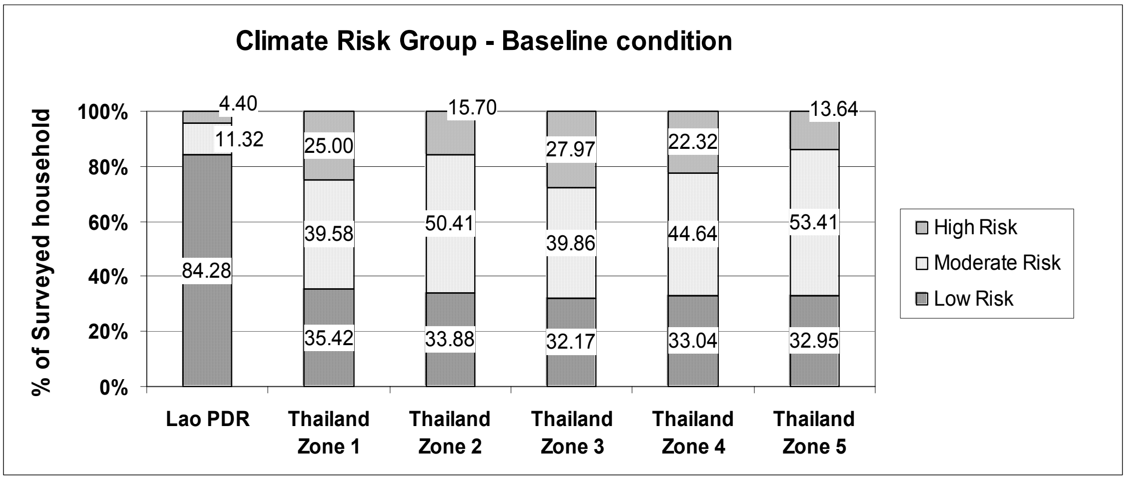


Figure 31: Structure of risk groups to climate impact in each study site – Baseline condition

From the assessment, the analysis shows that the low risk groups in every study site are highly resilience to climate impact and their risk profile is substantially differ from the moderate and high risk group. Their risk score is low in every criterion. In most cases, moderate and high risk group are riskier to climate impact because they lack of coping capacity and also expose to climate stress as the analysis result shows in the risk profile chart (see Figure 32), particularly the cases of the moderate and high risk groups in Thailand. On average, total risk score of the low risk groups in both Lao PDR and Thailand are approximately around 2 points, while the total risk score of the moderate and high risk group are around 7 and 10 points, respectively. The risk profile of each risk group in each location is shown in the chart below;

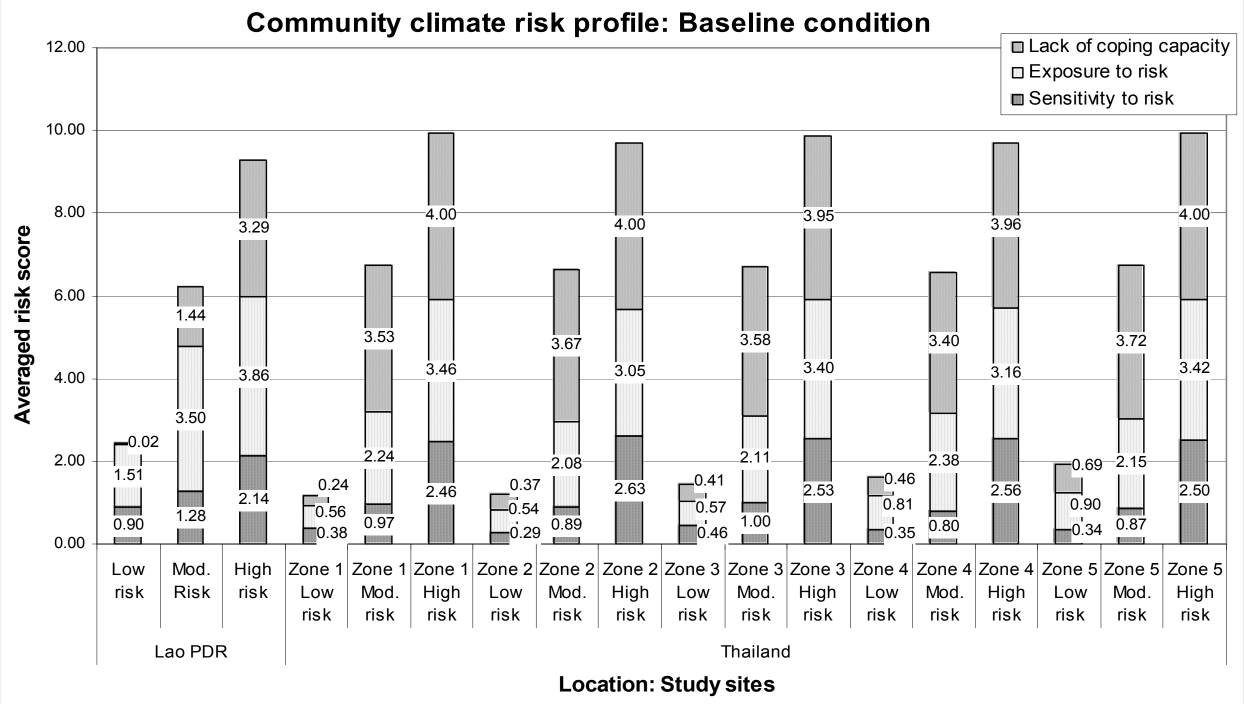


Figure 32: Profile of risk from climate impact each risk group at each study site

Majority of the rain-fed farmer in Lao PDR is in low risk category, they are considered to be able to maintain their livelihood condition well under climate impact, partly because their household productivity is diversified over various activities, both on-farm and off-farm sources. As per interviewing with farmer in the study site, the rice production does not dominate the household productivity. They also live in the rural area where the population is low and surrounded by intact natural ecosystems that can provide sufficient products for alternate source of food as well as excess products that can be converted to or exchanged for other products required for daily necessity and cash. They also have other savings in form of reserved rice and cash convertible livestock to help them cope with impact from climate threat, even though cash saving is almost non-exist. In addition, the debt level of the farmer in Lao PDR is also virtually none, partly due to the limited availability of source of loan or other institutional lending mechanism, as well as social norms that is against indebt (Boulidam, 2005).

From the field survey, the interviewed data revealed that the farmers in Thailand have very limited coping capacity, by having little saving and also high debt. They highly rely on income from rice production with little diversification. These conditions may cause them to be riskier to climate impact.

Farmer's risk and vulnerability to climate change: Climate condition under CO_2 concentration 540 ppm

By using changes in rice productivity, based on climate change impact scenarios as stated in Table 12, as proxy of climate change impact in the analysis and recalculating the risk scoring of each surveyed household, the analysis results shows that the profile of the risk groups has changed slightly.

Under impact of climate change, over 80% of surveyed farmers in Lao PDR still are under low risk category. Approximately 10% is in moderate risk and slightly over 5% is in high risk category. There is no substantial different between the situation under normal condition and also the condition with influence of extreme climate event.

In Thailand, there is no substantial change in the risk groups, which the moderate risk group is still the largest group in most cases, except in Zone 3 under influence of extreme event which the high risk group has become the largest group in the community. However, in case of the influence in extreme climate event, even though the low risk groups only slightly change in every zones, but there are noticeable changes in the moderate and high risk group, where there are number of household that move from moderate to high risk group.

The risk group to climate change in climate condition under CO_2 concentration of 540 ppm is shown in the chart below;

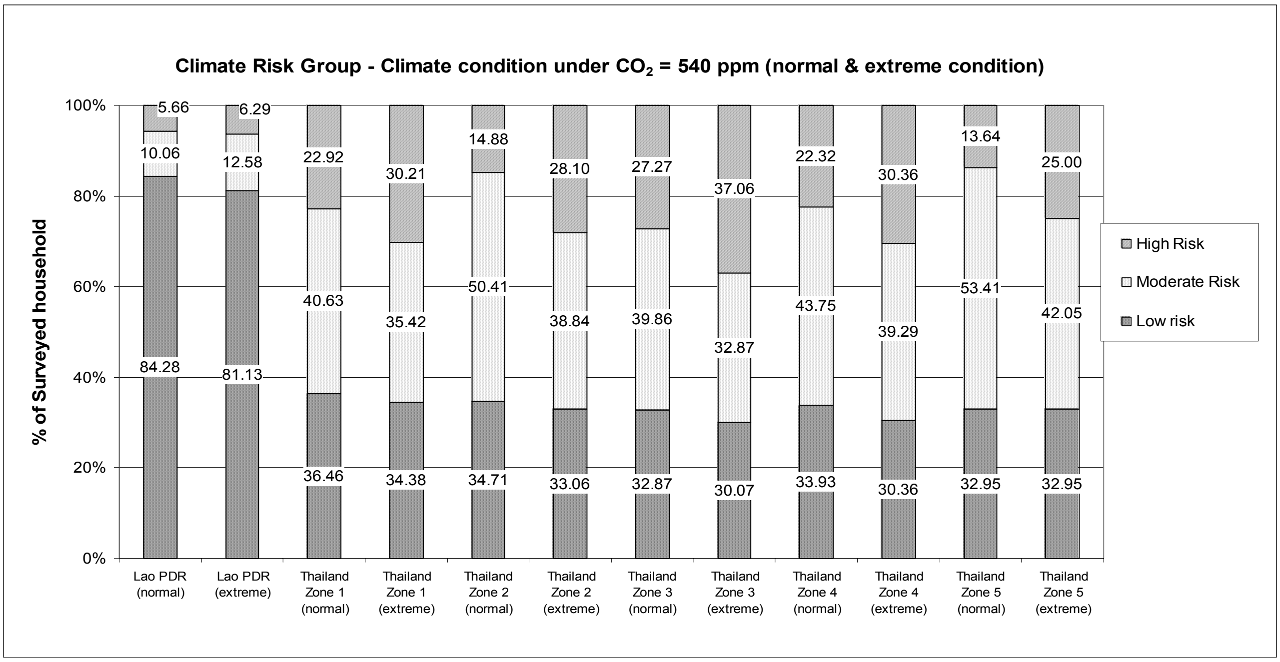


Figure 33: Structure of risk groups in each study site to impact of climate change – Climate condition at CO_2 = 540 ppm

When compare to the baseline condition, the impact of climate change under normal condition would cause almost one-fifth of the population in Lao PDR to be vulnerable and more than half of the population would be vulnerable under the influence of future extreme climate event coupled with climate change impact. However, in Thailand the impact of climate change is favorable to some households in the study sites and would make them to be less risky to climate impact, particularly in Zone 1. But the positive impact of climate change cannot cover the influence of extreme climate event, which causes large number of population, ranged from about 30% in Zone 1 to almost 50% in Zone 5, to be vulnerable.

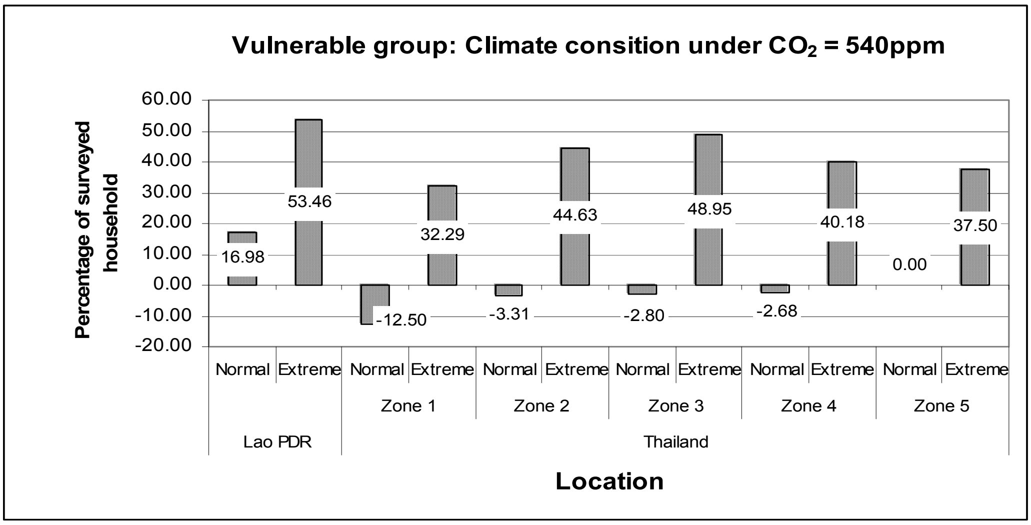


Figure 34: Vulnerable group from impact of climate change at each study site – Climate condition at CO_2 = 540 ppm

Farmer's risk and vulnerability to climate change: Climate condition under CO_2 concentration 720 ppm

Under impact of climate change in the climate condition at atmospheric CO_2 concentration of 720 ppm, the change in rice productivity cause only slight change to the structure of risk groups, when compare to the condition under climate condition at CO_2 concentration of 540 ppm, because climate change impact on rice productivity is slightly differ. The structure of risk groups in Lao PDR changed slightly and almost unchanged in case of study sites in Thailand when compare to the impact of climate change under climate condition at atmospheric CO_2 concentration of 540 ppm.

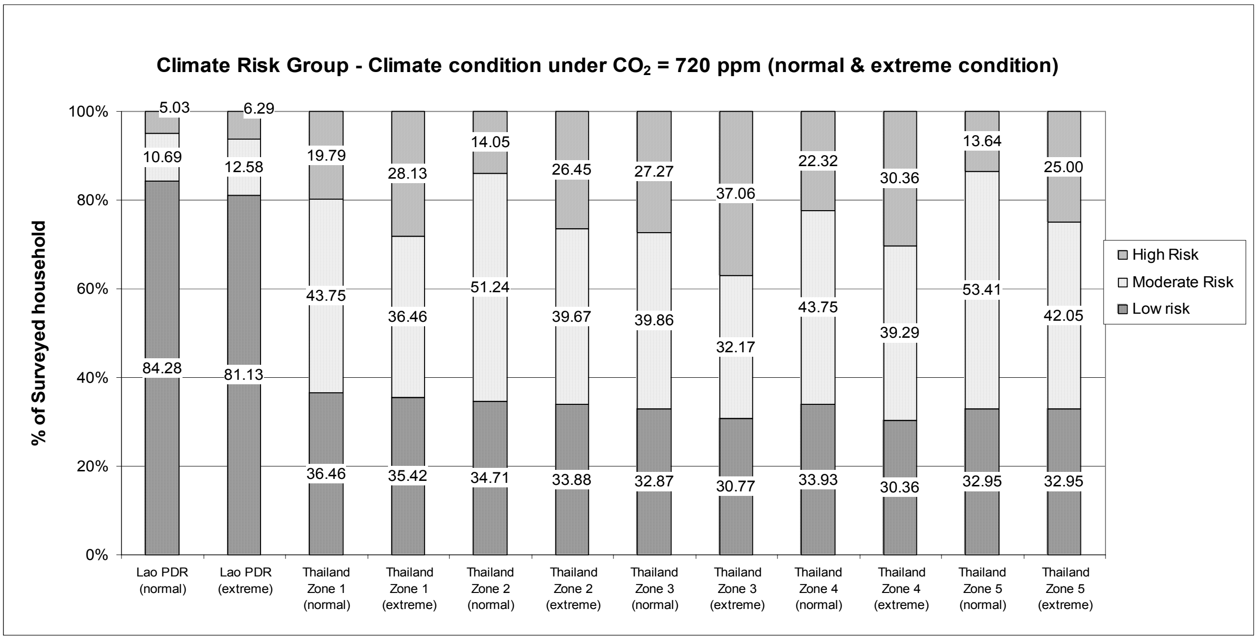


Figure 35: Structure of risk groups in each study site to impact of climate change – Climate condition at CO_2 = 720 ppm

Under impact of climate change at climate condition under CO_2 concentration of 720 ppm, less population in Lao PDR is vulnerable when compare to the climate condition under CO_2 concentration of 540 ppm. In Thailand, about one-fifth of the population in Zone 1 is less risky to climate impact and this is also the case for small number of population in other areas. In the case of influence from extreme climate event coupled with climate change impact, high numbers of population in most areas are vulnerable, where the worse case is in Lao PDR and the least vulnerable is Zone 1 in Thailand, as summarized in the chart below;

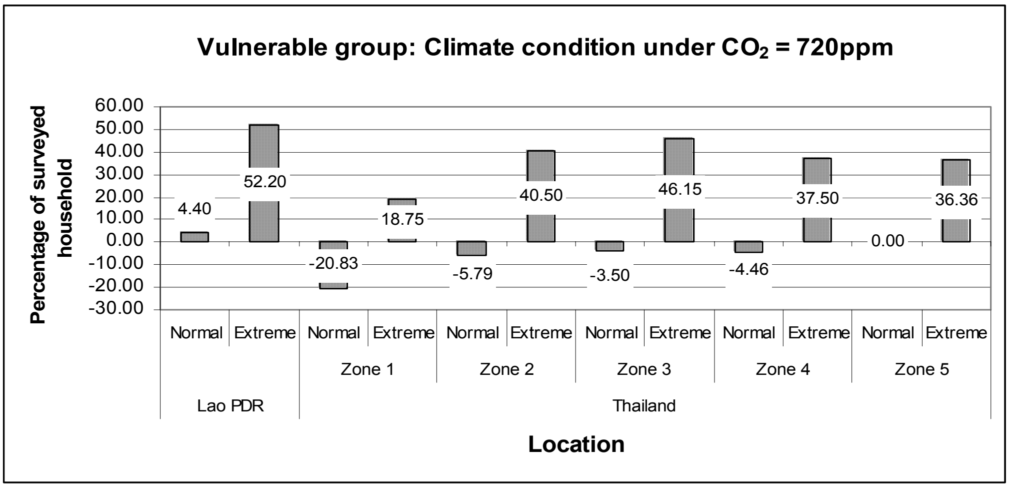


Figure 36: Vulnerable group from impact of climate change at each study site – Climate condition at CO_2 = 720 ppm

5.4.3 Conclusion

The analysis result in this research gives an overview picture of farmer's climate risk and how they would be vulnerable to the future climate change, as their rice productivity may be affected from changes in climate pattern by using quantitative approach on impact and risk analysis.

The analysis result shows that vulnerability is a place-based condition, which depends upon the degree of impact as well as socio-economic condition and physical condition of each location. The profile of risk to climate change impact would differ from community to community and climate risk seems to be more serious from the impact of climate variability in the future, which impact of climate change that is favorable to some locations may not be able to cover. The local context that contributes to the livelihood of the society is also key factor to the vulnerability condition of the household in the community to climate change impact. In addition, the vulnerable society may not be high risk to climate impact, at least under definition of this study.

This study is an effort in developing of quantitative approach for the vulnerability assessment process that also capture local context into the analysis, such as household expenditure that may vary from household to household and from community to community as well as from society to society. However, as this study is one of the pilot studies on the subject in this region, there still are many gaps in the process that need to be further improved for the future study activity. First of all, this study did not cover other non-climate stresses particularly the changes in socio-economic condition, which may have influence on farmer's livelihood. The future socio-economic condition, e.g. cost of living, inflation, market structure and market condition, national and regional development policy, etc., could be greatly differ from current situation, especially in the timescale of climate change study. These non-climate factors are important drivers that may have significant influence on the future vulnerability and risk of any social group in the society to climate change impact. Therefore, appropriate socio-economic change scenarios should be developed and also be used in the risk analysis along with the climate change impact scenarios. In addition, single proxy of climate stress as used in the analysis of risk and vulnerability to climate change may be insufficient. Secondly, this study also did not cover the analysis on the threshold of farmer's tolerance to climate impact, particularly in the categorizing of the risk groups. In addition, the accumulative impact to the household livelihood in the case of multi-year or consecutive year occurrence of extreme climate event should also be taken under consideration.

The issue of accumulated risk and vulnerability condition may be a serious matter, especially in the case of farmer in Thailand, whose coping capacity is low with limited resource to buffer the serious climate impact on their on-farm productivity until the next cropping season. In addition, most of the households also have debt, which in many cases the debt is even higher than the annual income. The impact from multi-year climate threat, especially the extreme climate event that may occur in consecutive years, may drive them into very serious difficult economic condition. The vulnerability of farmer may accumulate over the threshold; they not be able to repay their debt and end up in losing their most important production resource, which is their farmland, and finally be forced to change their way of life or social status from being independent farmer to be hired farm labor or permanently move away from the sector to work in other economic sector. Future study may include the annual household cash flow analysis over period of time under different scenarios in order to understand household financial condition which is the result of multi-year climate stress.

The focus on the understanding about vulnerability and adaptation to climate change of farmer in the lower Mekong region may need to be set on impact of climate variability over number of years, particularly the case of extreme climate anomaly that may increase in its frequency and magnitude in the future as result of climate change, especially in the case of serious extreme climate in consecutive years. This may help in the better understanding of how vulnerability could be accumulated and how farmer would be vulnerable to climate change.

6 Adaptation

Climate risks are not new to farmers of the lower Mekong. Important climate risks that are common to farmers of the region include mid-season dry spells that can damage young plants and late season floods just before harvest that can cause severe crop loss. Rice farmers' experiences with measures to manage climate risks, and their perspectives on the potential for applying the same measures to adapt to climate change, are investigated through interviews and focus group discussions conducted in selected farming villages in Lao PDR, Thailand and Vietnam. While the climate hazards are similar for rice farmers across the study areas, significant differences are found in the measures used to cope with climate risks in the different villages. These differences in risk management practice arise from local and national differences in social, cultural, economic, and environmental conditions and policies, and suggest that effective strategies for adapting to climate change need to be attuned to the specific context of a place and time.

Farmers of the lower Mekong River basin have been adapting to climate impacts throughout history and strategies for managing climate risks have evolved through time. However, it is difficult to separate adaptations made in response to climate pressures from actions taken in response to other forces emanating from demographic, social, economic, technological, environmental and other changes. In many cases, farm practices are a response to multiple risks from a variety of sources. Our study examines two types of actions: (i) actions that farmers consider to be mainly driven by climate risks and (ii) actions that are likely driven by other considerations but nevertheless improve the resilience of the farmer society with respect to climate stresses.

6.1 Activities Conducted: Assessment adaptation to climate change of rain-fed farmer in lower Mekong River basin

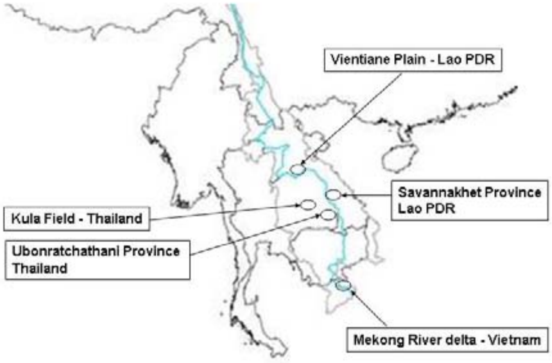


Figure 37: Study sites on the assessment of adaptation to impact of climate change in lower Mekong River basin

6.2 Description of Scientific Methods and Data

The assessment was based on field interview and group meeting with local stakeholders selected study sites, which are major rice farming areas in the region. The field interviews covered 290 households in Vientiane plain (May-June, 2005) and 160 households in Savannakhet province (September, 2004) in Lao PDR; 560 households in Ubonratchathani Province (June-July, 2004) and 625 households in Kula Field (April-May, 2005) in Thailand; 60 households and provincial officials in the Mekong River delta area (June-July, 2004) in Vietnam. In addition, group discussion was also conducted with community leaders in Vientiane Plain and Kula Field during 2005 to discuss and evaluate adaptation options, which was summarized from the household interview.

