FINAL REPORT for APN PROJECT
CRP2008-03CMY-Jintrawet

APN
Asia-Pacific Network for Global Change Research
CAPaBLE

- Making a Difference –

Scientific Capacity Building & Enhancement for Sustainable Development in Developing Countries

Climate Change in Southeast Asia and Assessment on Impact, Vulnerability and Adaptation on Rice Production and Water Resource

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Project Reference Number: CRP2008-03CMY-Jintrawet
Final Report submitted to APN

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OVERVIEW OF PROJECT WORK AND OUTCOMES

Non-technical summary

This research project aims to enhance research capacity of scientists in Southeast Asia on the subject of climate change with a focus on impact, vulnerability and adaptation, especially on rice production and water resource. Activities under this research project include developing of high resolution future climate scenarios for Southeast Asia region as well as southern region of People Republic of China based regional climate model simulation. A field experiment was conducted to measure rice productivity under different soil fertility treatments and weather conditions. Impacts of climate change was assessed as pilot study in two scales: watershed scale, which assessed the future rice productivity and concerns on water resource in the Chi & Mun river basins, and also at the community scale, which focused on risk and adaptation to future climate change of farmer communities in the Chi watershed and in central region of Lao PDR. The assessment at watershed scale shows various plausible futures of rice productivity under influence of climate change and change in cropping area, which may be driven by future socio-economic condition. Changing climate and cropping pattern may alter water demand for agriculture activity, in this regard; concern on water resource in the Chi-Mun river basins was assessed. At the community scale, the assessment was conducted at Lao-oi District, Chi river watershed in Thailand and Champhone District, central region of Lao PDR, which addressed risk and possible adaptation to cope with future risk from changing climate. The major outcomes from this research consists of data, which has been used for many studies on climate change in Southeast Asia region, and method on climate change impact, vulnerability and adaptation assessment was tested, of which knowledge gained from the research activities was transferred to number of researchers in the region.

Objectives

To enhance research capacity in the Southeast Asia countries on the assessment of impact, vulnerability and adaptation to climate change on food production and water resource sectors through the following research activities:

- Developing high resolution regional climate scenarios for Southeast Asia
- Pilot study on impact of climate change on soil fertility and rice productivity in pilot study site(s) in Southeast Asia.
- Pilot study on impact of climate change on food production and hydrological regime in major watershed(s) in Southeast Asia.
- Pilot study on assessing vulnerability and adaptation options to impact of climate change for community at the pilot study site(s).

In addition to enhancing research capacity of researchers, this study also aims to create awareness on climate change and its impact to policy maker and public in the Southeast Asia as well as to international research community.

Amount received and number years supported

The Grant awarded to this project was:
US$ 59,553.79 for 1 Year 2006
US$ 57,811.85 for 1 year 2007/2008
US$ 49,269.45 for 1 year 2009/2010

Total support fund: US$166,635.09

Activity undertaken

- Developing high resolution climate scenarios for Southeast Asia region and Mekong River basin for 1960-2100
    - Assign researchers to attend regional climate model training workshop conducted by Malaysia Meteorological Department and Hadley Centre, The Met Office, UK.
    - Set up simulation system at Institute of Meteorology, Hydrology and Environment (IMHEN), Vietnam and Southeast Asia START Regional Center, Thailand to simulate future climate projections.
- Pilot study on impact of climate change on soil fertility and rice productivity in Southeast Asia
    - Rice field experiment at Chiang Mai University in Chiang Mai Province, Thailand
- Pilot study on impact of climate change on food production and hydrological regime
    - Simulation of future rice productivity under influence of climate change and change in crop production area pattern from change in socio-economic condition in Chi & Mun River basin, Thailand
    - Analyze change in future water requirement for agricultural sector in Chi & Mun river basin, Thailand and assess concern on water resource under influence of future change
- Pilot study on assessing risk, vulnerability and adaptation options to impact of climate change at study sites in Thailand and Lao PDR as follows:
    - Lao-Oi District, Kalasin Province, Thailand
    - Champhone District, Savannakhet Province, Lao PDR
- Dissemination
    - Demonstration on climate change risk assessment for researchers in Southeast Asia region at workshop, which was conducted at Can Tho University, Vietnam
    - Set up website for data distribution: Climate Change Data Distribution System (http://cc.start.or.th)

Results

- High resolution future climate scenarios for Southeast Asia region (downscale result from PRECIS regional climate model base on ECHAM4 GCM A2 and B2 SRES scenarios).
- Field test result on soil fertility and rice productivity under different weather patterns.
- Framework on assessment of risk, vulnerability and adaptation of system/sector/community to climate change.
- Policy support data & information: data and part of research finding were used to support the preparation of the Second National Communication of Thailand to UNFCCC, National Target Program to Response to Climate Change (Vietnam), Climate Change Adaptation Initiative of Mekong River Commission, etc.
- Research network:
    - Lao PDR: Water Resources and Environment Research Institute (WERI)
    - Thailand: Chiang Mai University, Southeast Asia START Regional Center, Khon Kaen University
    - Vietnam: Institute of Meteorology, Hydrology and Environment (IMHEN), Can Tho University
    - United Kingdom: Hadley Centre, The Met Office

Relevance to APN's Science Agenda and objectives

This research focused on building knowledge on climate change and its impact on food production and water resource in the Southeast Asia as well as risk, vulnerability and adaptation at various scale in the selected pilot study sites. Result from the study has been used by policy makers at the national level in the regions, e.g. Ministry of Natural Resource and Environment of Thailand and Vietnam, National Social and Economic Development Board (NESDB), Thailand, as well as regional organization, such as Mekong River Commission, etc. as well as support research and academic community in the region. Result and lesson learned from the study as well as research capacity, which was built under this research project were used to supports adaptation decision making at community level as well as national level, e.g. the study to support preparation of Second National Communication of Thailand to UNFCCC, the 11th National Social and Economic Development Plan (Thailand), National Target Program to Response to Climate Change (Vietnam), etc.

Self evaluation

The research project delivered results and produced outcomes as intended, which has been adopted and actively involved in the climate change policy making in the region. However, the project has stretched longer than expected, of which, partly due to the commitment on active involvement of some research partners as well as under estimation of technical complication, and also due to the administration process at the end of each year.

Potential for further work

- In this study, the research team had initiated the development of high resolution regional climate scenario, but the study on climate change would need multiple scenarios in order to cope with uncertainty from long term climate projection. Diversity of scenarios would enhance robustness in the assessment on impact, risk, vulnerability and adaptation to climate change. Future direction would be to develop additional high resolution climate scenario for the Southeast Asia region. Moreover, access to high resolution global climate model, which would require no downscale process e.g. the climate projection which is being developed at National Institute of Environmental Sciences - Japan, and make the dataset accessible to the researchers and policy makers would be future direction of the research team.
- In this report, the research team presents the accomplishments from the first two years of the APN-funded project rice experiment at the Multiple Cropping Center, Chiang Mai University, Thailand, providing details of completed experiment and ongoing simulation studies. Future directions of our group in Chiang Mai University will continue on long-term rice experiment and to further improve the crop modeling - CropDSS interface shell to allow studies in other locations.
- Assessment on impact, risk, vulnerability and adaptation to climate change should be expanded to cover wider range of system / sectors in other key areas in the region using different climate and socio-economic scenarios. The assessment should base on integrated multiple sectors with area-based V&A assessment approach which take inter-relationship between and among sectors into consideration with linkage to sustainable livelihood framework in order to provide holistic view of the vulnerability and adaptation of the area at risk. Moreover, the combined ecosystem-based adaptation and community-based adaptation should also be further explored in the area where livelihood of the community depends on ecosystem integrity.
- More capacity research building should be further pursued to increase number of researchers who would work on the subject. The capacity building on climate change study should be planned as continuous short-course training program as well as embedded into formal education program in the longer term.
- Pilot implementation in disseminating knowledge on climate change to local stakeholders to initiate community long-term visioning process and strategic planning that take climate change into consideration.