Figure 38: Household interview and group discussion on climate impact and adaptation strategy – farmer community in the study sites.

The collected data are mostly qualitative information and reflect the opinions and perspectives of the respondents. The interviews and discussions focused on the following topics:

- Observed changes in current climate pattern compared to the past (25-30 years or even longer).
- The major climate threats and impacts to their farming activity.
- Change in climate threat over the period of time, in terms of nature of threat, degree of impact, and the frequency of occurrence.
- Measures and strategies for coping with the climate risks in the past, which include actions at household level, community level and external actions from government.

- Potential measures and strategies for responding to possible future increases in the frequency or magnitude of extreme climatic events.

6.3 Results: Adaptation strategy of rain-fed farmer in lower Mekong River basin to climate impacts

Surveyed farmers identified numerous practices currently in use in their communities in Lao PDR, Thailand and that in their consideration lessen their vulnerability to present day climate variability and hazards. Some of the measures are motivated primarily by climate risks, while others are motivated by other concerns yet nonetheless reduce climate risks by increasing the resilience of farmers' livelihoods to multiple sources of stress. They include measures that are implemented at the individual farm-level (see Table 13), the community-level (see Table 14), and the national-level (see Table 15).

Table 13: Farm Level Measures for Managing Climate Risks

Measure	**Objective**	**Current Implementation**	**Effectiveness**	**Enabling and limiting factors**
On-farm measures				
Change seed variety - seasonal	Food security - to maintain an acceptable level of productivity under the seasonal climate pattern.	_Lao PDR:_ Common practice - local seed varieties acceptable for local consumption. Indigenous knowledge still used for seasonal forecasting. _Thailand:_ Limited - farming practice driven by market conditions; local seed varieties not widely accepted. _Vietnam:_ Moderate - short cycle seed variety also accepted by the market, but at lower price.	Moderate – only able to cope with certain level of climate variability e.g. moderate dry-spell or moderate flood.	• Precision of seasonal climate forecast • Market acceptance • Consumption preference
Change seed variety - permanent	To meet market requirements and increase resilience of farming to severe climatic condition.	_Lao PDR:_ Limited - not influenced by market conditions due to the market structure. Also limited implementation in breeding research. _Thailand:_ Common practice - in commercial farming. Possible to research ways to breed new varieties. _Vietnam:_ Common practice - commercial farming.	Moderate - further research required in breeding new rice varieties	• New breed availability • Market acceptance • Consumption preference
Multiple farmland locations	To balance risks from climatic impacts	_Lao PDR:_ Limited - depends upon geographical characteristics of the village _Thailand:_ Limited – depends upon land availability and geographical characteristics of the village _Vietnam:_ Limited - depends upon the geographical characteristics of the village	High – can balance risk, but low future potential	• Land availability • Population growth in the community • Geographical characteristics of the area
Adjusting planting technique & crop calendar to match climate pattern	To maintain an acceptable level of productivity under the seasonal climate pattern.	_Lao PDR:_ Common practice – use of indigenous knowledge and flexibility in seed variety selection. _Thailand:_ Moderate – change in seedling technique; inflexible crop calendar for some seed varieties dictated by the market _Vietnam:_ Moderate - long rainy season allows more flexibility in crop calendar and seed variety selection.	Low	• Precision of seasonal climate forecast • Flexibility of seed variety

Maintain appropriate farming conditions – e.g. small scale irrigation system / embankments in the farm land	To maintain an acceptable level of productivity under seasonal climatic stress.	*Lao PDR:* Limited - lack of resources. *Thailand:* Moderate - limited investment capacity *Vietnam:* Moderate - limited investment capacity	Low in Lao PDR due to lack of resources. Moderate to high in Thailand and Vietnam.	• Geographical conditions • Initial investment • Operating cost
Planting alternate crops in between rice crop seasons	Additional food supply / additional income	*Lao PDR:* Limited to moderate - depends on water availability and market conditions. *Thailand:* Limited to moderate - depends on water availability and market conditions. *Vietnam:* Limited to Moderate – 2 crop seasons for rice is the normal practice.	Moderate.	• Market • Farm land - size and condition • Water supply
Changing to more climate resistant crops	Household income security under climate stress.	*Lao PDR:* Limited - lack of know-how; based upon market conditions and dependence on rice cultivation for food security. *Thailand:* Limited to moderate - depends on resources available. *Vietnam:* Limited - dependence upon rice cultivation for national food security.	High – only applicable to certain farms but has potential.	• Soil condition. • Size of farm land • Know-how • Market conditions • Financial reserve • Local culture
Livestock	Secure household income under climate stress.	*Lao PDR:* Common practice – at a small scale (household level). *Thailand:* Common practice - at a small scale (household level). *Vietnam:* N.A.	High	• Capital • Farm land - size and condition
• **Off-farm measures**				
Harvest natural products	Additional food supply / additional income	*Lao PDR:* Common practice. *Thailand:* Limited - due to high population and ecosystem degradation. *Vietnam:* N.A.	High in Lao PDR. Moderate to low in Thailand and Vietnam.	• Productivity, diversity and condition of the natural ecosystem
Non-farm products e.g. handicraft	Additional income	*Lao PDR:* Limited – due to the existing market structure. *Thailand:* Moderate – depends upon market conditions.	Low to moderate in Lao PDR and Vietnam. Moderate in Thailand.	• Know-how • Market

		Vietnam: N.A.		
Seasonal migrating	Additional income	*Lao PDR:* Limited - due to existing urban economic conditions. *Thailand:* Common practice. *Vietnam:* N.A.	Low in Lao PDR and Vietnam. High in Thailand	• Capacity of other economic sectors / urban areas • Networks for job search
Permanent migration	Income security under conditions of climatic stress	*Lao PDR:* Limited - due to existing urban economic conditions. *Thailand:* Common practice. *Vietnam:* Limited.	Low in Lao PDR and Vietnam. High in Thailand	Capacity of other economic sectors / urban area

Table 14: Community Level Measures for Managing Climate Risks

Measure	**Objective**	**Current Implementation**	**Effectiveness**	**Enabling and limiting factors**
Shared resources - rice reserve / fish pond	Buffered food supply / additional income for community	*Lao PDR:* Common practice - partly due to culture and practice from war era. *Thailand:* Limited - competitive living conditions and repetitive crop failure. *Vietnam:* N.A.	High in Lao PDR. Low in Thailand and Vietnam.	Guaranteed replenishment (community rice reserve)
Village fund	Funding to assist reinvestment in farming / sustaining livelihoods	*Lao PDR:* Limited – has begun to expand and come under community management. *Thailand:* Common practice - under government management. *Vietnam:* N.A.	Moderate in Lao PDR and Thailand.	Guaranteed repayment by borrower
Co-operative network among villages - off-village farming practice	To obtain partial rice production to sustain livelihoods	*Lao PDR:* Moderate - depends on relationship between community leaders. *Thailand:* Limited - competitive living conditions. *Vietnam:* N.A.	Low to moderate in Lao PDR. Low in Thailand and Vietnam.	• Relationship between village leaders
Processing farming and / or natural products		*Lao PDR:* Limited. *Thailand:* Limited. *Vietnam:* N.A.	Moderate	• Know-how • Capital • Market

Table 15: National Level Measures for Managing Climate Risks

Measure	Objective	Current Implementation	Effectiveness	Enabling and limiting factors
Financial support infrastructure	Funding to assist reinvestment in farming / sustaining livelihood	*Lao PDR:* Limited – limited institutional arrangement and local cultural influence. *Thailand:* Common practice. *Vietnam:* Moderate.	Low in Lao PDR. Moderate in Vietnam. High in Thailand.	• Sufficient funding • Mechanism to reach and allocate available funds to the farmers in need • Terms and conditions of loan
Support in transition to a more diversified farming system	Sustained farming practice	*Lao PDR:* Limited - due to limited know-how and resources. Livelihoods also sustained by reliance on ecosystem products. *Thailand:* Limited – Expanding farming sector driven towards mono-cropping by the market. Vietnam: N.A.	Low in Lao PDR. Moderate in Thailand and Vietnam.	• Budget • Know how transfer
Support in transition to other plants	Sustained farming practice	*Lao PDR:* Limited - need for focus on rice farming to provide food security. *Thailand:* Moderate - but limited to small farmland owners. *Vietnam:* Limited - need for focus on rice farming for food security.	Low in Lao PDR and Vietnam. Moderate in Thailand.	• Budget • Know how transfer • Soil property
Support in marketing village products	Income diversification	*Lao PDR:* Limited - market structure. *Thailand:* Moderate *Vietnam:* N.A.	Low in Lao PDR and Vietnam. Moderate in Thailand.	• Appropriate marketing mix • Mechanism to develop a sustained market
R & D - new seed varieties	Sustain farming	*Lao PDR:* Moderate - need to develop know-how. *Thailand:* Common practice. *Vietnam:* Common practice.	Low in Lao PDR. Moderate in Thailand and Vietnam.	• Budget • Time • Technology
Infrastructure development - dams,	Sustain farming	*Lao PDR:* Limited - limited investment capacity.	Moderate	• Budget • Geographical conditions

other water diversion infrastructure, underground wells, irrigation network		*Thailand:* Moderate - also limited technical feasibility. *Vietnam:* N.A.		
Information for farming planning – e.g. seasonal or inter-annual climate prediction	Proper planning of farming activities.	*Lao PDR:* Nonexistent. *Thailand:* Limited. *Vietnam:* Limited.	Moderate	• Technology • Communication channel and format

While none of the measures are motivated by perceived needs to adapt to human-induced climate change, many measures that are focused on near-term climate risks could be developed further for longer-term climate change adaptation (Kates, 2001). Implementation and effectiveness of the measures in the different countries, some of the enabling and limiting factors that give rise to differences across the countries, and their potential as adaptations to climate change are examined below.

Managing climate risks in Vientiane Plain and Savannakhet, Lao PDR

Most farmers in Vientiane Plain and Savannakhet Province are subsistence farmers, producing rice mainly for their own consumption. They have farms of moderate but sufficient size for producing rice to support annual consumption of the farm household. They produce a single rice crop each year and their use of mechanized and advanced farm technology and institutional instruments are limited. The communities are still surrounded by intact natural ecosystems from which natural products can be harvested. This strengthens livelihoods by supplementing and diversifying the farm household's food and income sources. (Boulidam, 2005)

Farmers of the Lao PDR study sites tend to rely mostly on farm level measures for adapting to climate hazards and to a lesser degree on collective actions at the community level. Measures at the national level are very limited. Consequently, the capacity of the individual farm household to adapt is a key limiting factor at present for managing climate risks. Their responses to climate hazards aim mainly at basic household needs, primarily food security of the household. Common measures implemented by rice farmers include seasonal changes in seed variety, cultivation methods, and timing of farm management tasks based upon seasonal climate forecasts made with indigenous knowledge. Also common are raising livestock, and harvesting natural products for additional food and income.

The use of indigenous knowledge to make seasonal climate predictions is still popular. Indigenous knowledge based upon observations and interpretations of natural, e.g. the height of ant nests in trees, color of frogs' legs, color of lizard's tails, and various indicators of the dry season climate pattern, is used to make forecasts of the onset and cessation of the rainy season, quantity of rain and other climate parameters (Boulidam, 2005). The forecasts are used for seasonally adjusting choices of seed varieties and time and methods for soil preparation, seeding, planting, fertilizing, weeding, harvesting and other tasks (Grenier, 1998). Because farmers in Vientiane Plain and Savannakhet Province grow rice mainly for their own consumption and/or to sell the excess production to the local market for local consumption, they have flexibility to select the seed variety to match local climate conditions without regard for the requirements of the market. Changing seed varieties in accordance with indigenous seasonal climate predictions is considered to be moderately effective by the surveyed farmers, while adjusting the methods and timing of farming practices are considered to have low effectiveness due to the precision in seasonal climate forecast and other physical limitations. Performance of these measures for adapting to climate change potentially could be enhanced by implementation of an early warning system based on modern inter-annual and seasonal climate forecasting, coupled with risk communication techniques to reach the populations at risk. Constraints on this measure include the precision of seasonal climate forecasts, ability and institutional network to communicate the forecasts in ways that are useful to farmers, acceptance of the forecasts by farmers, availability of suitable seed varieties, and flexibility for changing the crop calendar for their cultivation.

There is less flexibility for farmers in the Lao PDR sites to change the rice variety on a semi-permanent basis to one that is more climates resilient or switching to an alternative crop. Constraints on these measures include lack of appropriate seed types, consumption preferences, national dependence on rice for food security, market conditions, lack of know how, lack of required financial reserves and other factors. Consequently these measures have limited current use. Where they have been used, these measures are considered by farmers to have moderate to high effectiveness for reducing vulnerability to climate and so are potential options for adapting to climate change. But the factors that constrain current use would need to be overcome. Growing a crop other than rice during the dry season is another moderately effective measure that is practiced to a limited or moderate degree and which can be an effective adaptation to climate change. But its use is restricted to where there is access to water and suitable markets.

The community still has an important role in the management of climate risks in the study areas of Lao PDR. For example, in case of severe loss of rice production, the village leader would establish a cooperative network with other villages with small scale irrigation systems. Shared water would be applied to shared farmland for cultivation of short cycle rice varieties during the dry season to supplement the community's food. In addition, shared resources, such as a community rice reserve contributed by households in the village, or a community fish pond, also act as buffers to climate hazards that sustain livelihoods and food security of the community. However, some of these collective actions are becoming obsolete, or will be in the near future, due to changes in socio-economic conditions. Forces that have reduced the role of community level actions include population growth and expansion in the use of credit from an established institution as an alternative to shared community resources for coping with crop losses.

National level measures to manage climate risks are reported by surveyed farmers to be limited in scope and scale to date in Lao PDR. National action on climate risks has been constrained by local culture, lack of institutional arrangements to address climate risks, and limited know-how, resources, and investment. Looking to the future, climate change is magnifying climate risks and increasing the amount of resources, technology and know-how that will be needed to manage the risks. Farmers have very limited capacity to adapt to the changes and the diminishing role of communities is widening the gap between needs and capacities for managing risks. Consideration should be given to measures at the national level that would enhance capacity and enable actions for managing and adapting to climate risks at the farm level and at the community level.

Managing climate risks in Kula Field and Ubonratchathani Province, Thailand

Rice farmers in Thailand, particularly in the study areas in the northeast, are mostly commercial farmers who live in a monetary oriented society and grow rice primarily for national and international markets. They have farms of moderate size on which they produce a single rice crop each year using mechanized and modern technologies and institutional instruments. The sale of rice is their main source of income which is used primarily to purchase household basic needs, including rice for consumption, which could be cheaper in price and of different quality and texture than the rice the farm household grows. Only a small portion of farmers with larger farms are able to divide their farmland to grow both commercial rice variety for sale and a local rice variety for their own consumption or sale in the local market. The farming communities are closely linked to urban society The surrounding land area is populated and used for settlements or is deteriorated natural forest that can provide only limited natural products as supplement or alternate source of food and income. (Kerdsuk, et al, 2005)

According to the field assessment, farmers at the study sites in Thailand tend to rely on household and national level measures for reducing climate risks, while the role of community level measures has declined or been neglected. The household level measures focus on income diversification, primarily from off-farm sources that are not as sensitive to climate variations as income from rice (Kerdsuk et al., 2005). The main practice is seasonal migration to work in the cities, which can lead to the permanent migration of some members of the family in order to secure fixed income for the household. Wage income from city employment is less sensitive to climate and helps to insulate the farm household from climate driven variations in farm income. Seasonal and permanent migration to diversify and supplement household incomes are more common in the Thai study sites than in Lao PDR and Vietnam and are made possible by close links between the rural villages an urban areas where there is demand for labor.

Unlike the studied communities in Lao PDR, where seasonal changes in rice variety and the crop calendar made in response to seasonal climate forecasts is common practice, these measures are little used by rice farmers in Kula Field and Ubonratchathani Province. Because they grow rice for national and international markets, they are limited in their ability to use local seed varieties, which fetch lower prices than commercial rice varieties, and to alter their crop calendar. In contrast, semi-permanent changes in seed variety to commercial varieties that are more resilient to climate stresses is common practice of farmers at the Thai study sites. This is made possible by the greater financial resources of commercial farming and by research and development programs that provide new rice varieties that are both accepted in the market and more resistant to stress. This option could be moderately effective for adapting to climate change. Limitations on wider use are financial, technological and environmental.

Other on-farm measures for reducing climate risk practiced by rice farmers in Thailand include changing seedling technique, using hired, growing alternate crops between rice seasons and raising livestock. Some farmers make investments to increase and sustain the productivity of their farms in ways that make them more resilient with respect to climate variations and changes. For example, they construct small scale irrigation systems to provide an alternate source of water for mid-season dry spells or for growing a crop during the dry season. They may also build embankments to protect their fields from flood damage. Such measures are more common than in Lao PDR. But greater use is limited by financial requirements for investment and maintenance. A small number of farmers with large land holdings implement mixed farming practice or switch part of their farmland from rice to a crop that is more resistant to climate stresses. Harvesting of natural products from forests, a common practice in Lao PDR, is limited at the study sites in Thailand because of high population densities and the degraded nature of forests that are adjacent to farm lands.

National level policies and measures that serve to reduce vulnerability to climate hazards are more prevalent in Thailand than in Lao PDR and Vietnam. These policies and measures were not motivated by concerns about climate stress, especially climate change, but mainly by poverty reduction goals. Yet, national measures in Thailand have supported financial needs, infrastructure development, transitions to more diversified farming systems, marketing of local farm products, and farm planning that have helped to improve livelihoods of farmers and increase their resilience to climatic stresses. For example, an initiative of the Ministry of Agriculture and Cooperative in 2004 (Department of Livestock Development) diversifies farming activity by promoting and supporting farmers to raise livestock. Another initiative promotes transition from rice cultivation to other plantation crops that are more resistant to climate stresses such as rubber trees. Research and development by government research facilities have provided new varieties of rice that are more resilient to climate variations while maintaining the quality that is required by the market.

Community level measures are not common in Kula Field and Ubonratchathani Province, with the exception of village funds for local investments to support farm livelihoods, which are managed by the government. The role of community or local administration units for planning as well as implementing future adaptation to climate change in cooperation with the national agency could be promoted as local institutions can better address local needs and be more flexible and timely in implementation.

Managing climate risks in Mekong River Delta, Vietnam

Rice farmers of the Mekong River delta in Vietnam are mainly commercial farmers. They are able to grow two rice crops each year due to a longer rainy season, can sustain annual consumption, make moderate use of modern farm technology and use institutional instruments in farming practice. The household relies heavily on income from rice production. The farm communities are surrounded by populated areas and are not tightly tied to the urban economic system. (Field interview in Long An, Can Tho, Dong Thap and An Giang Provinces, Vietnam, 2004).

The rain-fed rice farmer in Vietnam tends to rely on measures implemented at the household level and aimed mainly toward on-farm actions to protect against climate hazards. Community and national level measures play very limited role in reducing their climate risks. The farm-level solutions include efforts and investments to increase and sustain the productivity of their farms such as construction and maintenance of small scale irrigation systems or embankments to protect their farmland from flood. But investment costs and limited financial capacity of farmers limit wider use of these measures. Using an alternative strategy, some farmers in the study sites have adapted to flood by accepting floods as part of the ecosystems of their farmland, adjusting their the crop calendar accordingly and allowing their lands to be flooded, thereby gaining advantages from nutrients being deposited that enhance soil fertility and pollutants being washed from their farmland. In addition, use of alternate crops and seed varieties are also common adaptation measures of the farmer in the Mekong River delta in Vietnam.

Changing the variety of rice grown, both seasonally in responses to climate forecasts and semi-permanently, is practiced by Vietnamese farmers, even though they are commercial farmers and grow rice to match market demand. Because the rainy season in the Mekong River delta is usually 7 months long, two crop cycles of rain-fed rice can be grown in one year. A two-crop cycle is also facilitated by the availability of short-cycle rice varieties that are suitable for growing in Vietnam and that are accepted by the market. This gives additional flexibility to farmers in Vietnam to select varieties of rice so as to balance the risk of losses from climate events against expected market returns according to farmers' preferences regarding risk. Consequently, seasonal change of rice variety is more commonly observed among rice farmers in Vietnam than in Thailand.

Community level measures at the study sites in Vietnam are very limited and have low effectiveness. Some measures are implemented on a national level in Vietnam that is considered by farmers to be moderately effective. National research and development programs have facilitated changes in rice varieties by farmers that lessen vulnerability to climate extremes. Also being implemented but on limited scale are national support for transition to alternative crops and provision of climate forecast information to farmers to assist with farm planning efforts.

Many measures for managing climate risks are common to all the study sites, at least in general characteristics. But, as shown above, there are substantial differences across the study sites in the degree to which the farmers' rely on farm-level, community-level and national-level actions, farm households' objectives, the status of enabling and limiting factors, and the prevalence and effectiveness of different measures. These differences are apparent despite our focus on farmers who all make their livelihood primarily from growing rain-fed rice in a common river basin of Southeast Asia and who are exposed to similar climate hazards. The differences demonstrate the strong influence exerted by the local context on climate risk management. The measures that are used and their effectiveness are place and time specific.

Still, some commonalities do emerge from the experiences of farmers across the study sites. We summarize some of the commonalities and differences below. In interpreting the findings, it should be borne in mind that the exploratory assessment surveyed farmers at only two sites in Lao PDR and Thailand and only one site in Vietnam. While for convenience of exposition, we write of farmers in Lao PDR, Thailand or Vietnam, it would be misleading to extrapolate from farmers at the selected sites to characterize the condition and practices of farmers nationwide in any of the three countries. Differences in local context within a country can yield different risk management approaches and performance across communities of the country, just as they do in our comparisons of study sites from different countries.

At all of the study sites, farmers rely primarily upon their own capacity for implementing farm-level measures. But the context for farm-level action is shaped by what is done at community and national levels. Community-level measures are most prevalent in the farm communities of Vientiane Plain and Savannakhet Province in Lao PDR, where they play an important role in providing food security buffers and strengthening livelihoods. Farmers from the study sites in Thailand and Vietnam report that community-level measures are used only to a limited degree and are much diminished relative to the past. This too is the trend in Lao PDR sites. The diminishing role of collective action at the community-level may be an important deficit in the capacity of these communities to adapt to future climate change.

Our evaluation of national-level measures are based on the perspectives reported by farmers and community leaders at the study sites and do not reflect a comprehensive evaluation of national policies and programs that are related to climate risks. But this is an important perspective as it gives a sense of what is happening on the ground, at least in the communities surveyed. In none of the three countries can the national-level measures of which farmers are aware be described as constituting a national strategy for managing climate risks. The actions are not coordinated and typically are not designed specifically to combat climate risks.

Still, national-level measures in Thailand, as perceived and reported by farmers in the Thai communities of Kula Field and Ubonratchathani Province, are greater than what is reported by farmers surveyed in the other two countries and are an important complement to farm-level measures there. National level actions in Thailand provide financial and other support for investments in farming infrastructure, expansion of farming technologies, including climate resilient varieties of rice and other crops, sustainable farming practices, and diversified farm incomes. These efforts help to strengthen farm livelihoods and make them more resilient to climate and other shocks. In Vietnam, the national government supports research and development of seed varieties and provides financial support for investment in farm sector infrastructure, but other measures by the national government are reported by farmers to be limited. National-level measures are the least prevalent in Lao PDR and do not presently play a strong role in making farm households in the study sites climate resilient.

Farmers' objectives, priorities and capacities for using farm-level risk management measures vary across the study sites, and this influences their choice of measures. At the Lao PDR sites, most farmers practice subsistence agriculture and depend primarily on their own rice production for their food supply. Their choice of rice variety to cultivate need only satisfy their own preferences and are not constrained by market requirements. They have access to healthy forests, from which they can harvest products to supplement their food supply but have little opportunity for earning monetary income and have low financial reserves and other assets. Consequently, their choices emphasize providing and protecting basic household needs, most particularly household food security, and employ strategies that have little financial cost and rely on household labor, indigenous knowledge, and use of natural products.

Rice farmers in Kula Field and Ubonratchathani Province in Thailand are very much oriented to the market economy. They grow rice for cash income and have opportunities to participate in nearby urban labor markets. Their participation in commercial activities provides them with important financial resources and capacity, but their income can be volatile due to climate and market events and market requirements for commercial rice can limit options for changes in rice cultivation. Consequently, their choices emphasize diversifying household income, particularly from off-farm labor, adoption of rice varieties that are more climate resilient and thus less variable in the income they provide, and investments such as small scale irrigation and flood control that improve the productivity and resilience of their farmland.

In the Mekong River delta of Vietnam, farmers grow rice commercially but have little opportunity to participate in urban labor markets and so are highly dependent upon the cash income from sale of their rice. They have some financial resources and benefit from a longer rainy season than occurs at the Thai and Lao PDR sites that allows them to grow two rice crops each year. The availability of short-cycle rice varieties that are suitable for growing on their farms and are accepted by the market also gives them greater flexibility to vary their rice cultivar and crop calendar if the season is expected to be unusually short or dry. Choices of the surveyed Vietnamese farmers emphasize varying cultivation practices to reduce the risk of damage or loss to the rice crop and investments to improve the productivity and resilience of their farms.

The adaptation strategy tends to link closely to the socio-economic condition of each country. In Thailand, where the urban economy provides opportunity for large number of labor force, transportation is easily accessible, lack of natural ecosystem to rely on for food security as well as to provide products to substitute the loss of income; has led the vulnerable farmer to take the option to do seasonal migration to the city as the most popular choice. However, in case of Lao PDR, farmer tends to fall back on natural eco-system to sustain their livelihood. This also due to the urban economy is smaller size, in addition, the natural ecosystem is still very much intact and population density is low, therefore, they can harvest natural product to compensate the lost of household income and also to use the harvested product as supplement source of food too. The Viet Nam framer tends to develop on-farm adaptation, e.g. adjusting farming technique, to cope with impact from climate on their rice production.

6.4 Conclusion

Farmers of the lower Mekong River basin are exposed to a variety of climate hazards that threaten their livelihoods, food security and wellbeing. Those who cultivate rain-fed rice as a primary source of food or income are particularly vulnerable to climate variations such as prolonged dry spells during the growing season and flooding at the end of the season prior to harvest, events that are common in the current climate. Human induced climate change is expected to bring greater and possibly more intense rainfall to the region, which would increase flood risks to farmers.

Rice farmers are experienced in managing climate risks and employ a variety of measures to reduce their vulnerability that are highly place and time specific. The measures used differ according to the specific climate hazards faced, physical and environmental constraints, available technologies, social and economic condition of the farm household and community, vitality of community institutions, degree of engagement in the market economy, market conditions, and the priorities and objectives of the farm households. Results from surveys of farmers in selected communities of Lao PDR, Thailand and Vietnam suggest a pattern that is shaped by the socio-economic condition of their surrounding community. Farmers in communities with less developed socio-economic conditions tends to pursue simple strategies targeted at increasing coping capacity and sustaining basic needs that can be implemented at the household or community level with limited financial and other resources. Farmers in communities with more developed socio-economic conditions tend to pursue strategies targeted at reducing the variability of income and at improving the productivity and resilience of their farms. The measures that they adopt tend to depend more on market and other institutions, improved technologies and financial resources than is the case for farmers in less developed communities.

The measures that are in use in the surveyed communities address current climate risks. They are not deliberate attempts to adapt to climate change. But they provide a basis of experience, knowledge and skills upon which to build a climate change adaptation strategy. They also demonstrate a history in the region of farmers acting effectively, within their constraints, in their self-interest to reduce their vulnerability to climate hazards. Despite these efforts, farmers in the region, particularly those who rely on rain-fed crops, are still strongly impacted by prolonged dry spells, floods and other climate events. They are highly vulnerable to climate hazards now and so can be expected to be highly vulnerable to climate change in the future.

Their vulnerability is partly due to lack of capacity of farm households, lack of capacity of rural communities and lack of coordinated national strategies to support farmers and their communities to manage climate risks. An effective starting point for a national strategy of climate change adaptation would be to integrate into farm, rural development and poverty reduction policies the objectives of raising the capacities of farm households and rural communities to manage present climate risks. Some national policies in the region already do this to a limited extent, though not with the explicit intent to do so.

Farm households need help with financial resources, opportunities for off-farm income, marketing of farm products, access to water and healthy ecosystems, information about current and changing climate hazards, know-how to diversify their farming practices and to apply new farming methods and technologies, and access to improved varieties of rice and other crops. They also need buffers to protect their food security, health and livelihoods when they suffer severe crop or financial loss. Delivering this assistance to bolster the capacity of farm households requires community level institutions with vitality and high capacity. Community institutions can also play a role in coordinating collective actions that require pooled resources to implement. Sadly, community level institutions in the surveyed communities are in decline and some community-level measures are becoming obsolete. A reversal of this trend will be important for maintaining existing capacity and raising capacity to the levels that will be needed to address the challenges of climate change.

While not addressed directly in the study, coordinated regional action by the countries of the lower Mekong River basin should also be considered. The countries share a common resource, the Mekong River. Climate change will alter water availability, water quality, flood risks, and the performance and sustainability of river dependent livelihood systems throughout the basin. The actions taken within any of the countries to adapt to these changes are also likely to have trans-boundary effects.

In this context, the countries of the lower Mekong River region should explore the potential for trans-boundary effects of their actions, options for reducing negative trans-boundary effects, and options for collective actions that may yield positive trans-boundary effects.

7 Capacity Building Outcomes and Remaining Needs

The research activity under this AIACC regional study, which also coupled with capacity building program under Asia-Pacific Network for Global Change Research (APN), had involved number of researchers and research assistants into the study under various steps and different disciplines in this integrate study. The workshop and training as well as hand-on exercise on research activity under this regional study had increased their abilities in climate change study, both on the natural science discipline as well as social science discipline.

The major capacity building outcome on research capacity consist of over 20 researchers, who had actively involved in the study, and network among the institutes in the 3 countries in the Southeast Asia region, as well as network with other research institutes outside the region, which had interaction through activities in the AIACC. The names of institutions that had been actively involved in the regional study are as follows:

- Chulalongkorn University, Thailand
- Chiang Mai University, Thailand
- Mahidol University, Thailand
- Khon Kaen University, Thailand
- Ubonratchathani University, Thailand
- Meteorological Department, Ministry of Science, Thailand
- Department of Agriculture, Ministry of Agriculture, Thailand
- Land Development Department, Ministry of Agriculture, Thailand
- National University of Laos, Lao PDR
- National Agriculture and Forestry Research Institute, Ministry of Agriculture, Lao PDR
- Environmental Research Institute, Science Technology and Environment Agency, Lao PDR
- Water Resource Coordinating Committee, Office of the Prime Minister, Lao PDR
- Sub-institute of Hydrometeorology of South Vietnam, Vietnam
- Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia

In addition to the researchers and research assistants, there were 2 graduate students who had been directly involved and developed their thesis under this regional study.

- Mrs.Somkhith Boulidam, lecturer from National University of Laos, Lao PDR MSc. (Natural Resource Management), Mahidol University, Thailand. Thesis title: *Vulnerability and Adaptation of Rain-fed Farmers to Impact of Climate Variability in Lahakhok, Sebangnuane, Tau, Dongkhamphou and Koudhi Villages of Songkhone District, Savannakhet Province, Lao PDR.*
- Mr.Somvang Bouttavong, Water Resource Coordinating Committee from Lao PDR. MSc. (Natural Resource Management), Mahidol University, Thailand. Thesis title *Application of Climate Change Scenarios in Studying the Effect of Climate Change on Crop Water Requirement and Water Balance in a Reservoir: A Case Study of the Planned Nam Nga Gnai Reservoir Project, Sanakham District, Vientiane Province, Lao PDR.*

Remaining needs includes improved tools and data which are vital and be fundamental for future study in climate change. Among various tools and data needed are high resolution climate scenarios. Local ability need to be developed to run climate model at high resolution, with ability to fine tune the simulation to match specific requirement of impact analysis in each area of study. This may include multiple climate models, particularly those that can execute on low cost computing facilities, e.g. PC or cluster of PC, and also global dataset under different scenarios. In addition to the tools and dataset, know-how transfer in form of training and/or consultancy to local researcher is also required, at least in the initial stage.

The study on climate change and its impact as well as vulnerability and adaptation still need to be conducted on many other systems and sectors in many other aspects to produce information that can support policy making. In order to do this, institution capacity as well as researchers still needs to be further developed and expanded. This also include needs for regular forum to exchange idea, new finding, initiative on new collaboration, which would not be limited only on academic community but also to include government agencies, public organization, NGO, press, etc. in order to raise higher awareness on climate change issues that may lead to further policy initiation and implementation, especially the trans-boundary issues and/or regional collaboration in collective adaptation to climate change.

8 National Communications, Science-Policy Linkages and Stakeholder Engagement

The next Second National Communications to UNFCCC would emphasize substantially more on the impacts of climate change on natural system and human society than its first generation, yet expertise and know-how to assess and formulate adaptive strategy in systematic ways are still much lacking in the Mekong River countries. The activities under this research had helped in develop research capacity of both personnel as well as network among institutions in Lao PDR, Thailand and Viet Nam to be able to assist or responsible in the preparation of the next National Communication to UNFCCC.

In addition, the result from the activities under this research, which includes tool, data, methodology, analysis summary, etc., such as model and dataset, high resolution regional climate scenario, analysis on impact of climate change on hydrological regime and crop productivity, etc., would be summarized and disseminated to relevant policy makers as well as other stakeholders in the Southeast Asia region for further study in wider scale as well as be used in future policy consideration.

However, as the preparation of second National Communications to UNFCCC has not yet started in the countries where this regional study had involved in the study, so the issue on future contribution from this research to the National Communications to UNFCCC is yet to be followed up.

As far as the science-policy linkage is concerned, the principle investigator of this research, Dr.Anond Snidvongs, was appointed a member of National Climate Change Committee of Thailand and the associate investigator, Mr.Suppakorn Chinvanno, was also appointed a member of working group in developing national climate change strategy for Thailand.

9 Outputs of the project

This regional study had produced tools, dataset and publications (even though, not published in peer reviewed publication, but could be useful for the region). These outputs are available for academic and non-profit used. The website is still under construction, but they also can be requested at:

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Thailand
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suppakorn@start.or.th

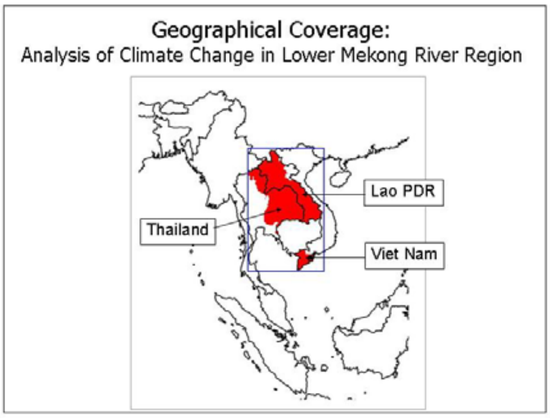
Tools

- Crop modeling tool – MRB rice shell.
  This is a tool to help in analyzing climate impact on rice productivity yield in the lower Mekong River basin.

Database

- High resolution future climate scenarios:
  Final output domain: 5-35 Degree N and 92 -110 Degree E
  Output resolution was interpolated to 0.1 degree (about 10 km)
  Temporal timestep for output: Daily
  Daily output variables:
    - Tmax, min and avg T (ºC)
    - Rainfall (mm/d)
    - Wind speed (m/s)
    - Radiation (W/m2)

However, the adjusted climate scenario is available as per illustration below:



- Hydrological regime of lower Mekong river

  Simulated discharge of major sub-basin of the tributaries in Lao PDR and Thailand under different climate scenarios.

Publications

- Proceeding: The APN CAPaBLE CB-01 Synthesis Workshop, Vientiane, Lao PDR – 29-30 July 2004. The Study of Future Climate Change impact on Water Resource and Rain-fed Agriculture Production – Case study in Lao PDR and Thailand
- Assessment on Impact, Vulnerability and Adaptation to Climate Change: Finding and lesson learned from pilot study in the Lower Mekong River basin

Technical research papers:

- Impact of Climate Change on Rainfed Lowland Rice Production in Savannakhet Province, Lao PDR
- Climate scenario verification and impact on rain-fed rice production in Thailand
- Impact of climate change on rice production in Kula Ronghai Field, Thailand
- Impact of climate change on maize, sugarcane and cassava production in northeastern region of Thailand
- Assessment on impact and adaptation to climate change: The study on vulnerability and adaptation options of rain-fed farmer in Kula Ronghai Field,

Thailand

- The study on vulnerability and adaptation of rain-fed farmer to impact of climate change: Case study at Vientiane Plain, Lao PDR

Website: Under construction

10 Policy Implications and Future Directions

This pilot study project has raised awareness among policy maker and public sectors in the region regarding the climate change issues; however, in developing the climate change policy, the policy maker still requires more explicit answer regarding climate change impact, vulnerability and adaptation on various key systems, which need more study to confirm. In addition, the study on climate change impact under this regional study is base on long timescale, which is too long for the policy planning scope of any country in the region. Future study may need to focus on the issue of climate change impact in shorter timescale or address more on the climate variability that may change its pattern from climate change influence. Furthermore, more involvement from the policy maker and policy implementing agency should also be planned for the future activity. Pilot implementation, which may help building resilience to climate impact that has immediate as well as long-term benefit, such as seasonal climate forecast, may be further explored and pilot test be implemented.

The climate change has impact on both bio-physical systems as well as socio-economic aspects, and in many cases, need to be considered in regional scale as it may impact large geographic coverage and may have consequences that are trans-boundary. Furthermore, the efforts to cope with climate change impact in one location may cause side effect the other locations or systems or sectors, which could also be trans-boundary issue. This call for regional collaboration to jointly look into the issues together in order to establish and share common understanding on the impact and adaptation in bigger picture at regional scale, of which would ultimately lead to the adaptation strategy that could be implemented collectively under holistic approach to achieve better efficiency and effectiveness in coping with the climate stress and also help avoid conflict that may arise from discreet planning and implementation.

References

Adger, W. Neil, Kelly, P. Mike, Nguyen Huu Ninh, 2001. Living with Environmental Change: Social vulnerability, adaptation and resilience in Vietnam, Routledge, London

Boulidam, Somkhit, 2005, Vulnerability and Adaptation of Rain-fed Rice Farmers to Impact of Climate Variability in Lahakhok, Sebangnuane Tai, Dong Khamphou and Khudhi Villages of Songkhone District, Savannakhet, Lao PDR, Mahidol University, Thailand

Department of Livestock Development, Ministry of Agriculture and Cooperative, Thailand [Online] Available at: http://www.dld.go.th/pvlo_ccs/p21.htm

Grenier, L., 1998. *Working with Indigenous Knowledge: A Guide for Researchers*. International Development Research Centre, Canada.

Hoogenboom, G., P.W. Wilkens, and G.Y. Tsuji (eds.). 1999. DSSAT version 3 v4. University of Hawaii, Honolulu, Hawaii.

IPCC, 2001 a. Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK.

IPCC, 2001 b. Climate Change 2001: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK.

IPCC. 2001c: Climate Change 2001: Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Watson, R.T. and the Core Writing Team (eds.). Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA, 398 pp.

Kates, Robert W., 2001. Cautionary Tales: Adaptation and the Global Poor. Societal Adaptation to Climate Variability and Change, Khuwer Academic Publishers, Dordrecht, The Netherlands.

Kerdsuk, Vichien, Kerdsuk, Varaporn, Sukchan, Somsak, 2005, Impacts Assessment and Adaptation to Climate Change: The Study of Vulnerability and Adaptation Options of Rain-fed Farmer in Tung Kula Ronghai, Khon Kaen University, Thailand.

Liang, X., Lettenmaier, D. P., Wood, E. F. and Burges, S. J. 1994. A simple hydrologically based model of land surface water and energy fluxes for general circulation model. J. Geophys. Res. 99: 14415-14428.

Lohman, D., Raschke, E., Nijssen, B. and Lettenmaier, D. P. 1998. Regional scale hydrology: I. Formation of the VIC-2L model coupled to a routing model. Hydrol. Sci. J. 43: 131-141

McGregor, J.L., and M.R. Dix, 2001: The CSIRO conformal-cubic atmospheric GCM. In IUTAM Symposium on Advances in Mathematical Modelling of Atmosphere and Ocean Dynamics, P.F. Hodnett (Ed.), Kluwer, Dordrecht, 197-202.

McGregor, J. L., Katzfey, J. J. and Nguyen, K. C. 1998: Fine resolution simulations of climate change for Southeast Asia. Final report for a research project commissioned by Southeast Asian Regional Committee for START (SARCS). Aspendale, Vic. CSIRO Atmospheric Research, 35 p.

Richey, J. E., Logsdon, M., Rodda, S., Nijssen, B., Lettenmaier, D. and Snidvongs, A. 2000. Sea-Basins: Towards A Coupled Hydrological and Material Transport Model of Southeast Asia and the Mekong River System. In R.W. Al-Soufi (ed.), Proceeeding of the Workshop on Hydrologic and Environmental Modelling in the Mekong Basin. Phnom Penh: Technical Support Division, Mekong River Commission MKG/R.00017, pp. 40-62.

Shukla, P.R., Ravindranath, N.H., Garg, Amit, Battacharya, Sumana, 2003. Climate Change and India: Vulnerability Assessment and Adaptation, University Press, India.

SRES, 2000. IPCC Special Report on Emission Scenarios. Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

Wang, Yuqing, Leung, L. Ruby, McGregor, John L., Lee, Dong Kyou, Wang, Wei-Chyung, Ding, Yihui, Kimura, Fujio, 2004. Regional Climate Modeling: Progress, Challenges, Prospects. Journal of Meteorological of Japan.

List of Figures and Tables

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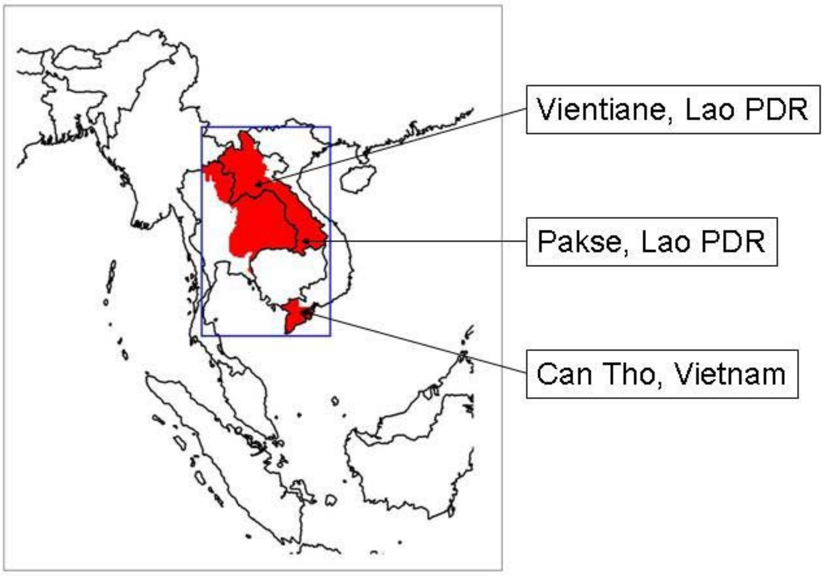
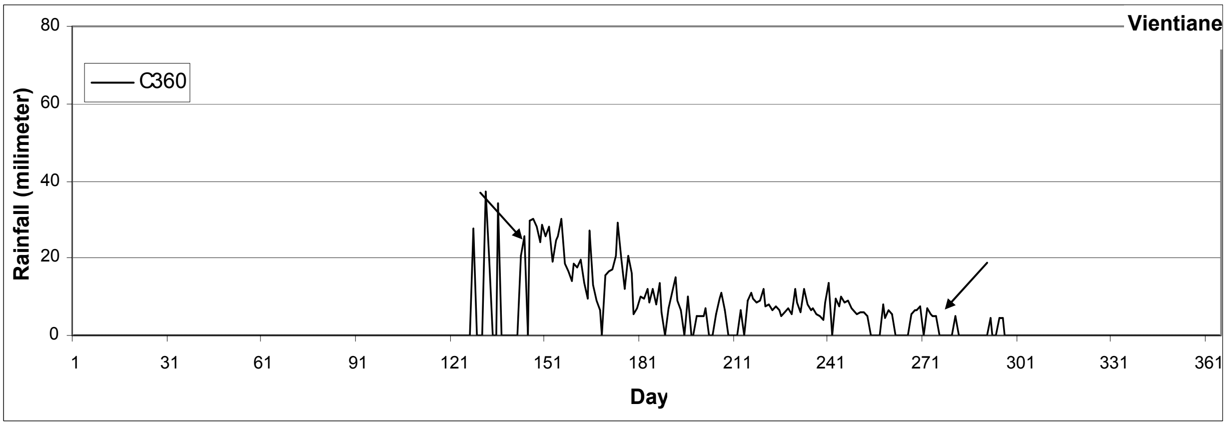
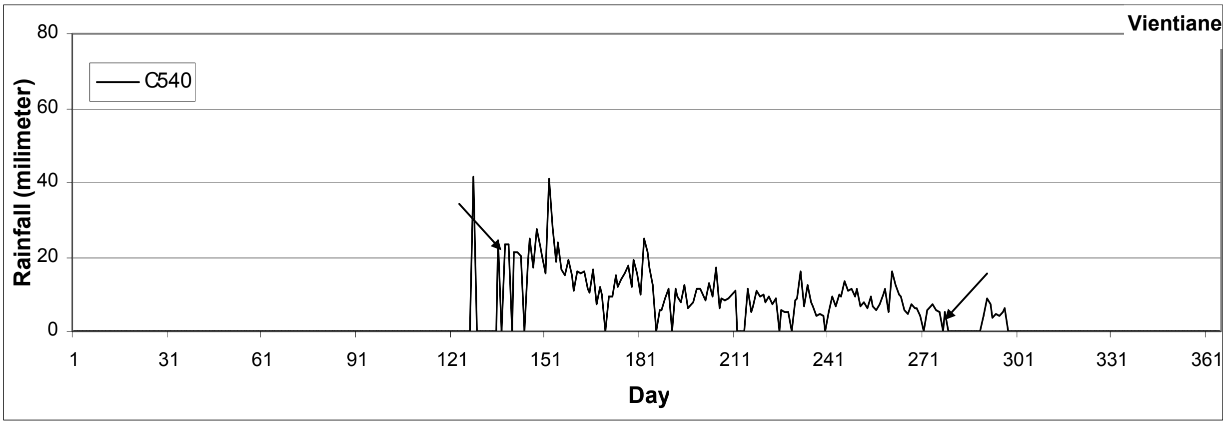
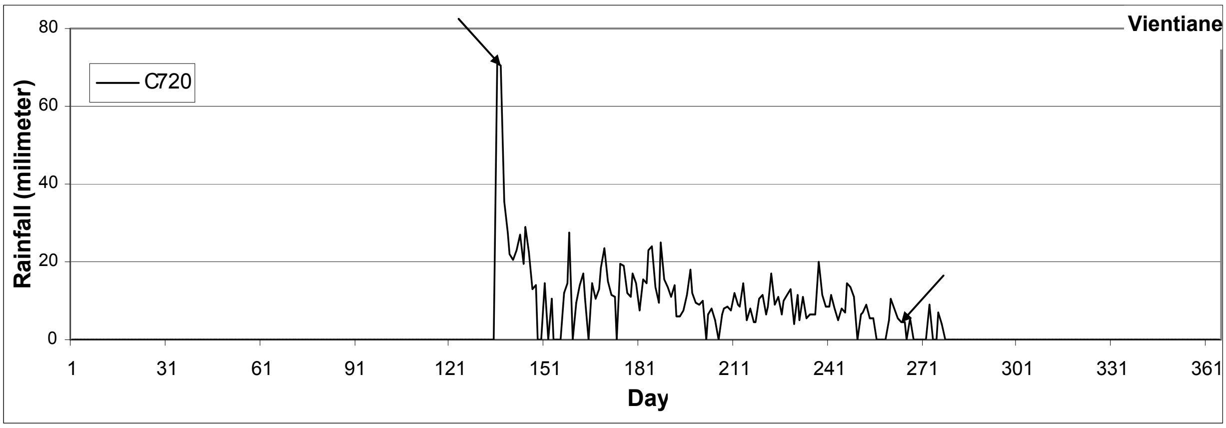
Table 15: National Level Measures for Managing Climate Risks