Publications (please write the complete citation)

- Chinvanno, S., V. Luang-Aram, C. Sangmanee and J. Thanakijmethavu. 2009. Simulation of future climate scenario for Thailand and surrounding countries. Southeast Asia START Regional Center technical report. Bangkok, Thailand. (Thai edition)

  (Note: English edition is being planned.)

Contribution to joint publication:

- TKK & SEA START RC. 2009. Water and Climate Change in the Lower Mekong Basin: Diagnosis & recommendations for adaptation, Water and Development Research Group, Helsinki University of Technology (TKK), and Southeast Asia START Regional Center (SEA START RC), Chulalongkorn University. Water & Development Publications, Helsinki University of Technology, Espoo, Finland.

Acknowledgments

The research team of CRP2008-03CMY-Jintrawet project would like to thank the following institutions and resource persons as follows (alphabetical order):

1. Environment Research Institute and Water Resources and Environment Research Institute (WERI), Lao PDR, for their support in the study of climate change risk assessment at local community in Lao PDR.
2. Hadley Centre, Met Office, United Kingdom for their support in providing regional climate model and initial data for simulation of regional future climate projection as well as other technical supports during the simulation process and conclusion of regional climate change scenarios.
3. Institute of Meteorology, Hydrology and Environment (IMHEN), Vietnam and Dr. Fredolin T. Tangang Professor School of Environmental and Natural Resource Sciences, Universiti Kebangsaan Malaysia (National University of Malaysia) for their contribution of data and sharing expertise in the climate scenarios development.
4. Thailand Research Fund for collateral fund to support regional climate modeling simulation and field work on vulnerability and adaptation assessment.
5. The ICASA provides technical supports for CSM-DSSAT rice model development.
6. The Multiple Cropping Center, Faculty of Agriculture, Chiang Mai University, Thailand provides field experimentation supports during 2007-2010.
7. Science and Technology Postgraduate Education and Research Development Office (PERDO), Thailand and ESRI Thailand Company for collateral fund and technical support in developing Climate Change Data Distribution System.
8. Water and Development Research Group, Aalto University, Finland and Ministry of Foreign Affairs, Finland and DRAGON Institute, Can Tho University, Vietnam and WWF Greater Mekong Region for their support in workshop to extend the work under this research further as well as create awareness on the climate change study into wider research community in the region.

TECHNICAL REPORT

Preface

This research aims to fill gap in the climate change study in Southeast Asia region by producing future climate scenarios, which is fundamental information on climate change study, and also conducting pilot study on climate change impact on water resource and rice production in the region as well as to test method in assessing risk, vulnerability and adaptation of system/sector/community to climate change. The output of this research will contribute directly to the preparation of Second National Communication to UNFCCC and support climate change policy planning for the countries in the region as well as be used as foundation for further study or assessment in various aspects of climate change in Southeast Asia as well as Mekong River basin.

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1.0 Introduction

Climate change, which is induced by global warming, could put various sectors in the Southeast Asia countries at risk. Long term strategy and national plan toward climate change adaptation would be required to cope with potential impact of climate change. However, knowledge, information and research capacity that would help lead to better understanding about impact of climate change as well as vulnerability and adaptation to climate change impact is still limited in the region. This project aims to fill these gaps by developing high resolution future climate scenarios to be foundation of climate change impact assessment. In addition, pilot study in selected areas will enhance research capacity and also produce framework for further impact, risk, vulnerability and adaptation assessment that would fit the context of the country and the region of Southeast Asia. Moreover, findings from this study about impact of climate change and concerns on water resources, which are the main concerns of the countries in the region, as well as knowledge on risk and adaptation to climate change has been and will be used to support various national policies planning and also to support the preparation of the Second National Communication (SNC) to UNFCCC, which would emphasize substantially more on the impacts of climate change on natural system and human society than its first generation.

2.0 Methodology

The study consist of various components, starting from dynamic downscaling of future climate using regional climate model, field experiment on rice production under different soil fertility, simulation of impact of climate change on future rice productivity and water resource based on data from climate model simulation. Furthermore risk, vulnerability and adaptation were assessed with focus on farmer community, who would directly get impact influence of climate change.

Experimental details are explained separately by each research component as follows:

2.1 Developing high resolution climate scenarios for Southeast Asia region and Mekong River basin for 1960-2100

Suppakorn Chinvanno, Viriya Luang-aram, Chalermrat Saengmanee, Jutatip Thanakitmetavut

Scope:

This study used PRECIS regional climate model (RCM) to downscale ECHAM4 GCM data, which is based on SRES A2 and B2 GHG scenario. The downscaling process was set to resolution of .22º and output was rescaled to 20x20km resolution. Domain coverage is lat. 0-35ºN and lon. 90º-112ºE. Period of simulation covers baseline condition during 1970-1999 and future projection during 2010-2100. The simulation provides output with daily time-step throughout the simulating period.

Method

- Dynamic downscaling

  A regional climate model (RCM) is a downscaling tool that adds fine scale (high resolution) information to the large-scale projections of a global general circulation model (GCM). GCMs are typically run with horizontal scales of few hundred kilometers; regional models can resolve features down to much more smaller scale, e.g. 50km or less. This makes for a more accurate representation of many surface features, such as complex mountain topographies and coastlines. It also allows small islands and peninsulae to be represented realistically, where in a global model their size would mean their climate would be that of the surrounding ocean. RCMs are full climate models, and as such are physically based. They represent most if not all of the processes, interactions and feedbacks between components of the climate system represented in GCMs. They produce a comprehensive set of output data over the model domain. This study used regional climate model called PRECIS for downscaling coarse scale GCM to get the climate change scenarios for Southeast Asia region as well as the southern region of People Republic of China.

PRECIS is a regional climate model that was developed by Hadley Centre for Climate Prediction and Research and is based on the Hadley Centre's regional climate modelling system. It can be used as a downscaling tool that adds fine scale (high resolution) information to the large-scale projections of a global general circulation model (GCM). It has been ported to run on a PC (under Linux) with a simple user interface, so that experiments can easily be set up over any region. PRECIS was developed in order to help generate high-resolution climate change information for as many regions of the world as possible. These scenarios can be used in impact, vulnerability and adaptation studies. (Simson et al, 2006).

- Rescaling
  The output from PRECIS regional climate model was verified by comparing against data from observation stations from the period of 1980s, which was selected as baseline for verification. The comparison shows that the result of RCM is somewhat differ from the observed weather data. PRECIS model tends to overestimate temperature and underestimate precipitation in many areas. "Rescaling" technique was developed and applied to the simulation result from PRECIS model in order to adjust the simulated data to better match real condition based on observation data.

  Rescale technique, which was developed and used in this study, is based on the difference of key climate parameters, i.e. temperature and precipitation, between the simulated and observation data from 130 weather observation stations in Thailand, China, India, Myanmar, Lao PDR, Vietnam, Malaysia and Indonesia. The rescaling process is the process to 'suppress' and 'lift' the simulated data throughout the simulation domain by using coefficient value that was calculated from different of average values of key weather parameters between simulated and observation data during 1980s at number of station grids in the simulation domain and those values at the station grids were interpolated using kriging technique to get the coefficient value for every grids that will be used to rescale the simulated result of each climate grid throughout the simulation domain over the period of the simulation. By applying this technique, simulated data of key climate parameters from the simulation were rescaled to be closer to the observation value. *(For more details please see Appendix 4: Developing regional climate scenarios using rescaling technique on regional climate model output)*

Result
Simulation results from PRECIS regional climate model, after rescaling process, shows that average maximum temperature as well as average minimum temperature in Southeast Asia region in the future will increase which tend to be more prominent from the middle of the 21st century onward. The trend of warming temperature is clearly seen in the central plain of Thailand and most part of Cambodia. Range of temperature increase in the future is approximately 2-3ºC during the middle of the century and trend continues to increase till the end of the century when most part of the region will be warmer.

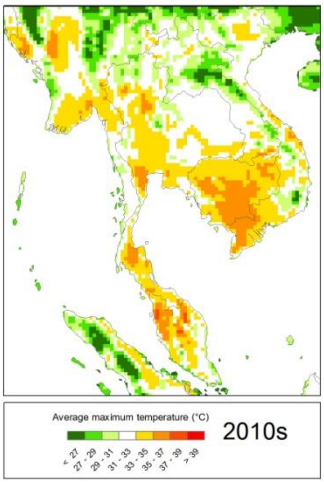
In addition to the changing in magnitude aspect, change in future temperature also occurs in temporal aspect. Southeast Asia region tends to have longer hot period during the year. This changing in temporal aspect can be seen in the change of number of hot day over the year. The number of 'hot day' or as defined in this study, which is the day with maximum temperature is 35ºC or higher, will be higher in the future, i.e. the simulation result from PRECIS model shows that during the baseline period most part of north and northeastern region of Thailand have hot period of 3-4 months over the year, while the central plain and southern region have slightly longer summertime.

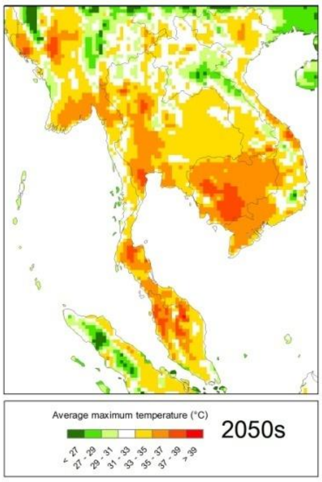
In the future by middle of this century, hot period over the year would extend longer by a few months in most of the lower latitude area in the mainland Southeast Asia region, e.g. southern and central region of Thailand, Malaysia, Cambodia and Mekong River Delta in Vietnam. Trend of change will be more prominent toward the end of the century when hot period will become even longer.

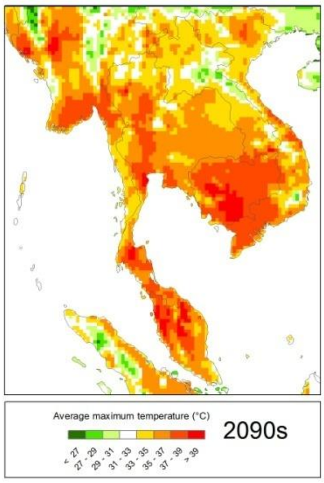
PRECIS result also shows trend of slight change on the 'cool period', or number of days in the year that the minimum temperature is 16ºC or below. Cool period, or in other word - wintertime, in Thailand and surrounding countries will become shorter than baseline climate pattern, even though not as prominent as the trend of change on the 'hot period'.

Annual total precipitation may fluctuate in the early decades of the century, but simulation result shows trend of higher precipitation throughout the Southeast Asia region in the future, especially toward the end of the century. Most part of Thailand may have higher precipitation by 25% or as high as 50% in some areas.

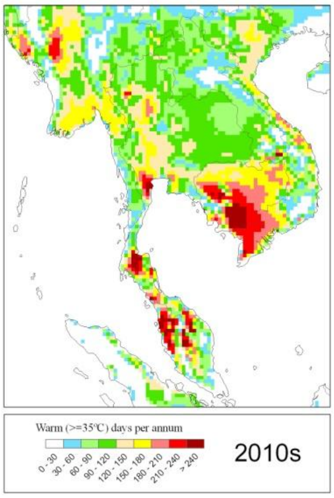
Illustrations below show example of future climate change in mainland Southeast Asia, which is result from the downscaling in this study. *(Also see Appendix 5: Future climate projection – climate change scenario for Southeast Asia)*

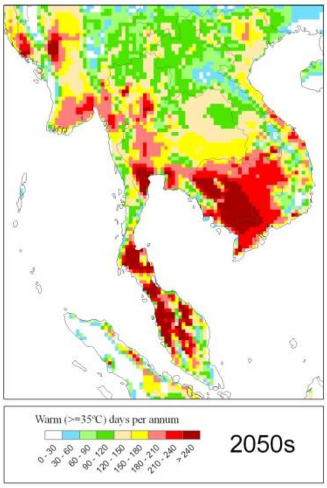


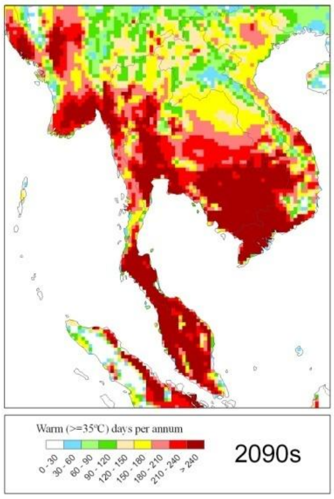




Average annual maximum temperature (ºC)







Average annual hot days (= >35ºC)