Appendix 1:
Rainy Season Pattern at Selected Cities in lower Mekong River Basin under Influence of Climate Change



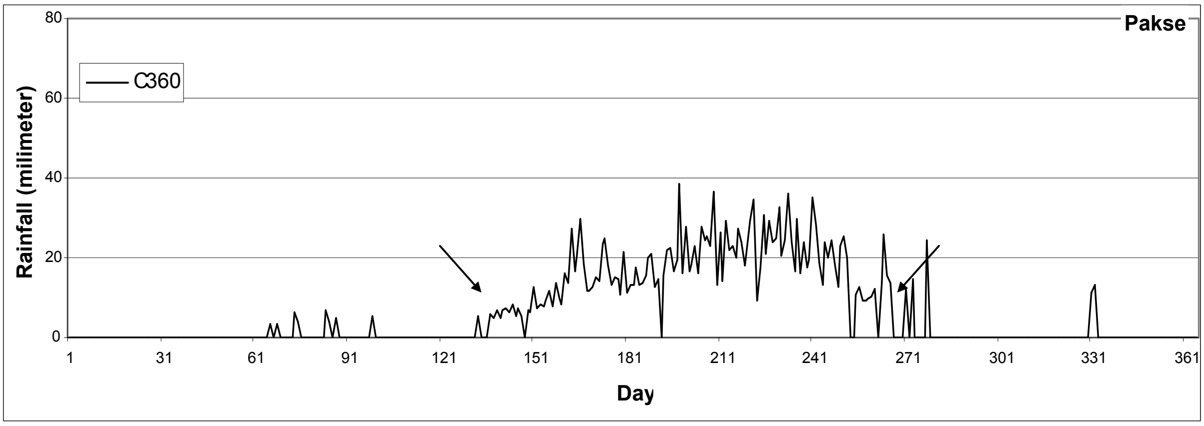


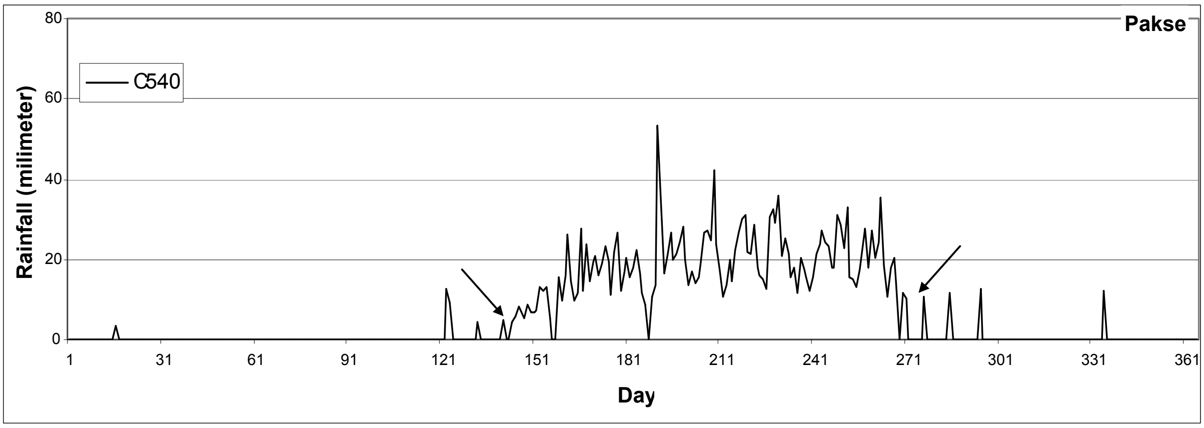


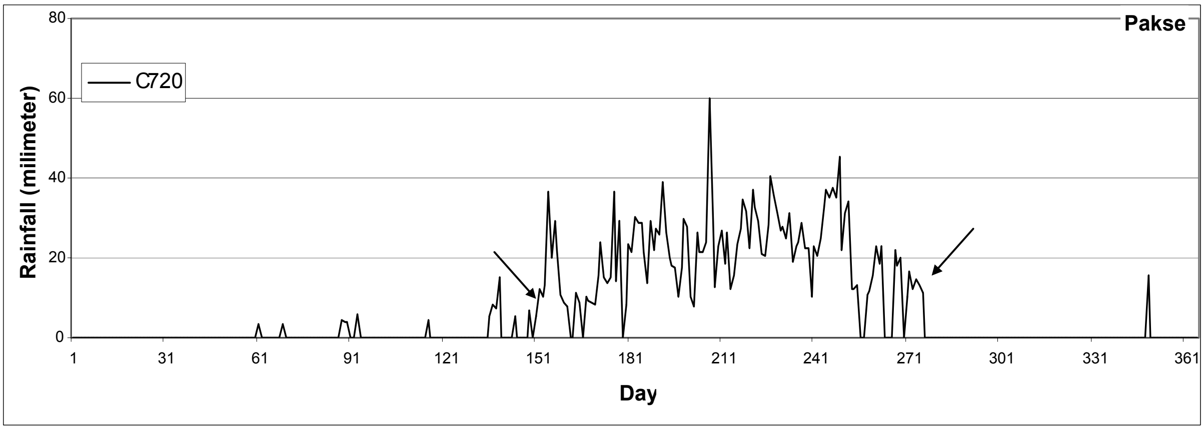


Rainy season at Vientiane, Lao PDR

CO_2 Scenario	On-set date	End date	Rainy season day	Annual rainfall (mm)
360ppm	146	275	130	1229
540ppm	136	278	143	1511
720ppm	136	267	132	1502

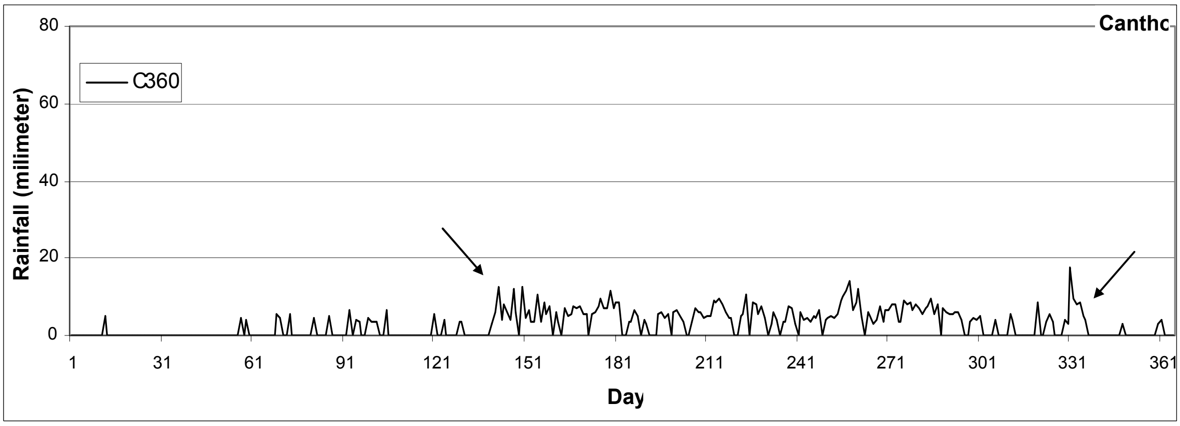


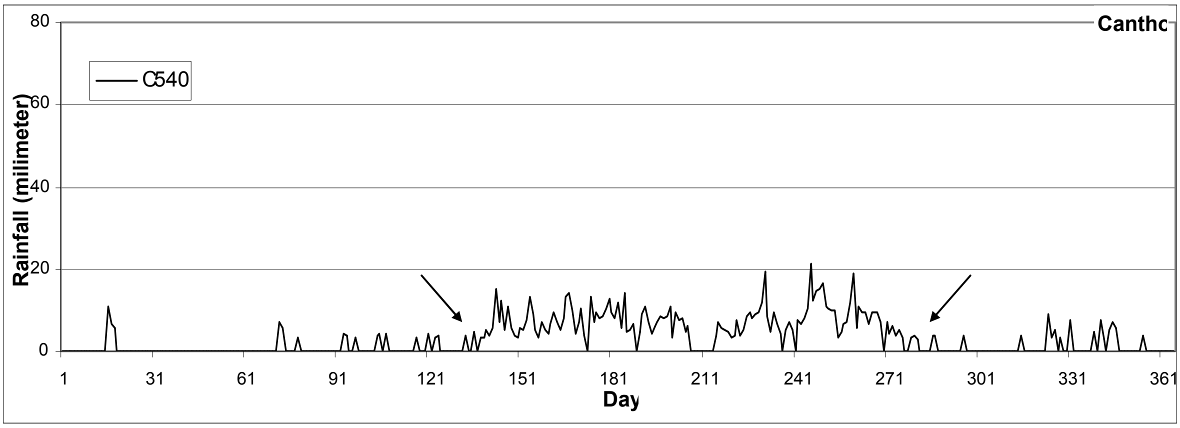


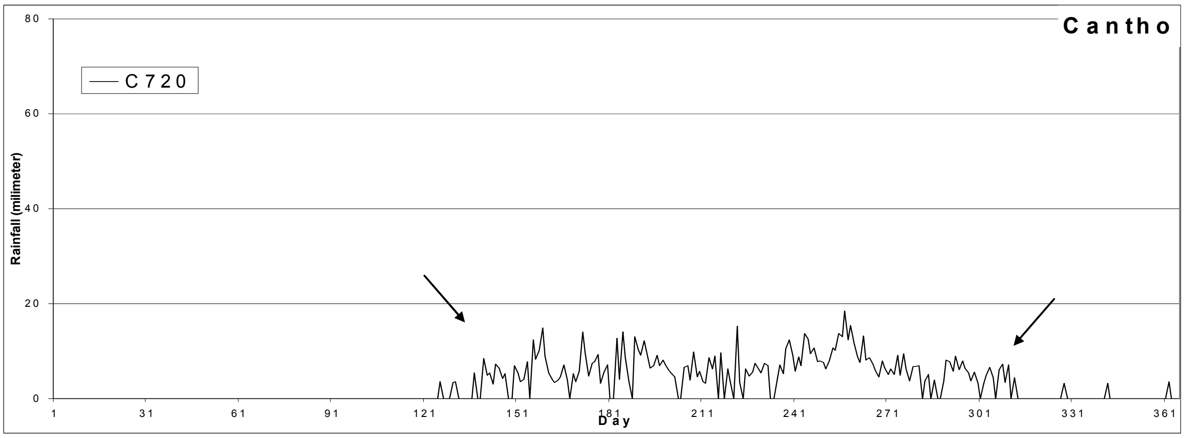


Rainy season at Pakse, Lao PDR

CO_2 Scenario	On-set date	End date	Rainy season day	Annual rainfall (mm)
360ppm	137	267	130	2213
540ppm	145	271	128	2370
720ppm	152	277	126	2551





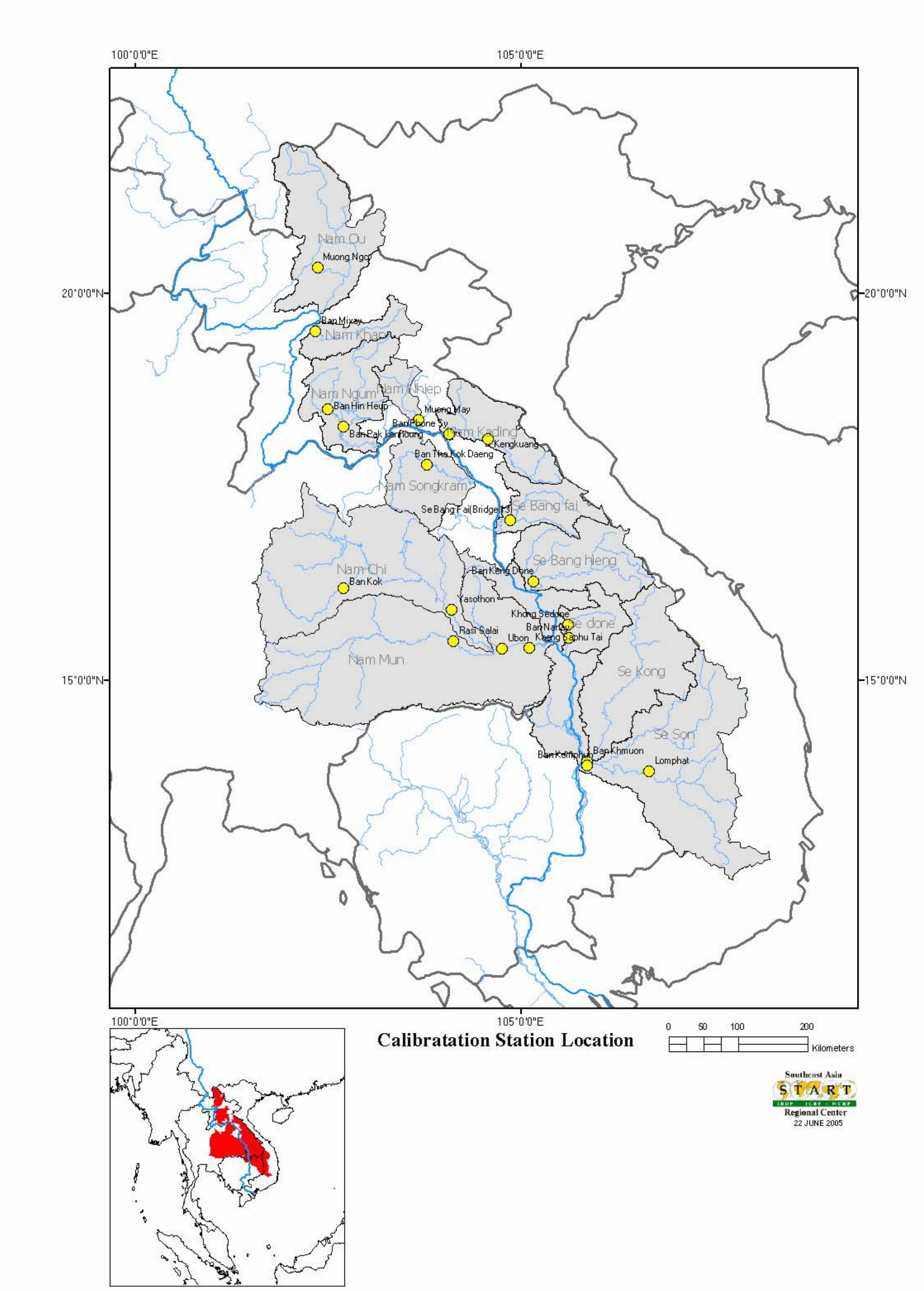


Rainy season at Cantho, Viet Nam

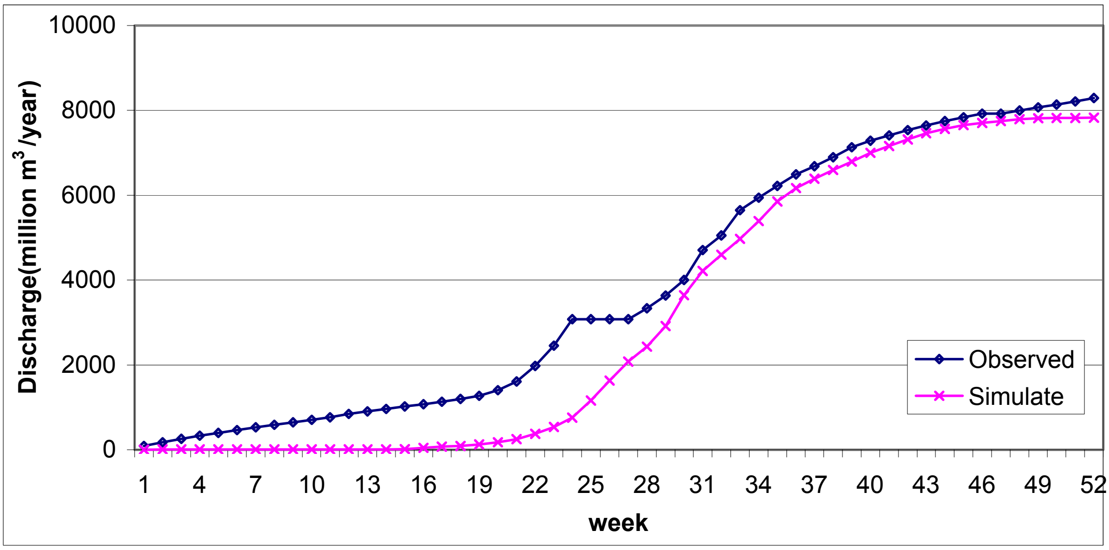
CO_2 Scenario	On-set date	End date	Rainy season day	Annual rainfall (mm)
360ppm	140	336	197	959
540ppm	133	287	155	1027
720ppm	137	312	176	1105

Appendix 2:
Result of Hydrological Regime Baseline Calculation and Model Calibration

Baseline hydrological regime simulation in the lower Mekong River basin and calibration result was calculated at the various locations:



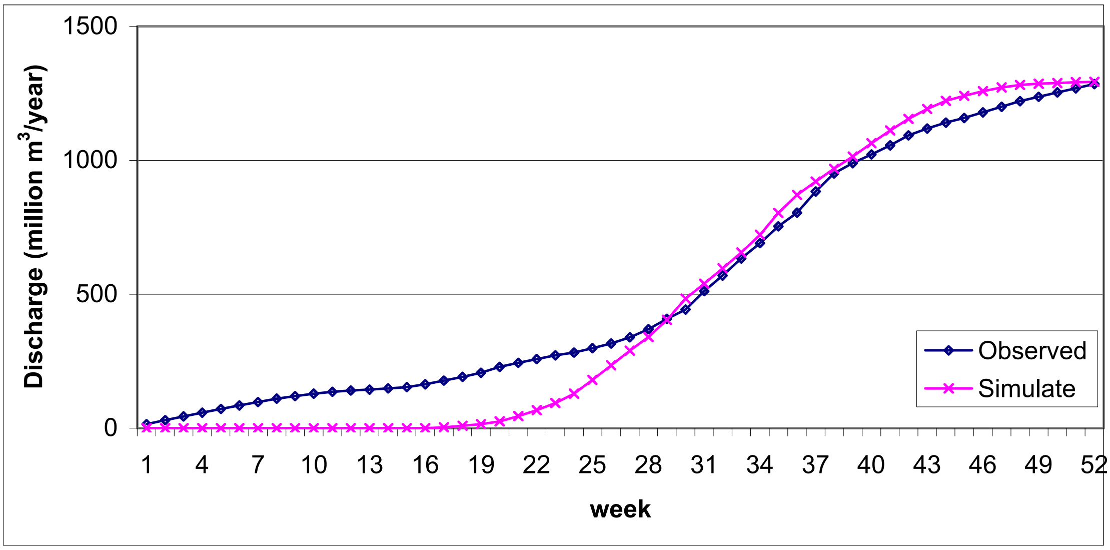
Sub-Basin:	**Nam Ou - Lao PDR**
Station:	Muong Ngoy
Coordinate:	N20.702 E102.335
Observed year:	1989
CCAM set:	P00



Parameter

Fraction of base flow	0.5
Fraction of Runoff	1
Diffusion	1
Velocity	0.007
RMSE	260.251

Sub-Basin: Nam Khan - Lao PDR
Station: Ban Mixay
Coordinate: N19.787 E102.177
Observed year: 1989
CCAM set: P00

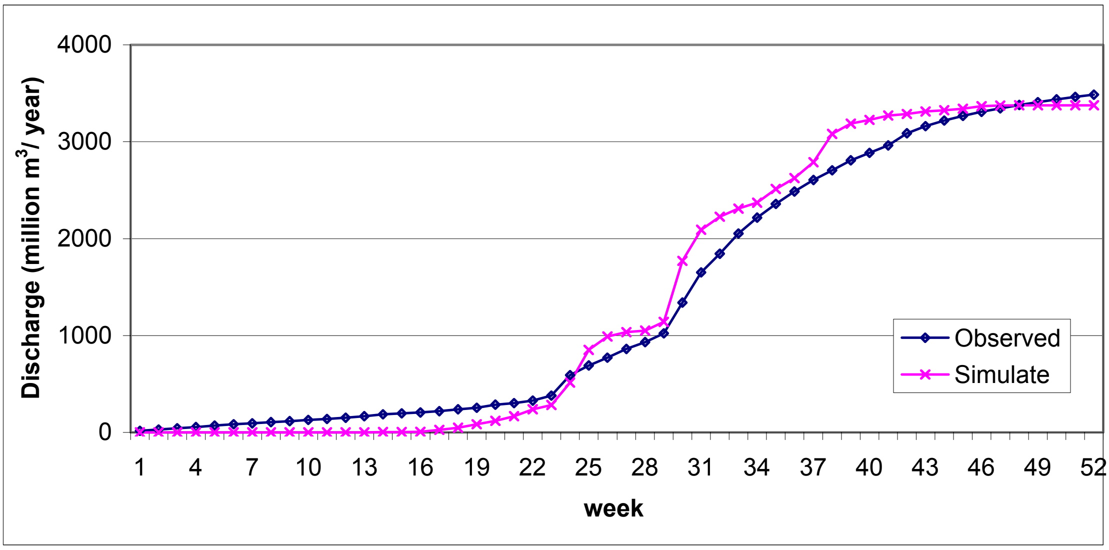


Parameter

Fraction of base flow	0.17
Fraction of Runoff	0.1
Diffusion	1
Velocity	0.001
RMSE	26.797

Sub-Basin: **Nam Ngum - Lao PDR**

Station:	Ban Hin Heup
Coordinate:	N18.663 E102.355
Observed year:	1989
CCAM set:	P00

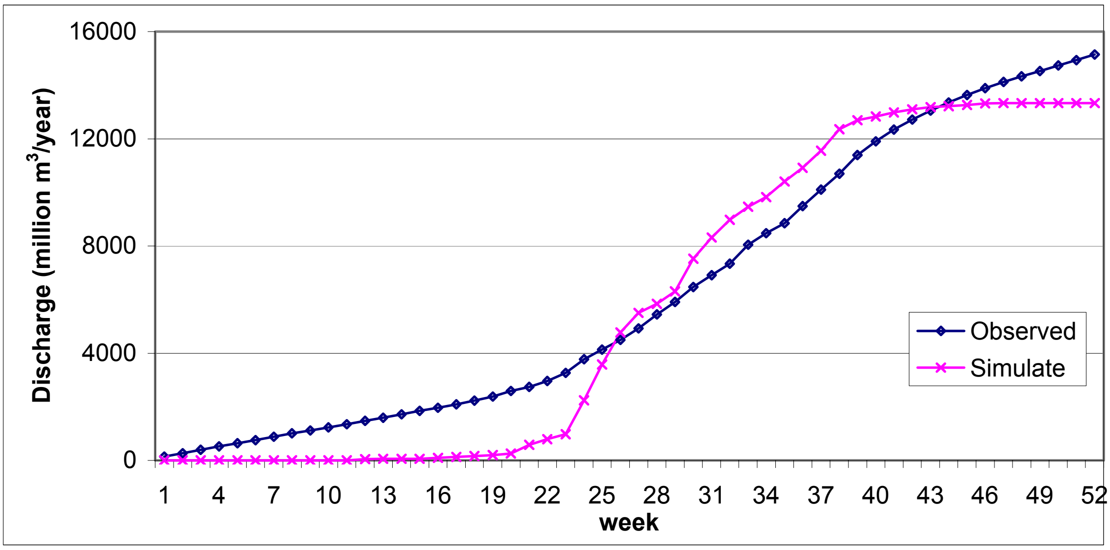


Parameter

Fraction of base flow	0.5
Fraction of Runoff	1
Diffusion	1
Velocity	0.03
RMSE	117.358

Sub-Basin: **Nam Ngum - Lao PDR**

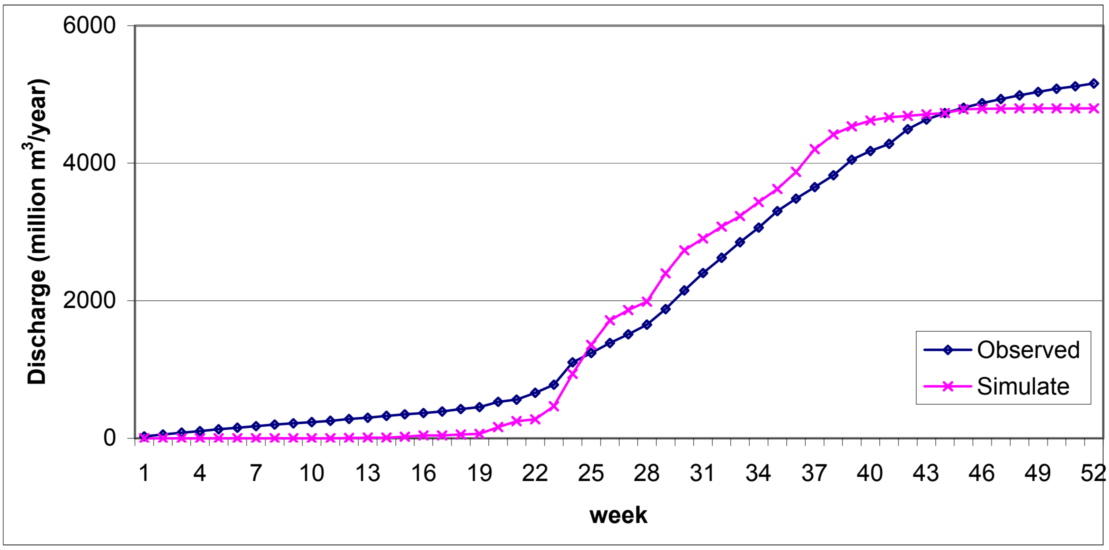
Station:	Ban Pak Kanhoung
Coordinate:	N18.417 E102.575
Observed year:	1989
CCAM set:	P00



Parameter

Fraction of base flow	0.6
Fraction of Runoff	1
Diffusion	1
Velocity	0.05
RMSE	476.844

Sub-Basin:	**Nam Nhiep - Lao PDR**
Station:	Muong May
Coordinate:	N18.505 E103.662
Observed year:	1989
CCAM set:	P00

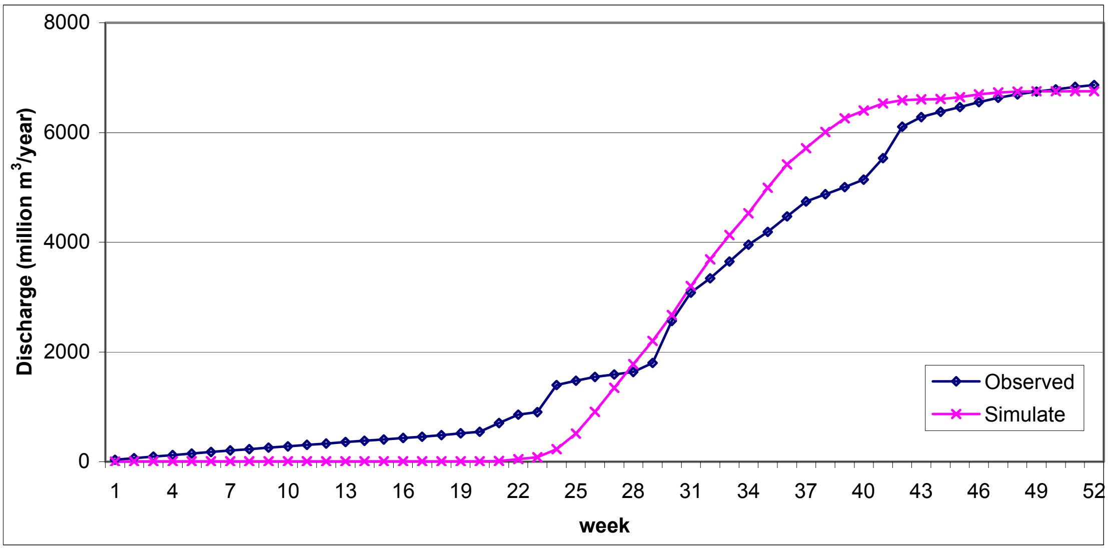


Parameter

Fraction of base flow	0.5
Fraction of Runoff	1
Diffusion	20
Velocity	1
RMSE	135.736

Sub-Basin: Nam Theun - Lao PDR

Station:	Bang Signo
Coordinate:	N17.850 E105.067
Observed year:	1989
CCAM set:	P00



Parameter

Fraction of base flow	2.45
Fraction of Runoff	1
Diffusion	1
Velocity	0.01
RMSE	266.937

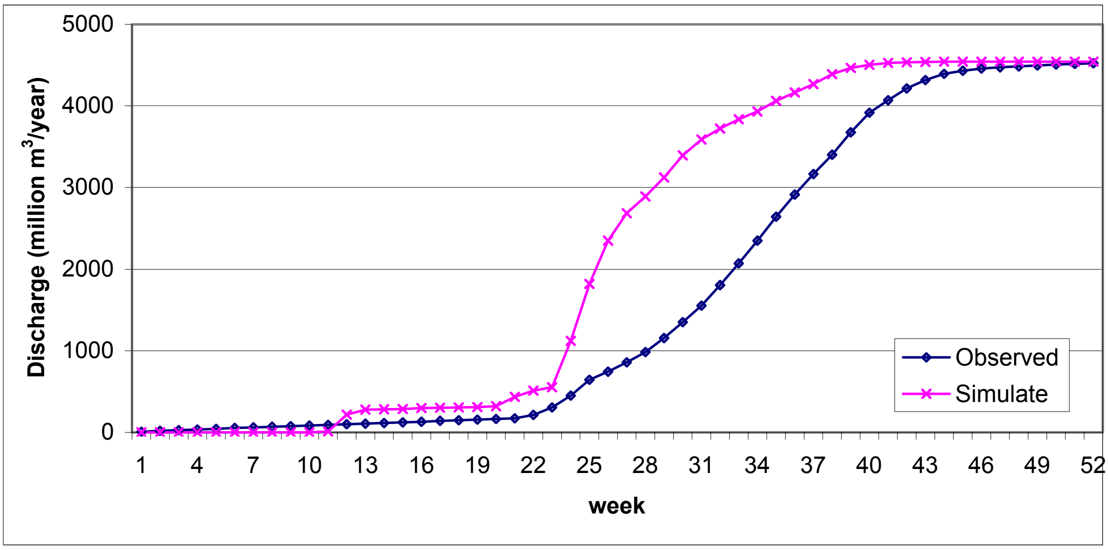
Sub-Basin: **Nam Songkhram - Thailand**

Station: Ban Tha Kok Daeng

Coordinate: N17.867 E103.783

Observed year: 1989

CCAM set: P00



Parameter

Fraction of base flow	1.6
Fraction of Runoff	1
Diffusion	0.5
Velocity	0.003
RMSE	233.616

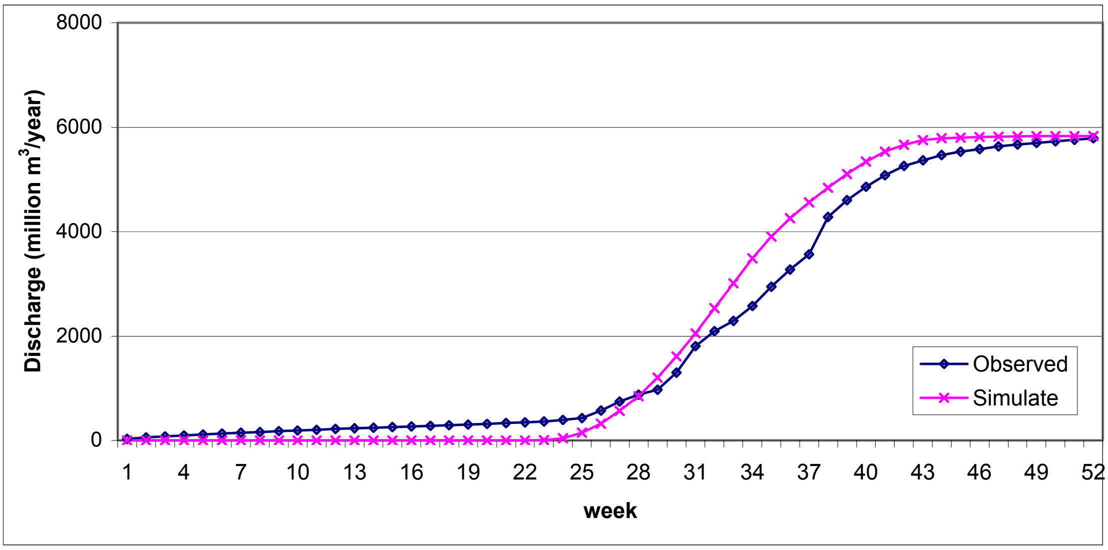
Sub-Basin: **Se Bang Fai - Lao PDR**

Station: Se Bang Fai Bridge-13

Coordinate: N17.072 E104.985

Observed year: 1989

CCAM set: P00



Parameter

Fraction of base flow	0.73
Fraction of Runoff	1
Diffusion	0.5
Velocity	0.005
RMSE	325.353

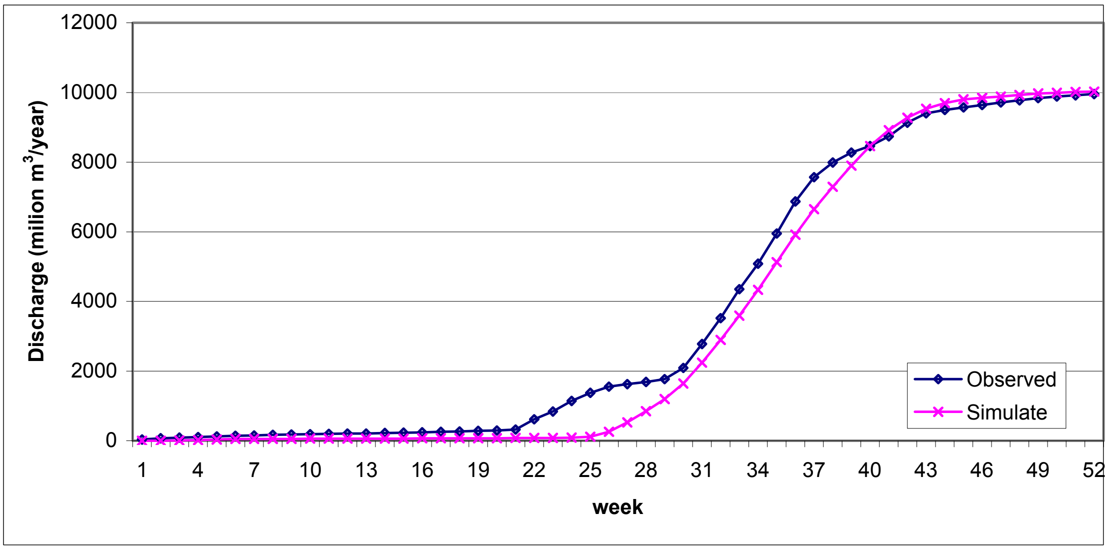
Sub-Basin: **Se Bang Hieng - Lao PDR**

Station: Ban Keng Done

Coordinate: N16.185 E105.815

Observed year: 1989

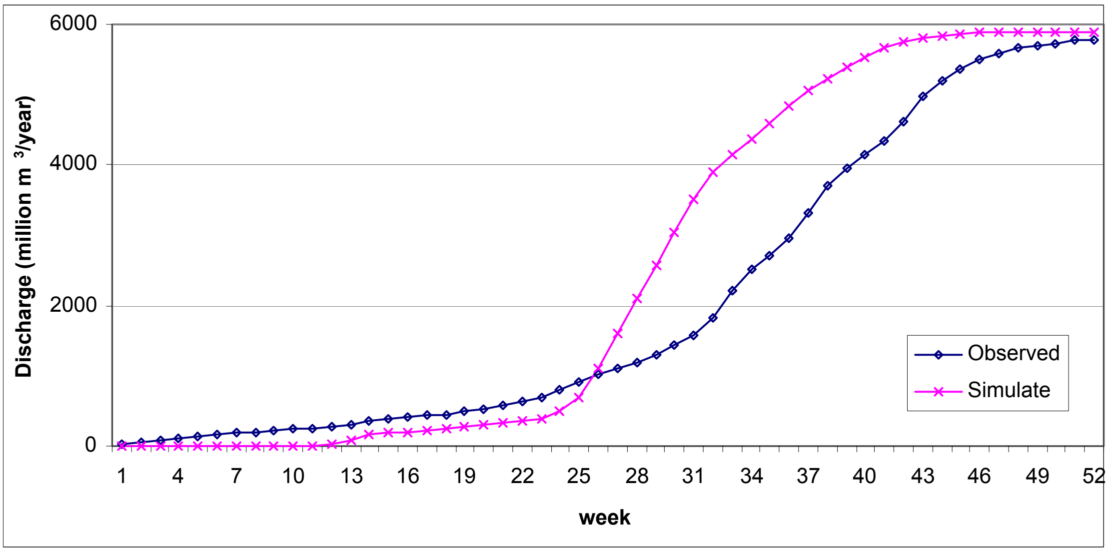
CCAM set: P00



Parameter

Fraction of base flow	0.6
Fraction of Runoff	1
Diffusion	1
Velocity	0.01
RMSE	529.739

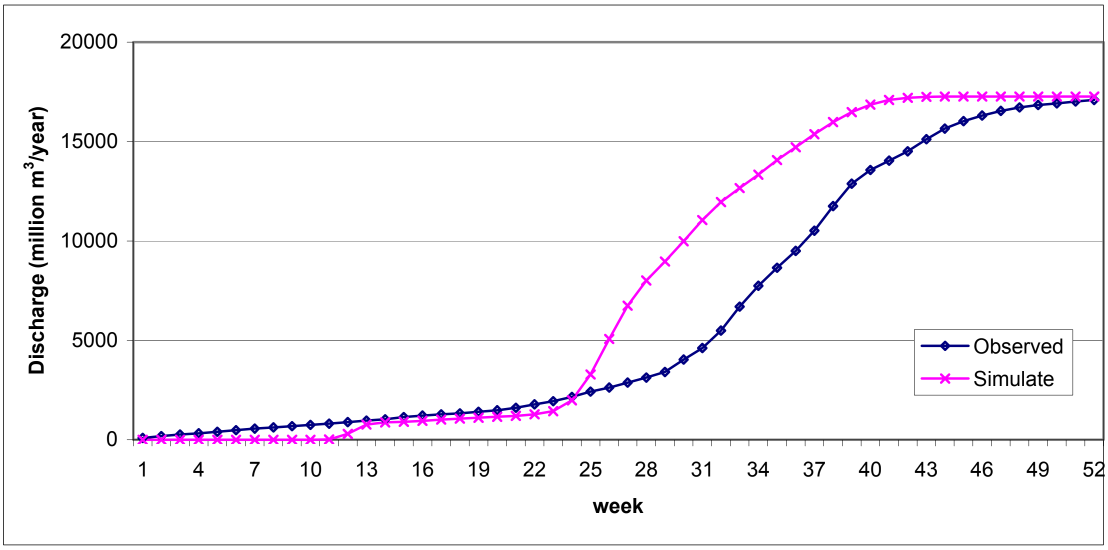
Sub-Basin:	**Nam Chi - Thailand**
Station:	Ban Chot
Coordinate:	
Observed year:	1989
CCAM set:	P00



Parameter

Fraction of base flow	0.5
Fraction of Runoff	1
Diffusion	1
Velocity	0.015
RMSE	244.755

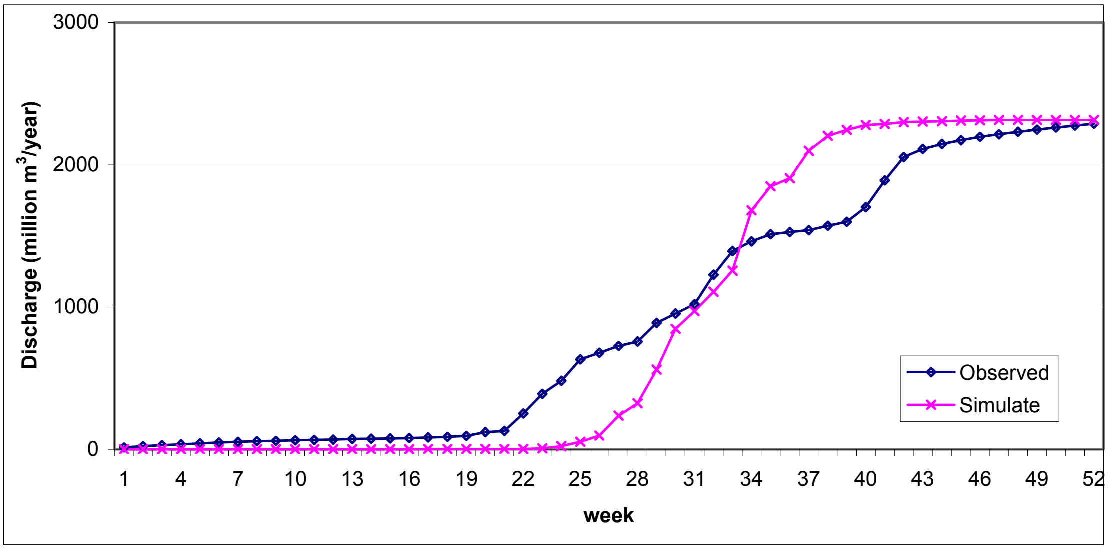
Sub-Basin:	**Nam Mun - Thailand**
Station:	Kaeng Saphu Tai
Coordinate:	N15.240 E105.250
Observed year:	1989
CCAM set:	P00



Parameter

Fraction of base flow	0.45
Fraction of Runoff	1
Diffusion	1
Velocity	0.05
RMSE	741.520

Sub-Basin:	**Se Done - Lao PDR**
Station:	Souvanakhili
Coordinate:	N15.383 E105.817
Observed year:	1989
CCAM set:	P00



Parameter

Fraction of base flow	0.14
Fraction of Runoff	1
Diffusion	20
Velocity	1
RMSE	141.828