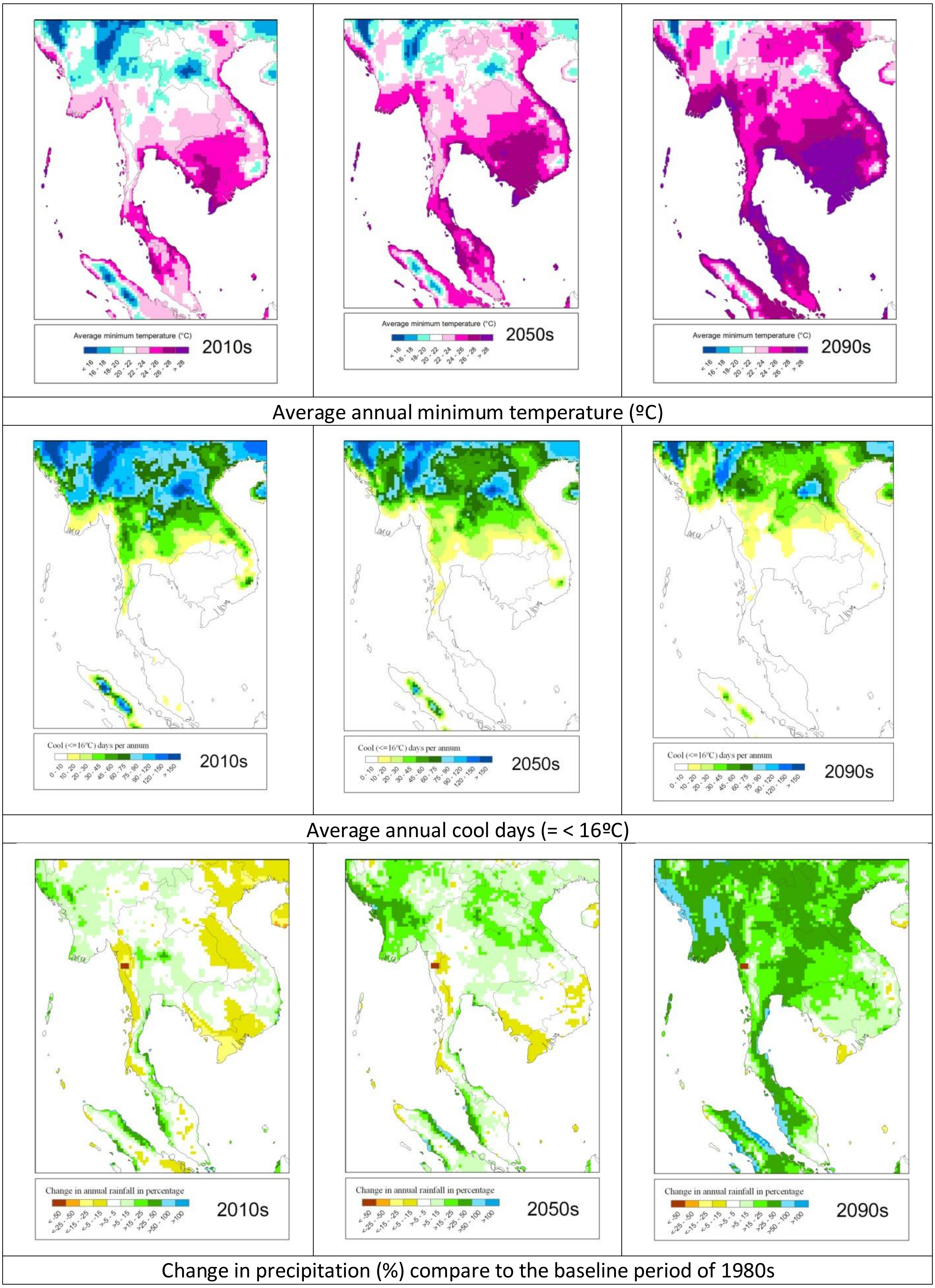


Figure 1: Examples of illustration show future climate in the mainland Southeast Asia

In brief, future climate in the mainland Southeast Asia countries tends to be warmer with longer summertime and heavier rainfall during rainy season with higher annual total precipitation. Future changes in climate pattern needs to be taken into consideration on various aspects, i.e. in addition to change in mean value of the climate variables, the change in range of each variable as well as fluctuation over period of time and change in temporal aspect e.g. change in the length of season and shifting of season, etc. These changes are likely that it will be irreversible and would have impact on various systems and sectors. However, this future climate projection is just one plausible future which was simulated by single climate model and single initial dataset. Additional climate change scenarios need to be further developed to address the uncertainty of the long-term climate projection. Moreover, inter-comparison among other climate models is required to evaluate the result of this experiment that would lead to improvement in future regional climate scenario simulation in the future.

2.2 Pilot study on impact of climate change on soil fertility and rice productivity in Southeast Asia: Field experiment in Chiengmai Province, Thailand

Attachai Jintrawet, Pantip Nontree, Tupthai Norsuwan, Thana Chantra and Jaturong Puangmanee

In major rice production systems, rice productivity is not directly based on soil fertility and its management and impact of climate change. However, it is relevant to explore whether the crop growth simulation and spatial database can be used to provide linkage between climate change, crop residue, nitrogen management, and rice productivity. In addition, regional and national assessment is not directly relevant for developing practical farm level interventions, however, it may help to formulate regional strategies and policies focusing at soil fertility improvement, preventing and restoring soil fertility decline, and proper soil fertility research programs. The purpose of this section is to report results of rice field experiments and results of a simulation study on soil fertility, climate variability and change as predicted by the ECHAM4 model under A2 and B2 SRES scenarios, using the CropDSS interface and CSM-DSSAT-Rice model, on rice production systems in Thailand.

Method

The field experiment was conducted at the Multiple Cropping Center, Faculty of Agriculture, Chiang Mai University, Thailand during dry season 2006-wet season 2010, with four planting dates (Table 1). SanPaTong, a glutinous non-photoperiod sensitive, rice cultivar was used. The soil was classified as San Sai soil series, according to Land Development Department, and Coarse loamy, mixed, isohyperthermic, Type Tropaqualfs, according to US Soil Taxonomy. The soil physico-chemical properties were analyzed by the standard methods of soil analysis and presented in Table 2. The chemical analysis of topsoil (0–15 cm) in showed pH (H2O) of 5.1 (a 1:1 ratio of soil/water), total nitrogen 1.27 g kg^{-1}, extractable P 518.3 mg kg^{-1} (Bray1), and exchangeable K 5.1 mg kg^{-1}.

	
Rice transplanting in row	Experimental field after rice transplanting

(25x25 cm spacing)	
	
Plant sampling	Chemical fertilizer application
	
Experimental field	Experimental field
	
Harvesting	Harvesting

Figure 2: Rice production in the experimental field at Chiang Mai University

Table 1: Planting dates of rice experiments at Multiple Cropping Center, Chiang mai University, Thailand during 2006-2010.

Planting dates	Rice phenological dates		
	Transplanting	Averaged Heading	Averaged Harvesting
Date 1	December 10, 2006	March 20, 2007	April 20, 2007
Date 2	August 10, 2007	November 10, 2007	December 12, 2007
Date 3	January 6, 2008	March 8, 2008	April 10, 2008
			Nargis cyclone April 27-May 3, 2008
Date 4	August 10, 2008	November 7, 2008	December 19, 2008
Date 5	scheduled for January, 2009.	not implemented due to drought and funding delay.	
Date 6	scheduled for August 2009.	not implemented due to drought and funding delay.	
Date 7	August 15, 2010	December 2010.	

Table 2: Soil physico-chemical properties of the experimental field.

	pH	Organic Matter (g/100 g soil)	Total Nitrogen (g/100 g soil)	Exch. P (mg/kg)	Exch. K (mg/kg)
Date 1	5.05	1.27		518.3	5.05
Date 2	5.22	-	0.064	364.3	39.6
Date 3	5.15	-	0.074	374.3	29.6
Date 4	5.35	-	0.054	484.3	20.6
Date 7	Samples are being analyzed by the Soil Science Laboratory. Chiang Mai University.				