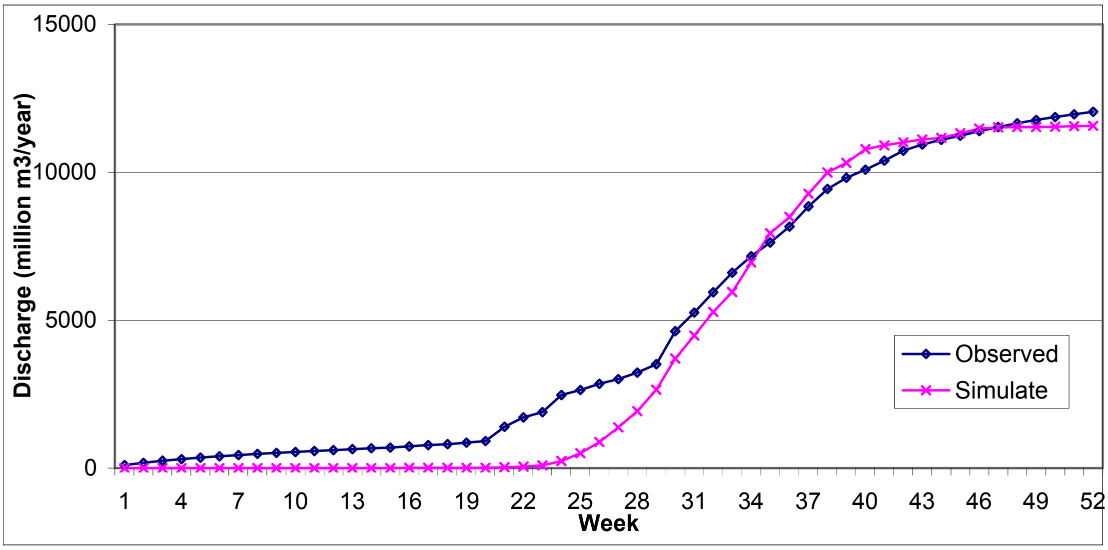
Sub-Basin: **Se Kong - Lao PDR**

Station: Attapeu

Coordinate: N14.800 E106.833

Observed year: 1989

CCAM set: P00

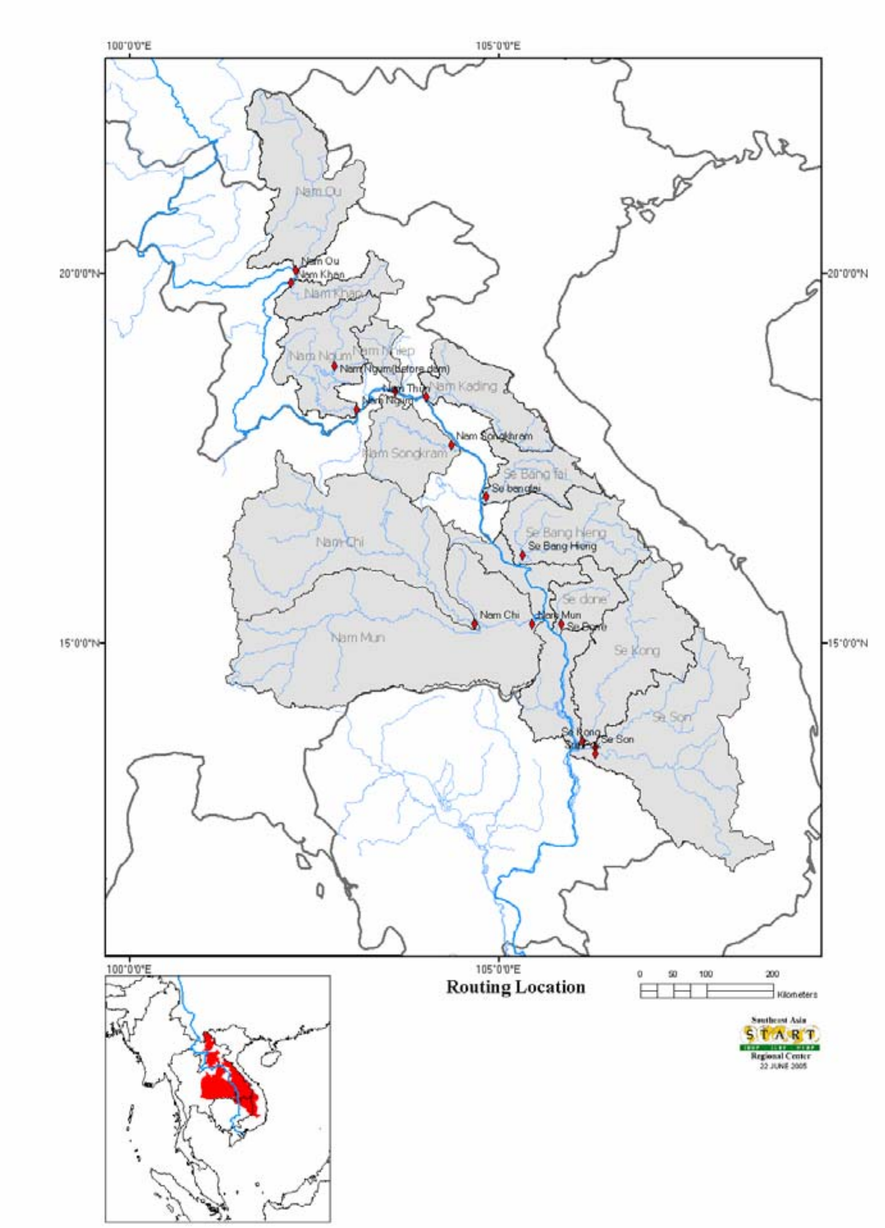


Parameter

Fraction of base flow	0.8
Fraction of Runoff	1
Diffusion	1
Velocity	0.05
RMSE	303.894

Appendix 3:
Simulation Result of Hydrological Regime of major Sub-basins of Mekong River in Lao PDR and Thailand under Different Climate Scenarios

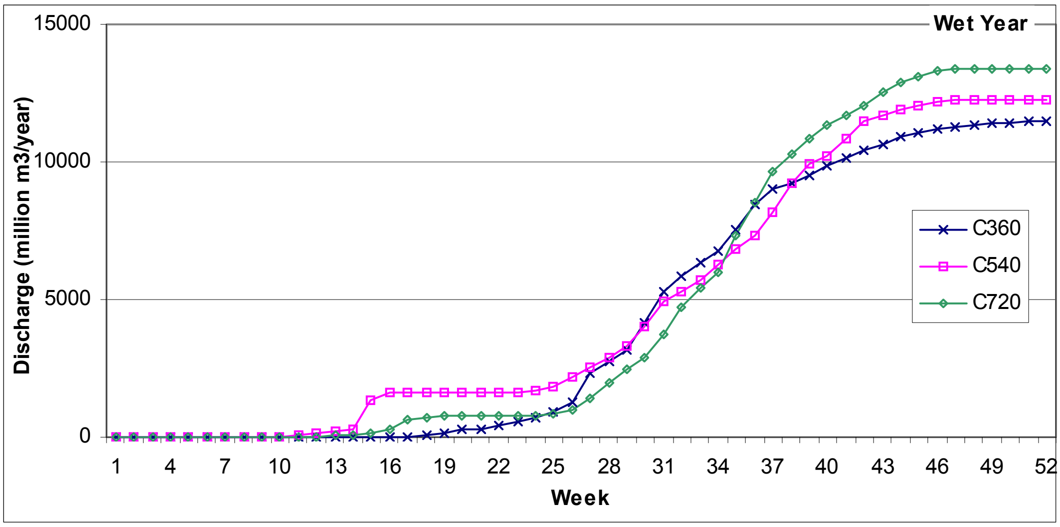
The discharge calculation for each individual sub-basin was simulated at the mouth of each major tributary in Lao PDR and Thailand:



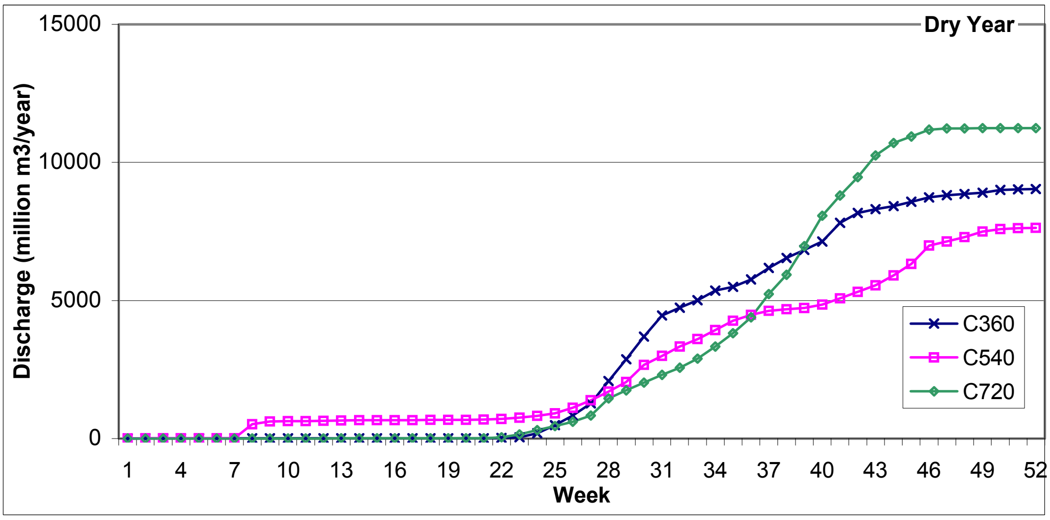
Sub-Basin: **Nam Ou - Lao PDR**

Station: Tributary mouth

Coordinate: N20.05 E102.24



Period	Discharge Level
Base line year Compare C-360 & C-540 Compare C-360 & C-720	11,458 million cubic meters / year + 7.23 % + 16.78 %

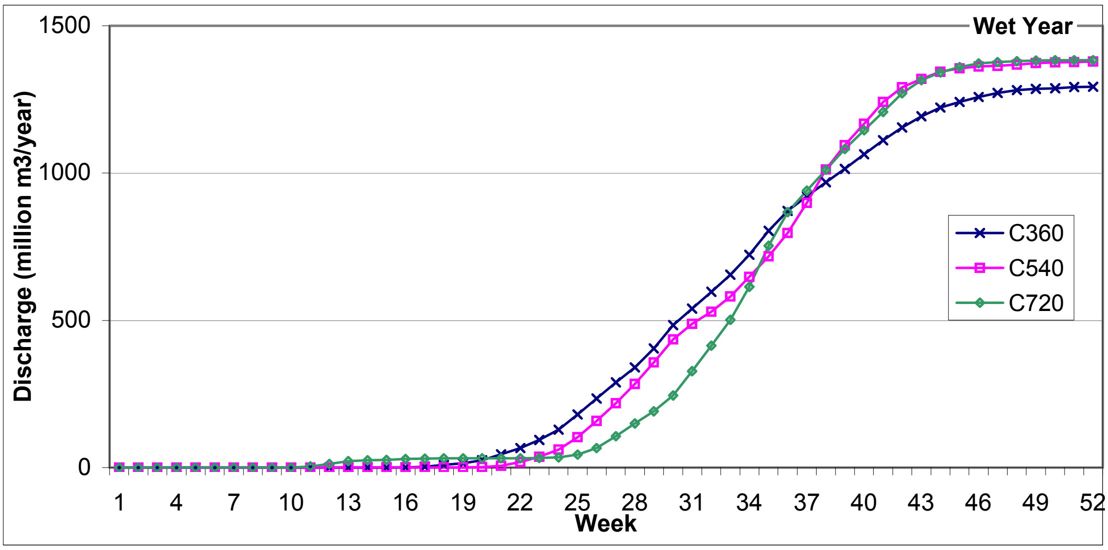


Period	Discharge Level
Base line year Compare C-360 & C-540 Compare C-360 & C-720	9,035 million cubic meters / year - 15.56 % + 24.38 %

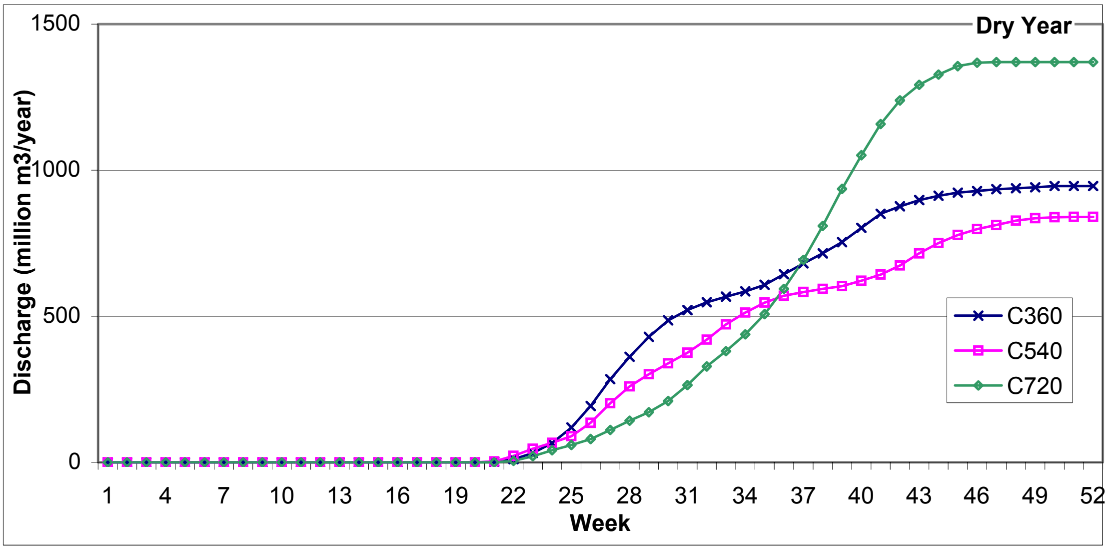
Sub-Basin: **Nam Khan - Lao PDR**

Station: Tributary mount

Coordinate: N19.87 E102.18



Period	Discharge Level
Base line year	1,293 million cubic meters / year
Compare C-360 & C-540	+ 6.65 %
Compare C-360 & C-720	+ 6.93 %

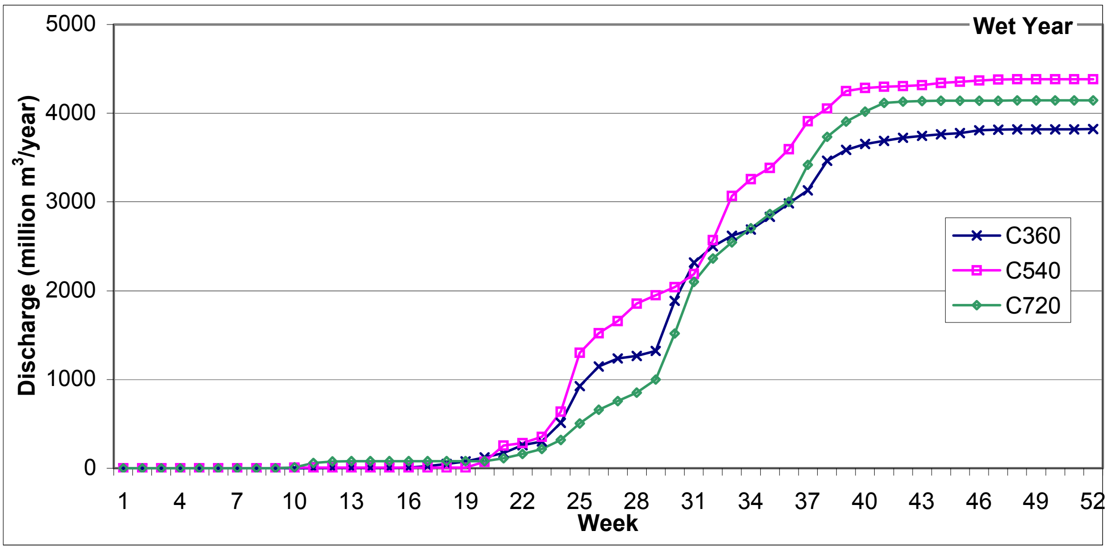


Period	Discharge Level
Base line year	946 million cubic meters / year
Compare C-360 & C-540	-11.17 %
Compare C-360 & C-720	+ 44.80 %

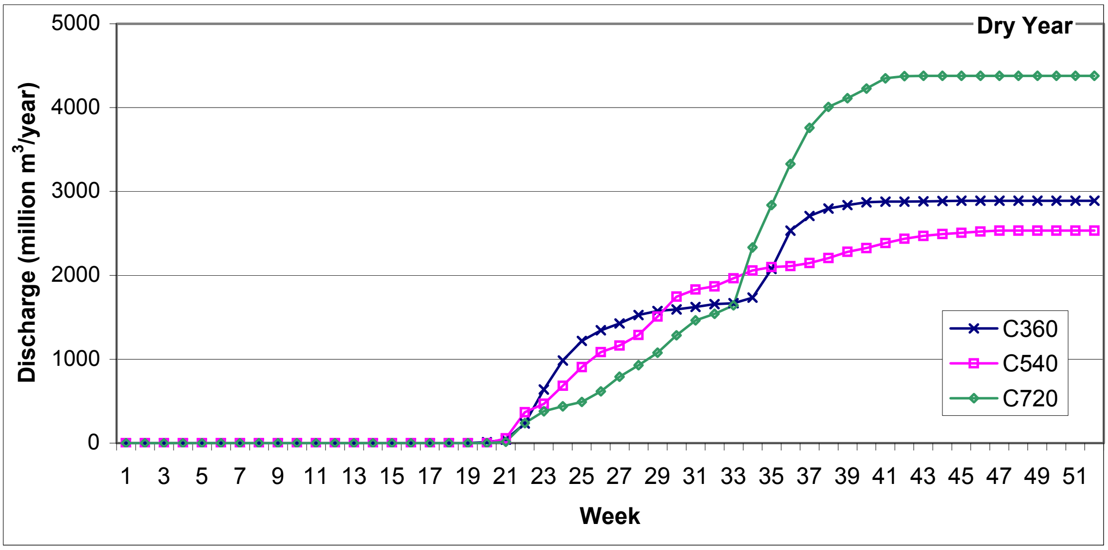
Sub-Basin: **Upper Nam Ngum - Lao PDR**

Station: Before Dam Entry

Coordinate: N18.75 E102.77



Period	Discharge Level
Base line year	3,820 million cubic meters / year
Compare C-360 & C-540	+ 14.77 %
Compare C-360 & C-720	+ 8.44 %

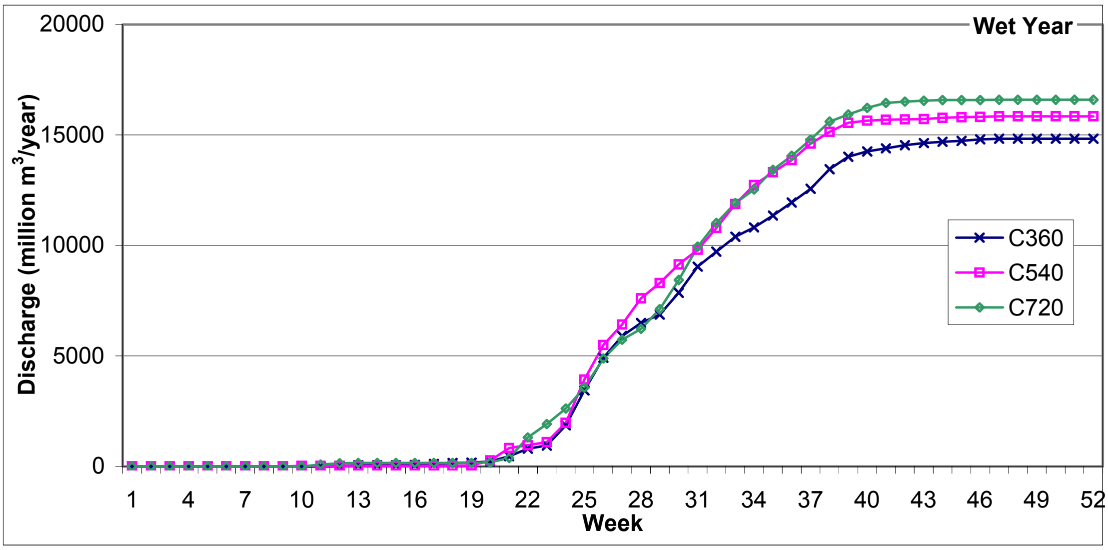


Period	Discharge Level
Base line year	2,891 million cubic meters / year
Compare C-360 & C-540	- 12.30 %
Compare C-360 & C-720	+ 51.49 %

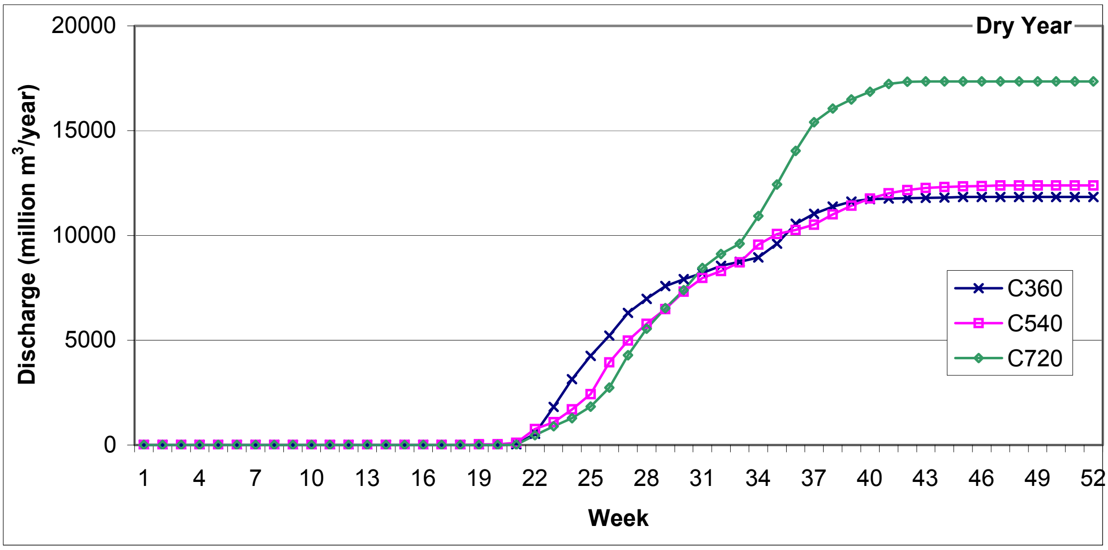
Sub-Basin: **Nam Ngum - Lao PDR**

Station: Tributary mouth

Coordinate: N18.16 E103.07



Period	Discharge Level
Base line year	14,837 million cubic meters / year
Compare C-360 & C-540	+ 6.83 %
Compare C-360 & C-720	+ 11.79 %

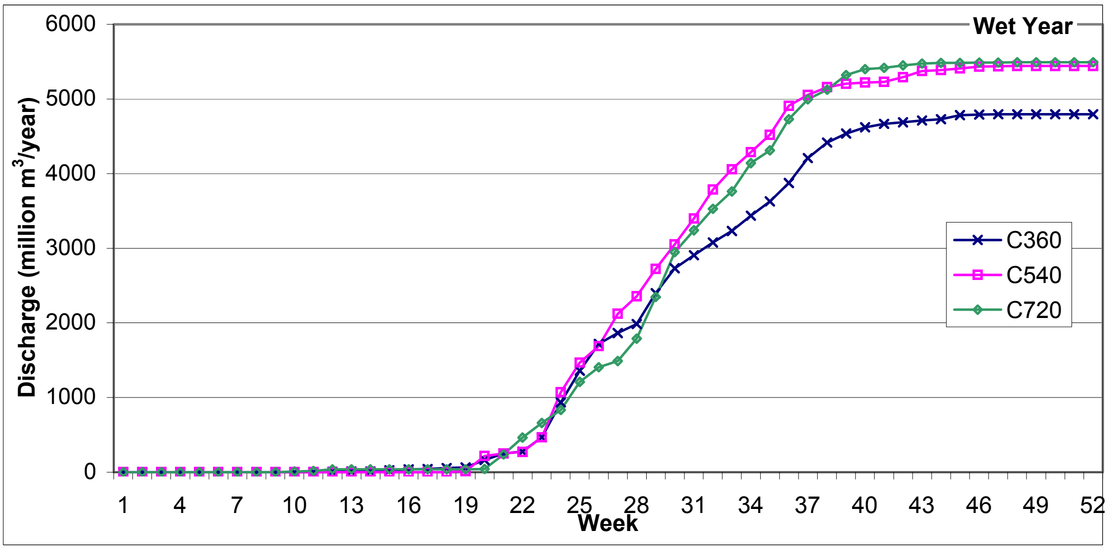


Period	Discharge Level
Base line year	11,837 million cubic meters / year
Compare C-360 & C-540	+ 4.70 %
Compare C-360 & C-720	+ 46.63 %