Four soil nutrient management treatments were implemented as follows;

T1: no mineral fertilizer application.

T2: Department of Agriculture recommendation, applications of 40 kg N/ha at 15 day after transplanted (DAT) and application of urea mineral fertilizer at 125 kg/ha at 45 DAT.

T3: Double T2 rate.

T4: Triple T2 rate.

Daily weather data, solar radiation, maximum and minimum temperature and rainfall, were collected from the research farm's weather station. The data was formatted for used with the CSM-DSSAT45 rice model and CropDSS shell.

The study of impact of climate change on food production is based on the field experiment and monitoring for input data to Crop Simulation Model (CSM) rice simulation model (CSM-Rice), a process-oriented model under the Decision Support System for Agrotechnology Transfer (DSSAT45) package version 4.5 (Hoogenboom *et al.*, 2003; Jones *et al.*, 2003; and Porter *et al.*, 2010). The model was used to simulate future potential soil fertility and yield of rice productivity in target study area(s) in the region under different climate scenarios.

The CropDSS shell (JINTRAWET, 2009), developed by Multiple Cropping Center, Chiang Mai University of Thailand, was used to link four types of databases needed by the crop models to facilitate simulation of future potential impact on soil fertility and yield of rice productivity in target study areas Figure .

The crop modeling software will use daily climate data, including maximum and minimum temperature, precipitation, solar radiation, etc. coupled with crop management scheme and soil property to calculate the yield of rice productivity.

In order to demonstrate the capacity of CropDSS in addressing environmental issues at the provincial level, the shell is used to study the impact of climate change on rice production. In this study, the climate scenario is based on a high-resolution regional climate model because the downscaling technique has been proven to elicit accurate and reasonable climate scenarios result for the region. The current resolution is being downscale for correct representation of hydrological cycle variations within river catchments.

Simulation study used SanPaTong 1, a glutinous non-photoperiod sensitive rice cultivar, two planting dates (January 15 and August 15), three production systems, namely potential, well-irrigated and well-supplied of nutrients, and rainfed nitrogen-limited production systems (Penning de Vries and van Laar 1982).

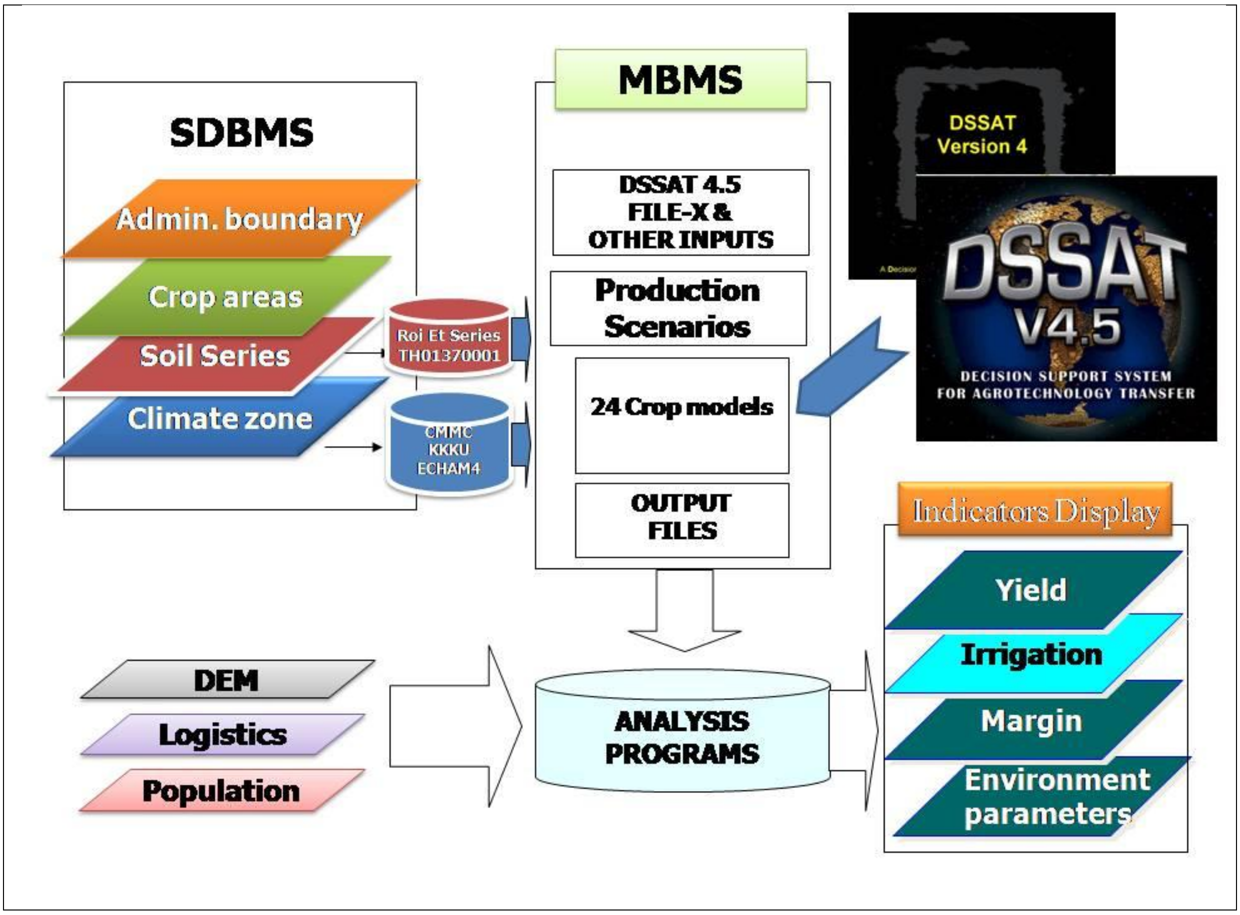


Figure 3 Schematic of CropDSS shell interface, linking spatial database management Systems (SDBMS) and ModelBase Management Systems (MBMS) and analysis programs for assessing impact of climate change in crop production systems (Jintrawet, 2009).

Results & Discussion

Reported rice yields in selected ASEAN countries

A review of existing databases reveals that rice yield per unit area are increasing throughout Southeast Asia countries *Figure* 4. Rice in Vietnam is the highest and Cambodia is the lowest, whereas Thailand rice yield is a little higher than those in Cambodia. The increasing trend is mainly due to success in green revolution technologies in the region. However, several recent studies (Dawe *et al.*, 2000, Yadav *et al.*, 2000; Dobermann *et al.*, 2002, and Ladha *et al.*, 2003) concluded that rice yields in Asia is in a declining trend. Continuous cropping systems and imbalanced soil nutrient management may be responsible for such declining trends and green and animal manure applications should be implemented to elevate the problem.

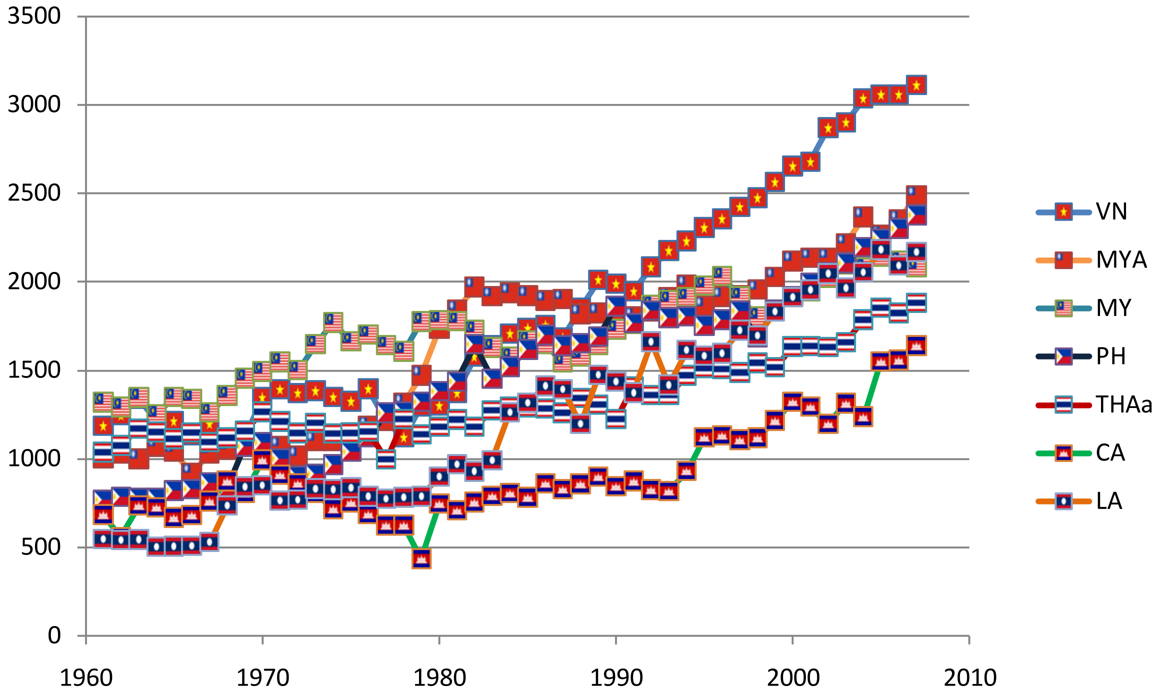


Figure 4: AVERAGED RICE YIELDS (KG/HA) OF SELECTED COUNTRIES IN SOUTHEAST ASIA. Source: http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor

Rice experiment results

Rice grain yields in the wet seasons (3,767 kg/ha) were higher than the dry season (3,204 kg/ha) and significantly different among fertilizer applications. Higher mineral fertilizer application rates yielded higher than un-fertilized treatments (Table 3). Averaged across all fertilizer treatments, rice yields were 2,543 and 3,184 kg/ha in dry and wet season crops in 2007, respectively, and 3,866 and 4,351 kg/ha in 2008, respectively.

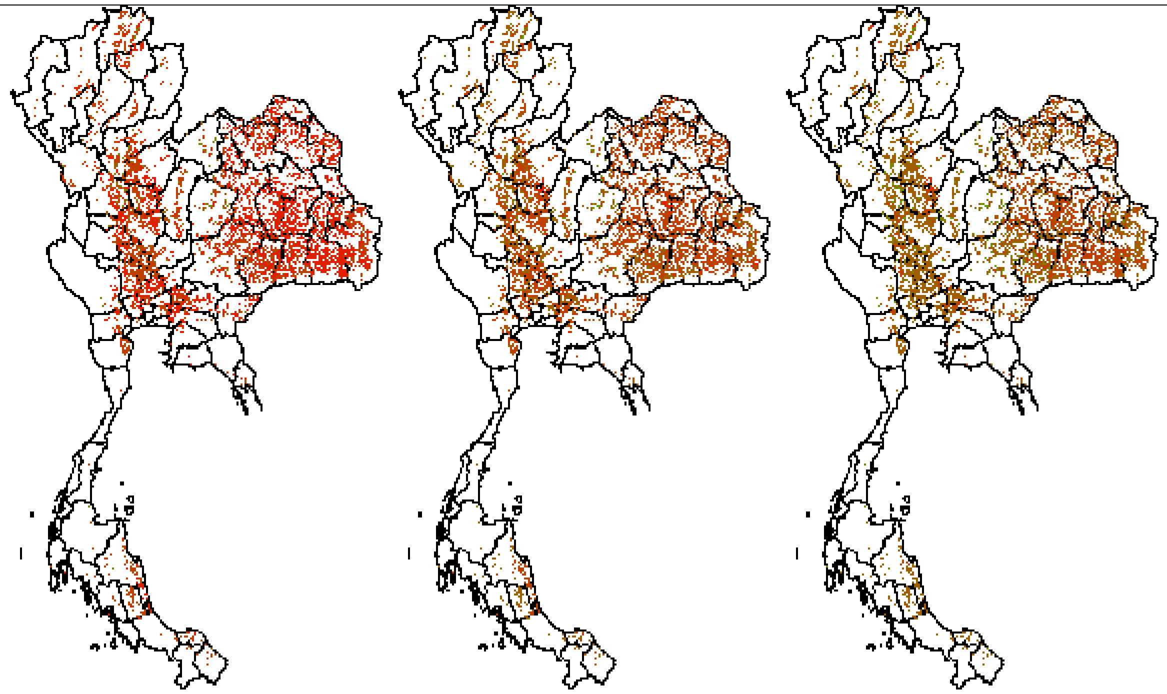
Dry season rice crops positively responded to applications of nitrogen fertilizer as compared to the wet season rice crop, 179% and 114%.in 2007 and 511% and 289% in 2008, respectively. Mineral nitrogen fertilizer application according to DOA's recommendation (T2) increased rice grain yield by about 150% and 262% in dry season of 2007 and 2008, respectively, and about 114% and 205% in wet season of 2007 and 2008, respectively.

Table 3: Mean and standard deviation of grain yields (kg/ha) of SanPaTong 1 rice variety conducted during 2007-2008 crop season at the Multiple Cropping Center, Chiang Mai University, Thailand.

Fertilizer treatments	2007		2008	
	Dry season	Wet season	Dry season	Wet season
		kg/ha		
T1: No fertilizer	1,692 ± 301	2,923 ± 277	1,152 ± 224	2,008 ± 337
T2	2,541 ± 366	3,344 ± 402	3,015 ± 201	4,108 ± 193
T3	2,907 ± 334	3,140 ± 469	5,405 ± 998	5,477 ± 1,037
T4	3,033 ± 341	3,328 ± 561	5,890 ± 732	5,810 ± 272
F-test	**	NS	**	**
$LSD_{0.05}$	242.9	79.1	884.9	693.9

Simulation of impact of climate change on rice yield and soil fertility

FIGURE 5 shows simulated rainfed rice yields during the period of 2010-19 under three soil nutrient management options, namely; a) no application of mineral nitrogen production option (0N), b) addition of 200 g of green manure (200GM) per sq.m production option, and c) application of 60 kg Urea per ha (60UREA).



a) Nitrogen-limited production No nitrogen applied

b) Nitrogen-limited, wtih 200 g GM per sq.m.