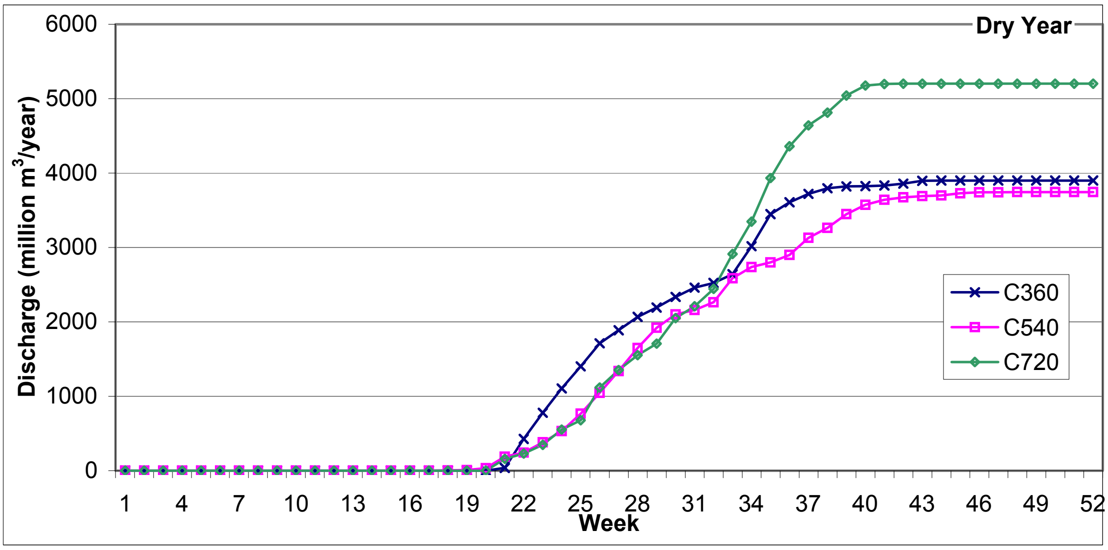
Sub-Basin: **Nam Nhiep - Lao PDR**

Station: Tributary mouth

Coordinate: N18.41 E103.59



Period	Discharge Level
Base line year Compare C-360 & C-540 Compare C-360 & C-720	4,796 million cubic meters / year + 4.70 % + 46.63 %

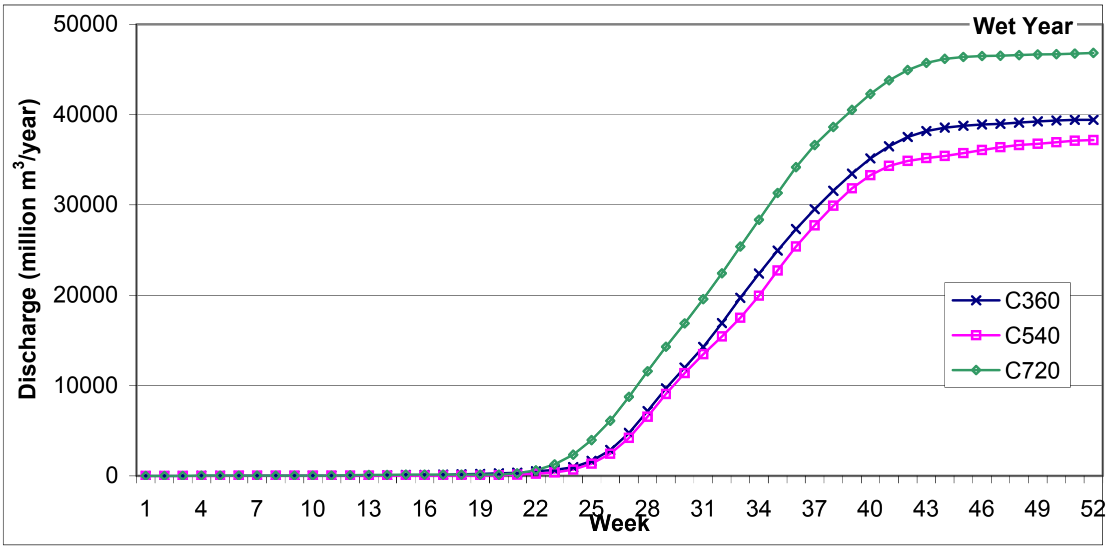


Period	Discharge Level
Base line year Compare C-360 & C-540 Compare C-360 & C-720	3,902 million cubic meters / year - 4.06 % + 33.28 %

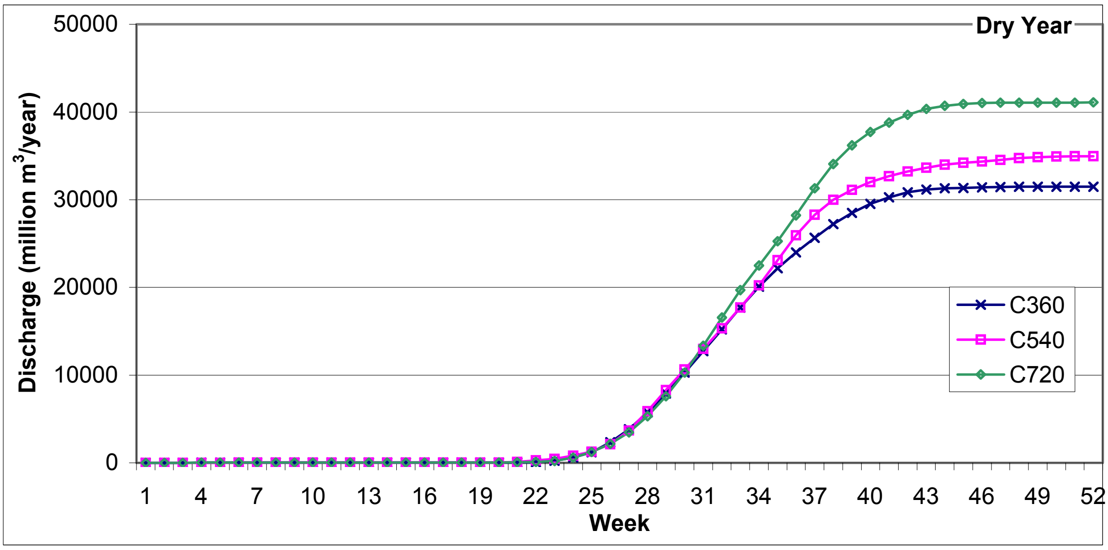
Sub-Basin: Nam Theun - Lao PDR

Station: Tributary mouth

Coordinate: N18.33 E104.01

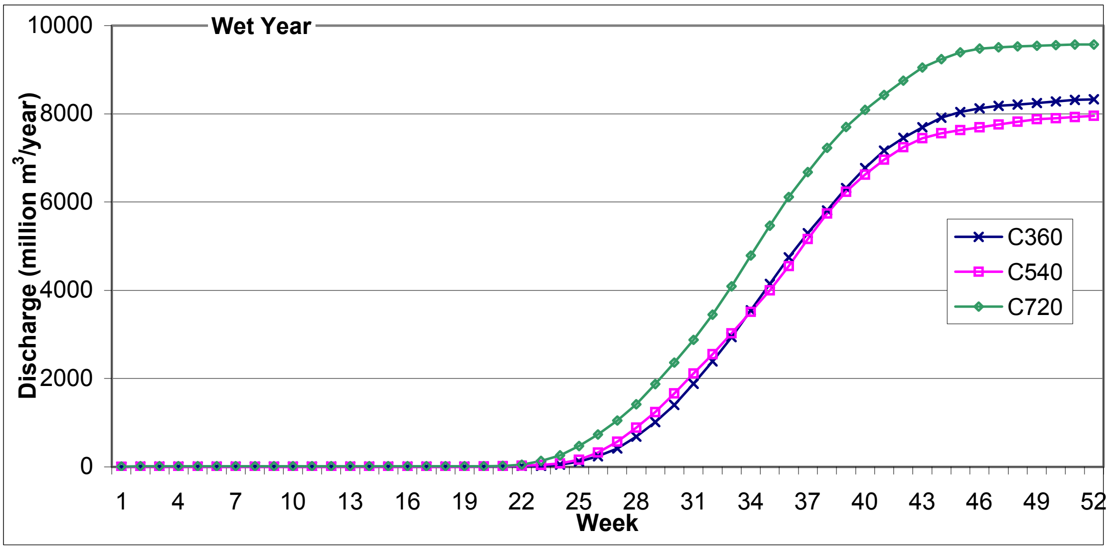


Period	Discharge Level
Base line year Compare C-360 & C-540 Compare C-360 & C-720	39,427 million cubic meters / year - 5.68 % + 18.75 %

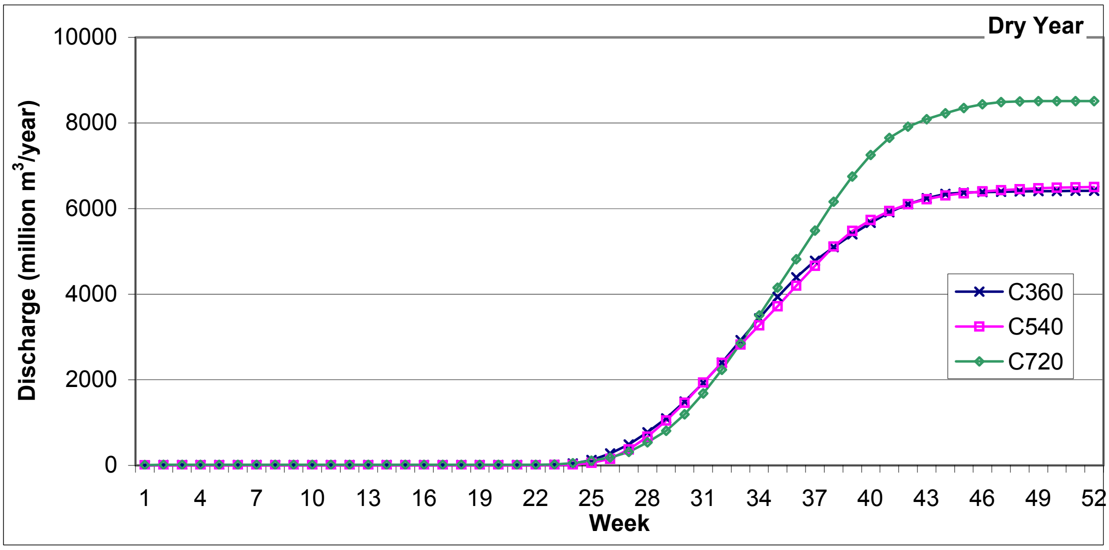


Period	Discharge Level
Base line year Compare C-360 & C-540 Compare C-360 & C-720	31,483 million cubic meters / year + 11.03 % + 30.47 %

Sub-Basin: **Se Bang Fai - Lao PDR**
Station: Tributary mouth
Coordinate: N16.98 E104.83

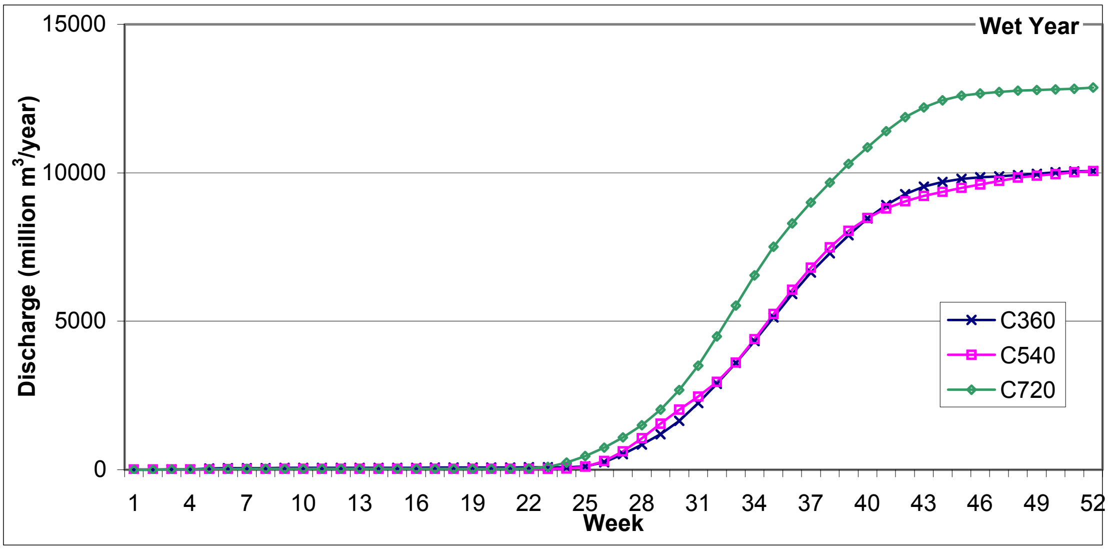


Period	Discharge Level
Base line year	8,330 million cubic meters / year
Compare C-360 & C-540	- 4.54 %
Compare C-360 & C-720	+ 14.92 %

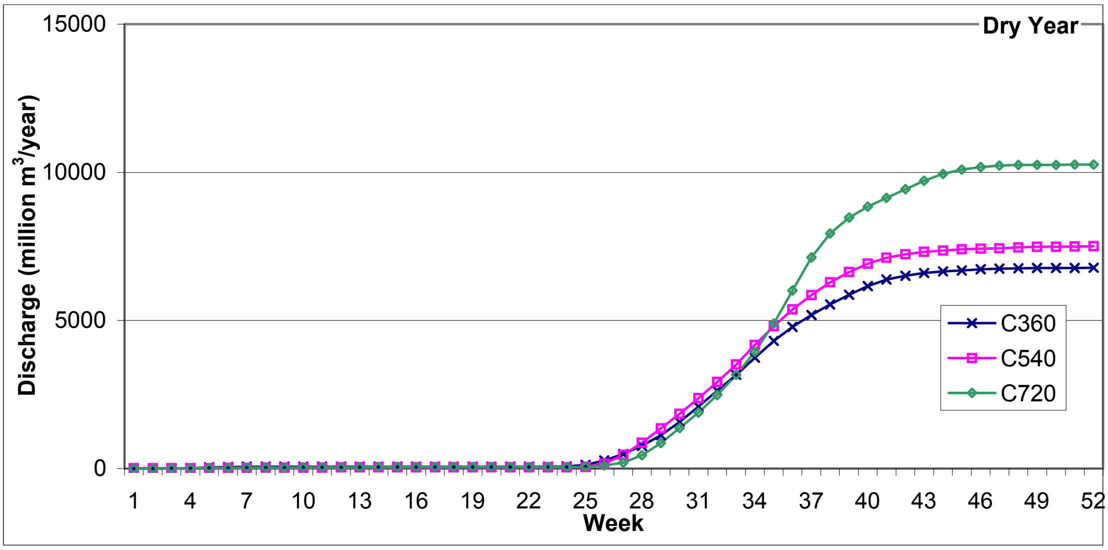


Period	Discharge Level
Base line year	6,412 million cubic meters / year
Compare C-360 & C-540	+ 1.40 %
Compare C-360 & C-720	+ 32.69 %

Sub-Basin: **Se Bang Hieng - Lao PDR**
Station: Tributary mouth
Coordinate: N16.19 E105.32



Period	Discharge Level
Base line year Compare C-360 & C-540 Compare C-360 & C-720	10,057 million cubic meters / year + 0.04 % + 27.95 %

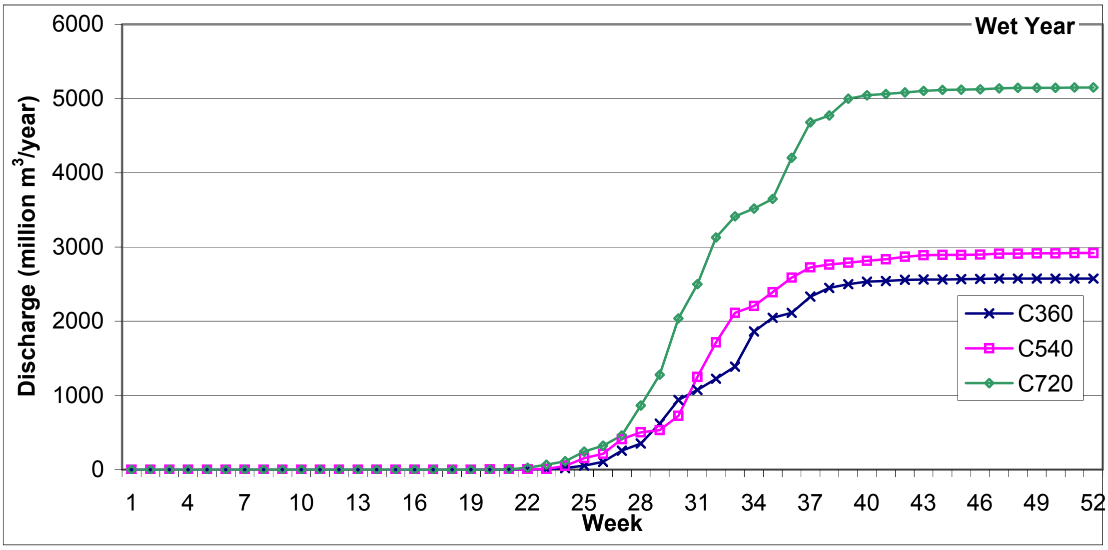


Period	Discharge Level
Base line year Compare C-360 & C-540 Compare C-360 & C-720	6,784 million cubic meters / year + 10.60 % + 51.21 %

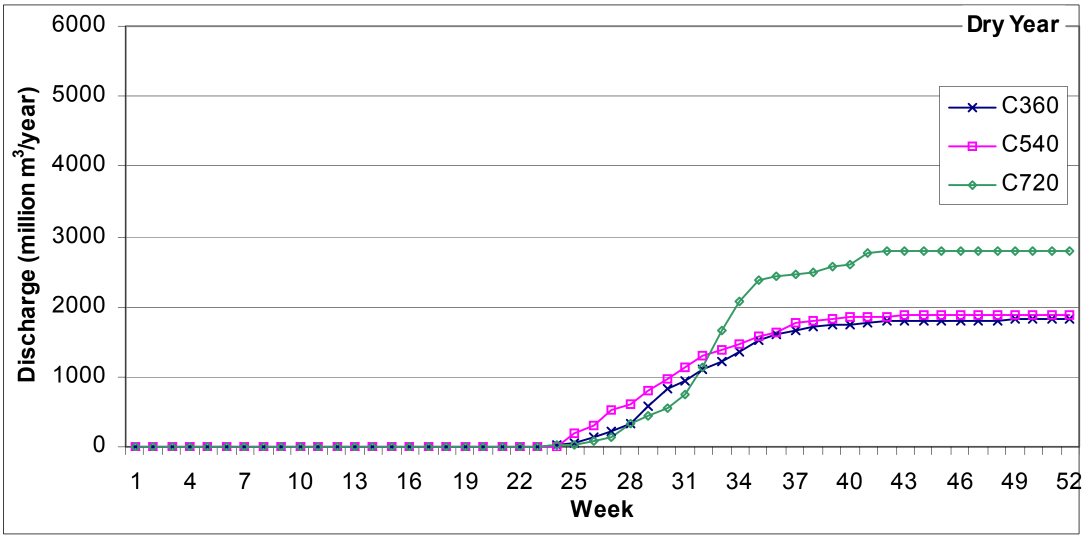
Sub-Basin: **Se Done - Lao PDR**

Station: Tributary mouth

Coordinate: N15.26 E105.84



Period	Discharge Level
Base line year Compare C-360 & C-540 Compare C-360 & C-720	2,574 million cubic meters / year + 13.30 % + 100.05 %

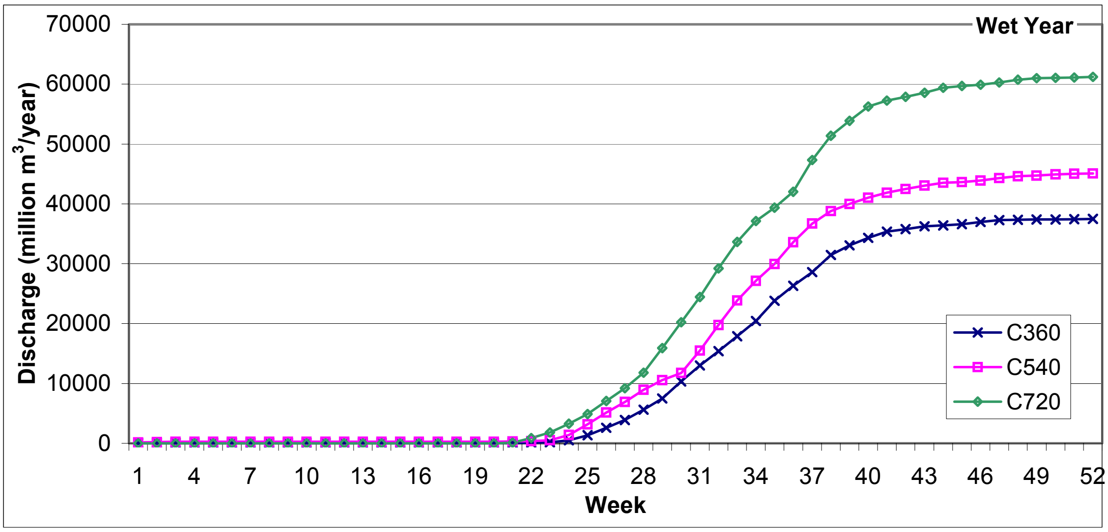


Period	Discharge Level
Base line year Compare C-360 & C-540 Compare C-360 & C-720	1,829 million cubic meters / year + 2.91 % + 53.43 %