c) Nitrogen-limited production 60 kg per ha.applied

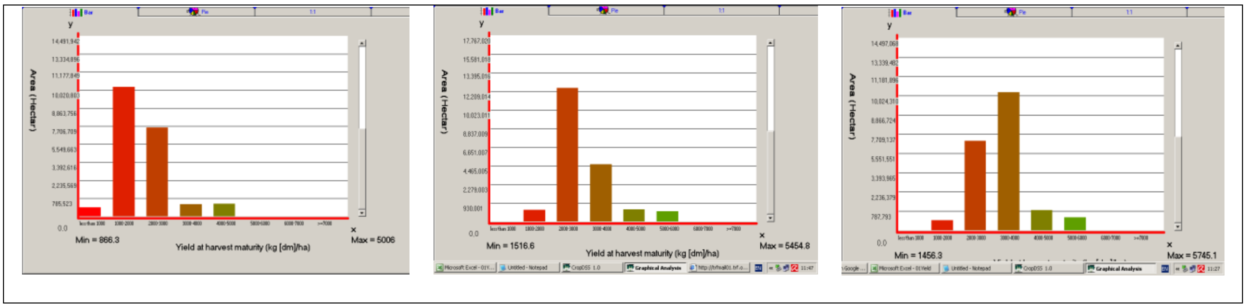


Figure 5: Simulated rice yields (kg/ha) in Thailand under ECHAM4 A2 climate scenario, a) averaged yields of no-nitrogen input production strategy during the period of 2010-19 (FP1); b) 200 g of green manure (GM) per sq.m production strategy; and c) 60 kg per ha.

For the period of 2010-19, under rainfed conditions, the 60UREA option provides 17% and 18% higher simulated rice yields than the 200GM and 0N rice production options, respectively. Also, the 0N and 200GM rice production options provided similar range of simulated rice yields. This is due mainly to in rainfed conditions and low soil fertility level situation the lack of available soil moisture causes low availability of soil nutrients for crop to uptake and utilization. Therefore, moisture regimes must be favorable for decomposition of green manure to take advantages of the addition of 200 g of green manure.

By using daily climate data for the simulation process, this study is able to capture the impact of climate change on rainfed 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.

2.3 Pilot study on impact of climate change on food production and hydrological regime

Suppakorn Chinvanno, Pornwilai Saipothong, Chalermrat Saengmanee, Jutatip Thanakitmetavut

Global warming will induce change in climate pattern, especially rainfall distribution and temperature, which would affect the rain-fed agriculture and water resource. However, climate change is slow process and takes years to be noticeable. Therefore, assessment on impact of climate change would need to incorporate other changes on the system and sector, which in most cases would be driven by social and economic dynamic into the assessment process. Such long term change is highly dynamic, and has great degree of uncertainty, so projection of future change would have to base on scenario from number of assumptions. This concept, while is not new, has been rarely implemented in the climate change assessment in the Southeast Asia region. This study demonstrates the assessment of impact of climate change on rice productivity under different cropping pattern scenarios.

The pilot study was done in the Chi and Mun river basin (see Figure 6), the major river basins in northeastern region of Thailand which covers area of approximately 119,000 km^2, of which over 75% of the area in the river basin is used for agriculture. This area is important annual crop production area in Thailand and most of the agricultural activity is under rain-fed system, therefore, would be directly exposed to influence of climate change.

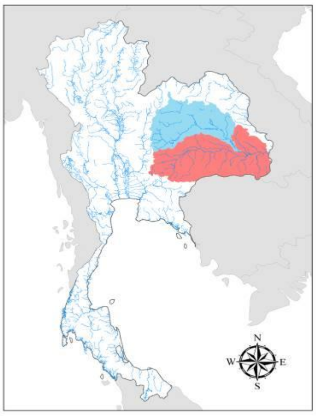


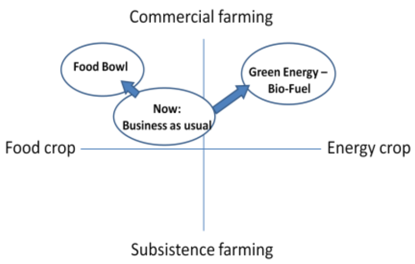
Figure 6: Chi & Mun River basin in northeastern region of Thailand

Scope

- Assess future rice productivity in the Chi & Mun river basin in the decades of 2010s and 2030s compare to the baseline period of 1995-2004.
- Assess concerns on water resource under different cropping pattern scenarios and future climate.

Method

- Develop future cropping pattern scenarios based on the assumption that the future crop production pattern in the study area could evolve in 2 different directions as result from social and economic dynamic, namely Food Bowl and Green Energy – Bio-fuel scenario. The different directions of change are based on the assumption that the agriculture system in the watersheds may turn toward maximizing rice production or, on the other direction, to emphasize more on annual crop that could be used to produce renewable energy, of which sugarcane and cassava would be main crops to be used as raw material for ethanol production. *(For more detail, see Appendix 6: Future land-use scenarios (cropping pattern) and rice production area in the Chi-Mun river basin)*



	Future scenario	
	Food Bowl	Green Energy - Biofuel
Wet season / Rainfed rice	↓	↓
Dry Season / Irrigated rice	↑	↑
Sugarcane	→	↑
Cassava	→	↑
Other crops	↓	↓

Figure 7: Future cropping pattern scenarios and direction of change in cropping pattern in Chi & Mun watershed

- Simulation of future rice productivity in Chi & Mun River basin. Rice production is used as proxy of food production in the assessment on impact of climate change on food production. Assessment was based on simulation using crop model, The Decision Support System for Agrotechnology Transfer (DSSAT) model, and data from high resolution climate scenario as one of the primary input. The assessment was conducted on various future land-use scenarios, which cropping area in the study area could change under influence of social and economic dynamic in order to incorporate plausible future from social and economic dynamic into the assessment of climate change. Timeframe of assessment was set for comparison of rice productivity under baseline climate condition during 10 years period of 1995-2004 and compare with future production during the decades of 2010s and 2030s. The assessment was limited to future climate change under SRES A2 GHG scenario condition.

- Assess concerns on water resource under different cropping pattern scenarios and future climate. The assessment was based on calculation of crop water requirement in the future and compare with discharge of the river basin, in case of irrigated agriculture, and rainfall distribution, in case of rain-fed agriculture. Future river basin discharge was simulated using hydrological model, Variable Infiltration Capacity (VIC) model, and future climate data from the climate scenarios was used as key input. The assessment was limited to future climate change under A2 SRES condition.