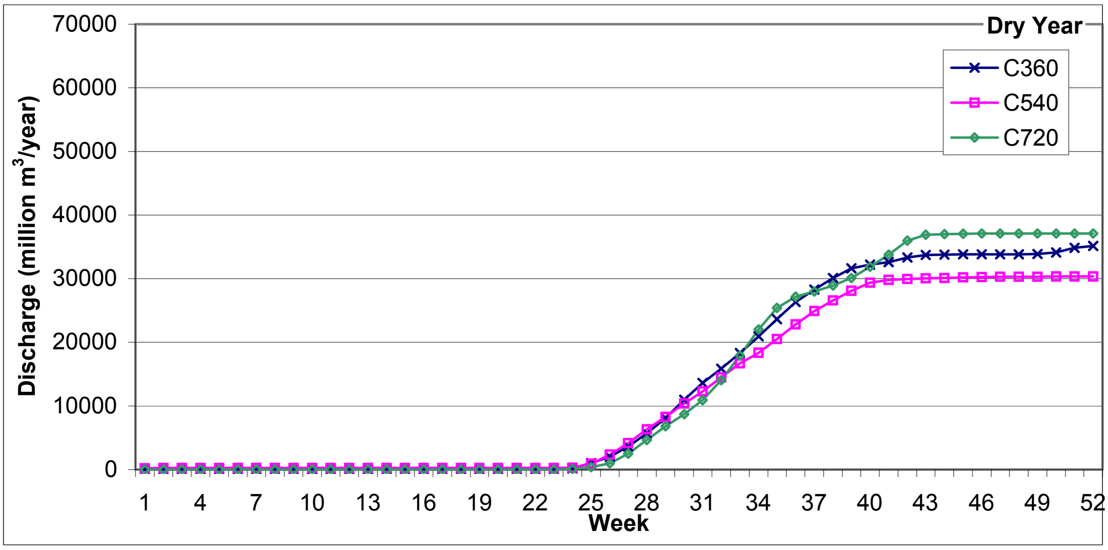
Sub-Basin: **Se Kong - Lao PDR**

Station: Tributary mouth

Coordinate: N13.67 E106.13



Period	Discharge Level
Base line year Compare C-360 & C-540 Compare C-360 & C-720	37,506 million cubic meters / year + 20.20 % + 63.21 %

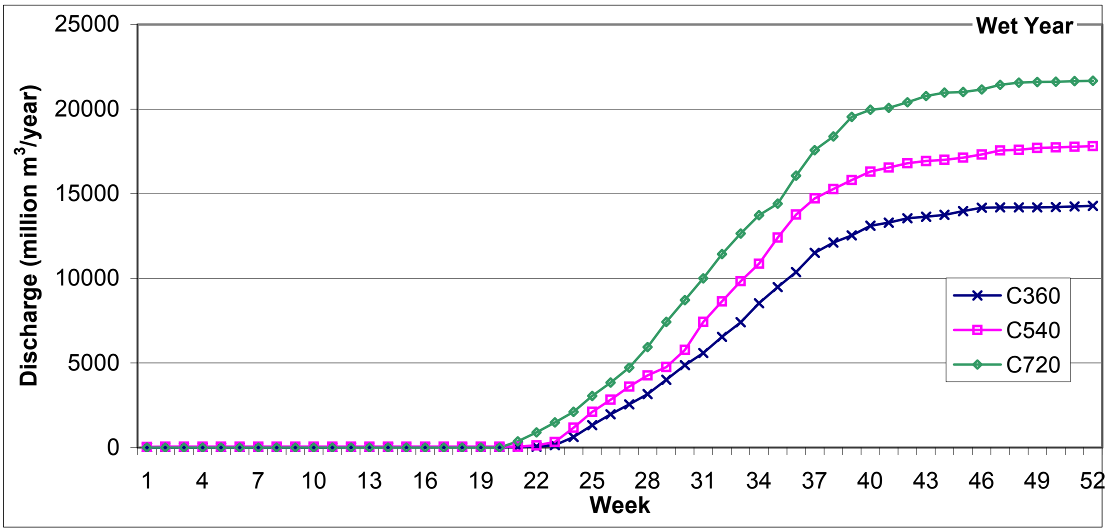


Period	Discharge Level
Base line year Compare C-360 & C-540 Compare C-360 & C-720	35,138 million cubic meters / year -13.64 % + 5.57 %

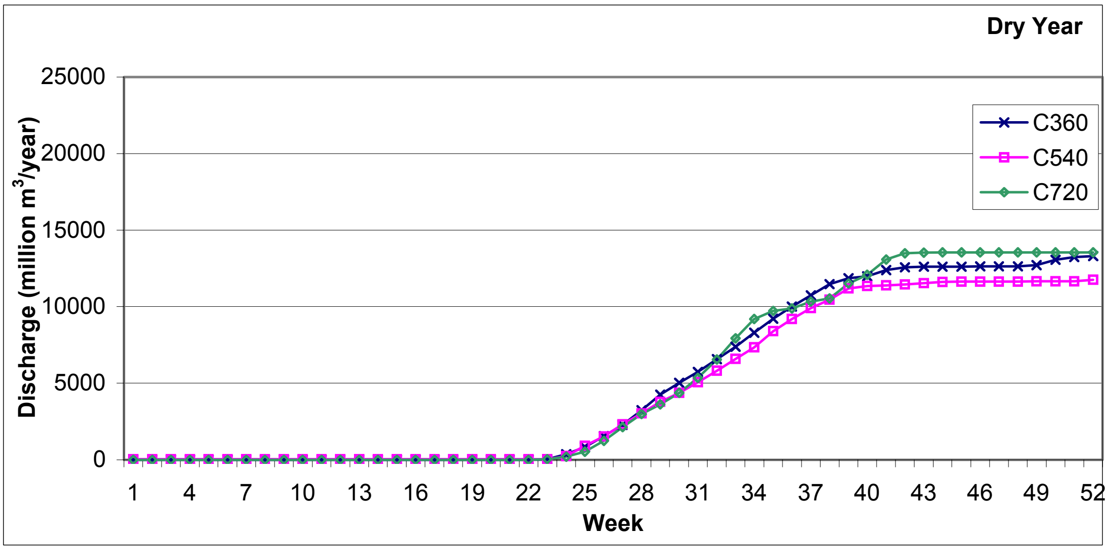
Sub-Basin: **Se Son - Lao PDR**

Station: Tributary mouth

Coordinate: N13.58 E106.30



Period	Discharge Level
Base line year	14,279 million cubic meters / year
Compare C-360 & C-540	+ 24.74 %
Compare C-360 & C-720	+ 51.75 %

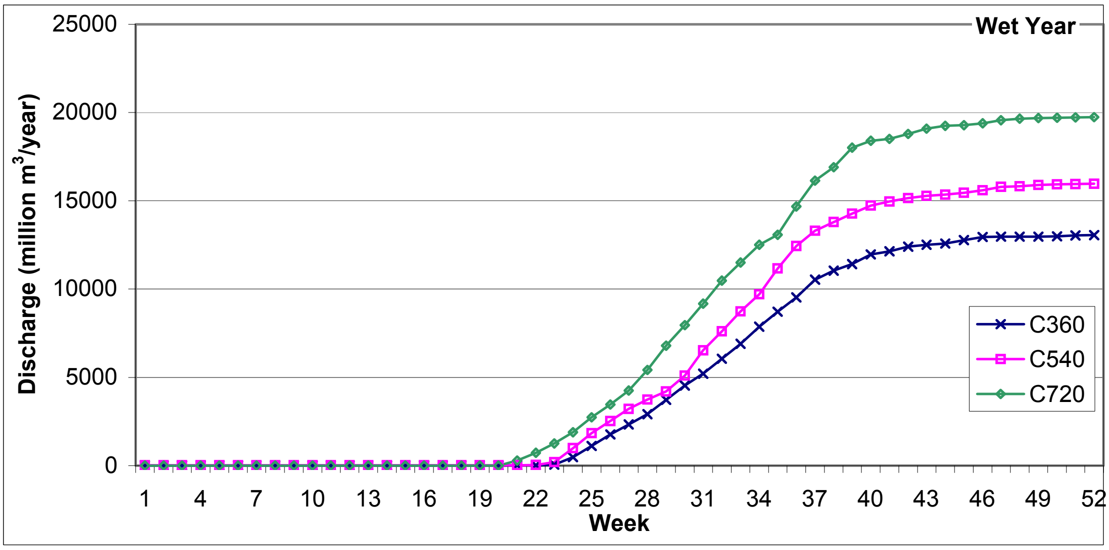


Period	Discharge Level
Base line year	13,303 million cubic meters / year
Compare C-360 & C-540	- 11.60 %
Compare C-360 & C-720	+ 1.84 %

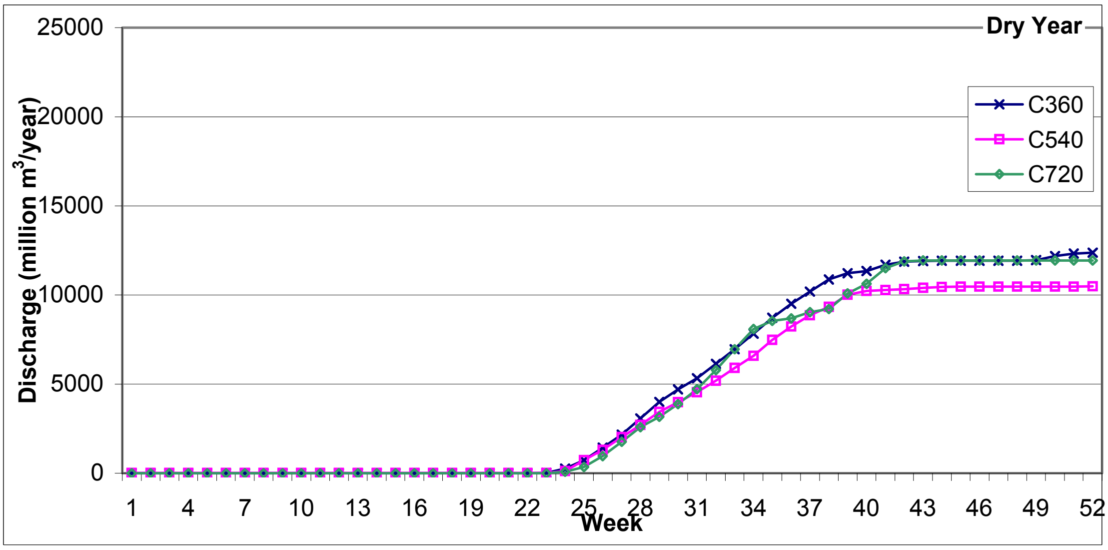
Sub-Basin: **Se Pok - Lao PDR**

Station: Tributary mouth

Coordinate: N13.50 E106.30

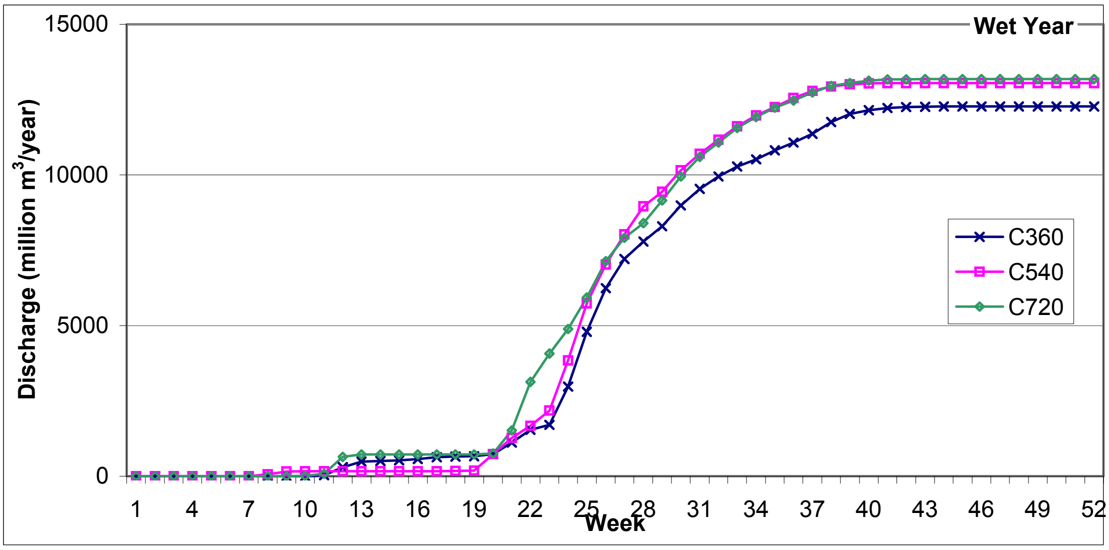


Period	Discharge Level
Base line year	13,050 million cubic meters / year
Compare C-360 & C-540	+ 22.39 %
Compare C-360 & C-720	+ 51.26 %

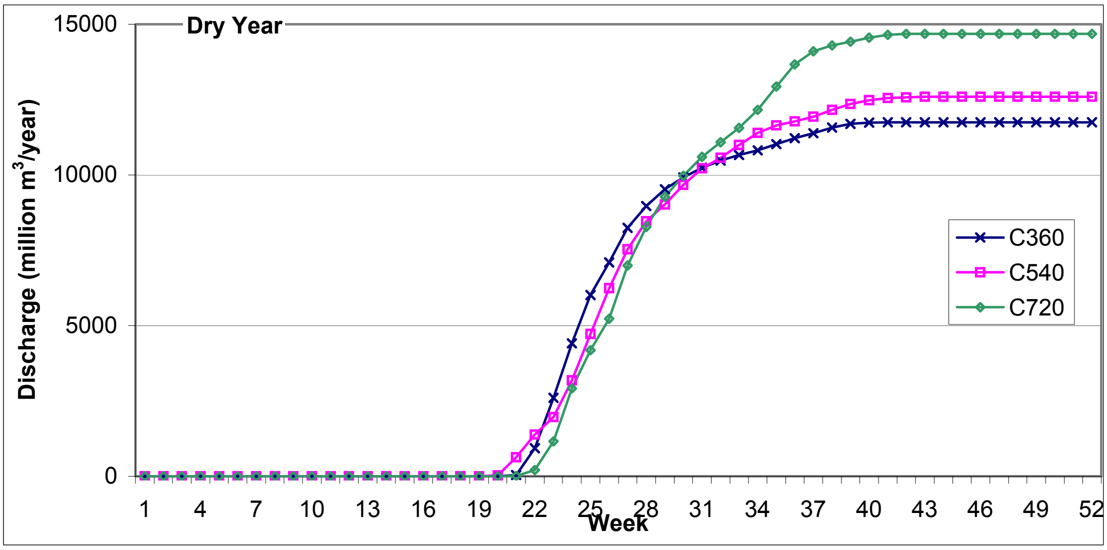


Period	Discharge Level
Base line year	12,382 million cubic meters / year
Compare C-360 & C-540	- 15.29 %
Compare C-360 & C-720	- 3.53 %

Sub-Basin:	**Nam Songkhram - Thailand**
Station:	Tributary mouth
Coordinate:	N17.68 E104.35



Period	Discharge Level
Base line year	12,270 million cubic meters / year
Compare C-360 & C-540	+ 6.34 %
Compare C-360 & C-720	+ 7.41 %

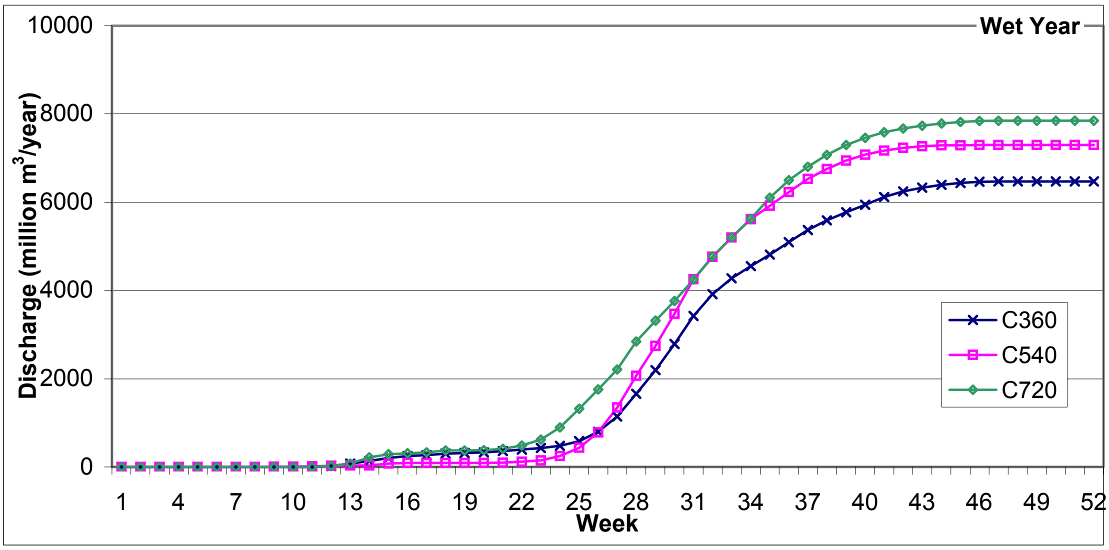


Period	Discharge Level
Base line year	11,750 million cubic meters / year
Compare C-360 & C-540	+ 7.18 %
Compare C-360 & C-720	+ 24.98 %

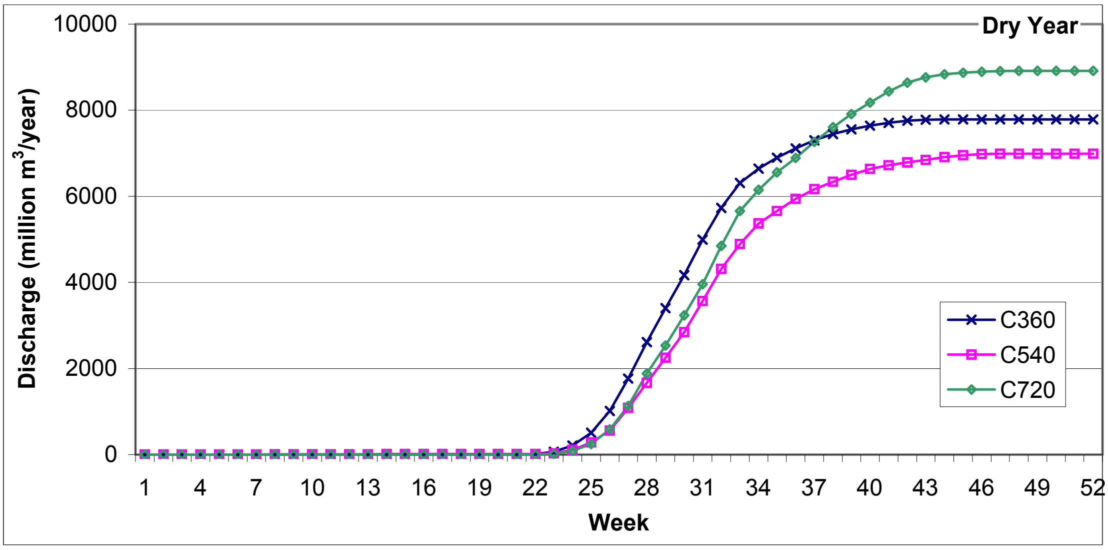
Sub-Basin: **Nam Chi - Thailand**

Station: Tributary mouth

Coordinate: N15.26 E104.66

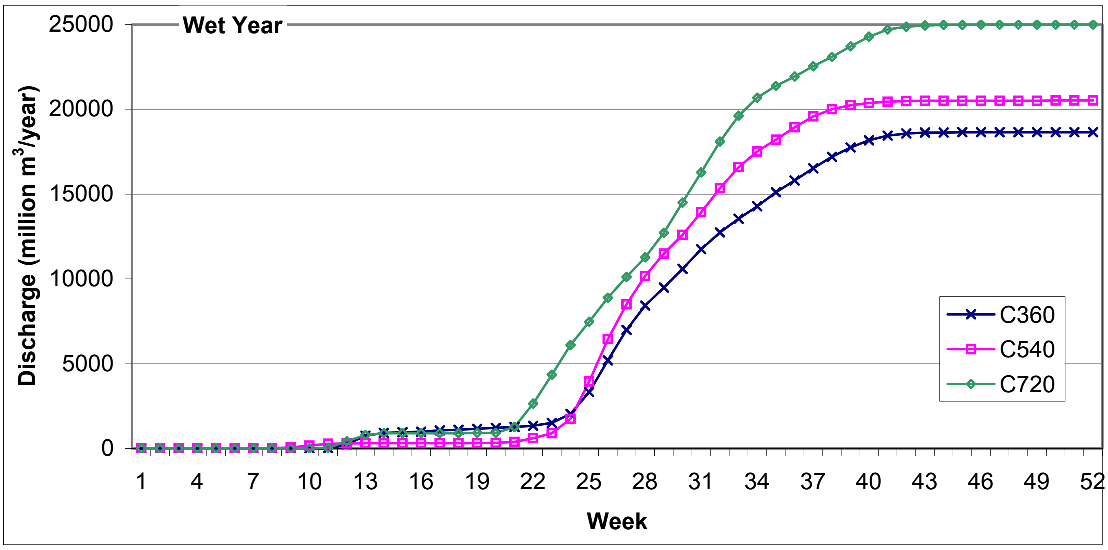


Period	Discharge Level
Base line year Compare C-360 & C-540 Compare C-360 & C-720	6,473 million cubic meters / year + 12.73 % + 21.27 %

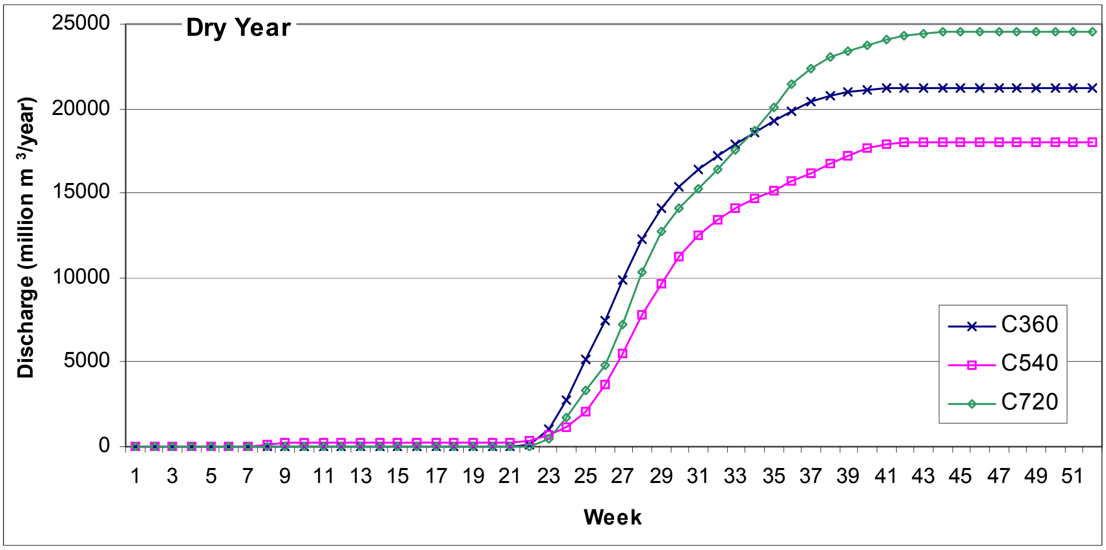


Period	Discharge Level
Base line year Compare C-360 & C-540 Compare C-360 & C-720	7,788 million cubic meters / year - 10.24 % + 14.43 %

Sub-Basin:	**Nam Mun - Thailand**
Station:	Tributary mouth
Coordinate:	N15.26 E105.45



Period	Discharge Level
Base line year Compare C-360 & C-540 Compare C-360 & C-720	18,645 million cubic meters / year + 10.02 % + 34.06 %



Period	Discharge Level
Base line year Compare C-360 & C-540 Compare C-360 & C-720	21,232 million cubic meters / year - 15.01 % + 15.39 %