Crop water requirement = crop water use + water required for plantation preparation + seepage

- Crop water use (ET) is calculated from crop coefficient x Potential Evapotranspiration (PET)

$$ET = Kc \times PET$$

Crop coefficient (Kc) is referenced from Royal Irrigation Department, Thailand

Potential Evapotranspiration (PET) is calculated by:

$$PET = C\,[WR_n + (1 - W)\, f(U)\, (e_a - e_d)$$

C : the correction factor to compensate the day and night effect under climatic conditions, and relates the solar radiation, the maximum relative humidity and the day and night wind speed) C = 1 for this study)
W : the weighing factor related with the temperature
e_a : the water vapor saturation pressure (mbar)
e_d : the real saturation pressure of the vapor in the air (mbar)
R_n : liquid radiation (mm/day)
f(U): the function related with the wind

- water required for plantation preparation and seepage are based on reference figure from Royal Irrigation Department, Thailand

Result & Discussion

Impact of climate change on rice productivity:

The analysis shows that under Business-as-Usual (BAU) scenario, average annual rice productivity during the decade of 2010s will slightly drop below baseline production level in both Chi and Mun River basin, but will rise back to approximately at the same level as baseline production in the 2030s. By changing cropping pattern to focus on crops for bio-fuel production, rice productivity in both river basins will significantly drop by approximately 1/3 of baseline production in Chi River basin and reduce by almost half of baseline production in Mun River basin under impact of climate change and changes in production system. However, on the other hand, sugarcane and cassava productivity will also increase significantly as well. If future annual crop production may focus on food production, rice productivity will slightly by approximately by 15-20% in the Chi River basin and will increase slightly fewer than 10% in the Mun River basin. *(See Figure 8 & Table 4: Future rice productivity in Chi and Mun River basins)*

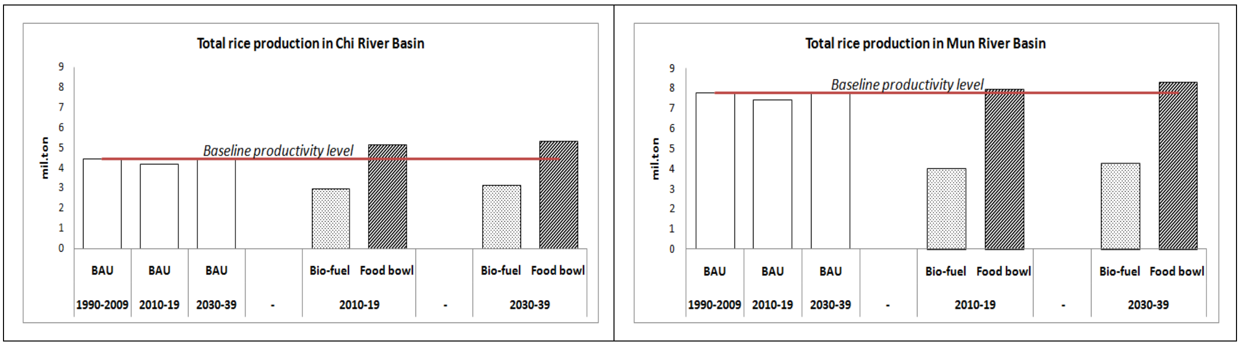


Figure 8: Future rice productivity in Chi and Mun River basins

Table 4: Future rice productivity in Chi and Mun River basins compare to present time

Total Rice production in Chi River Basin *(unit: million ton)*			
Period	BAU	Bio-fuel	Food bowl
1990-2009	4.46		
2010-19	4.19	3.00	5.18
2030-39	4.41	3.15	5.37
Total Rice production in Mun River Basin *(unit: million ton)*			
Period	BAU	Bio-fuel	Food bowl
1990-2009	7.75		
2010-19	7.43	4.03	7.96
2030-39	7.80	4.28	8.33

Concerns on water resource under different cropping pattern scenarios and future climate: Concerns on water resource to support rain-fed agriculture.

Change in rainfall distribution and temperature will affect rain-fed agriculture, both in terms of change in crop water requirement and water supply. Currently, the crop water requirement of wet season agriculture (May-Oct.) in the study area is well covered by rainfall in the watersheds. The dry season crop water requirement, especially during the months of December – March, even though exceeds the monthly rainfall, however is covered by irrigation system. *(See Figure 9)*

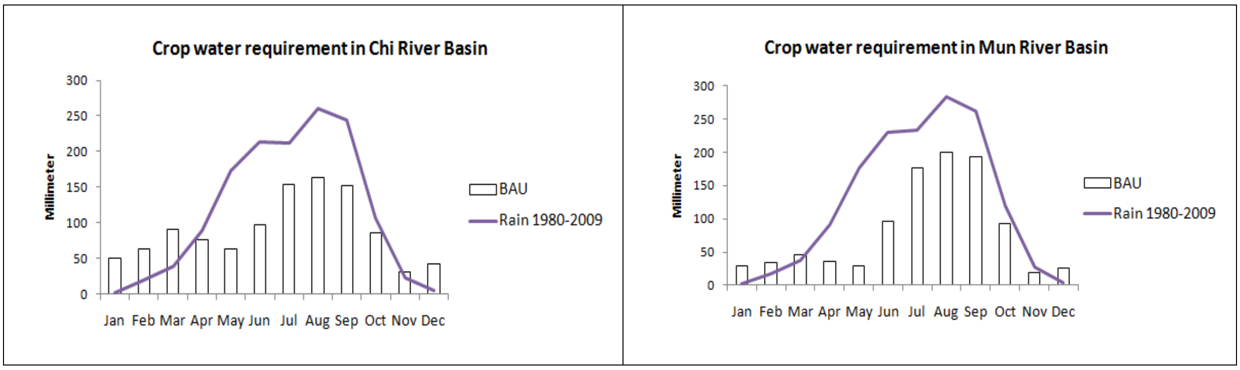


Figure 9: Current crop water requirement compares with rainfall distribution – average 1980-2009

In the future, when looks into climate pattern of 2010s and 2030s, if cropping pattern remains the same as present condition (Business as Usual scenario – BAU), change in rainfall distribution and temperature may not affect crop water requirement and water supply from rainfall in the watersheds as the pattern does not differ much from the baseline condition. (see Figure 10). Or in case that there would be change of agricultural structure that would drive cropping pattern to focus on maximizing rice production, so called Food Bowl scenario, water resource from rainfall as well as current irrigation system to supply agricultural system should still be sufficient. (see Figure 11)

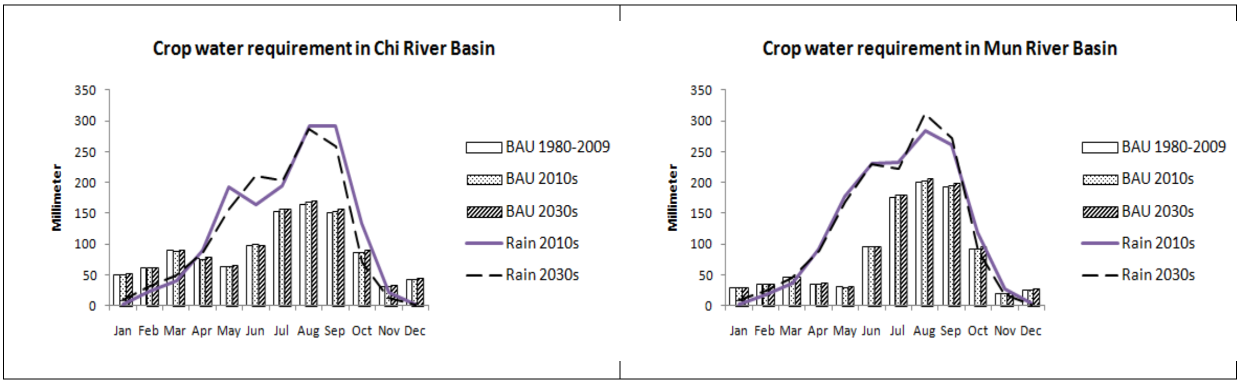


Figure 10: Future crop water requirement compares with rainfall distribution – current land-use (Business as Usual scenario – BAU)

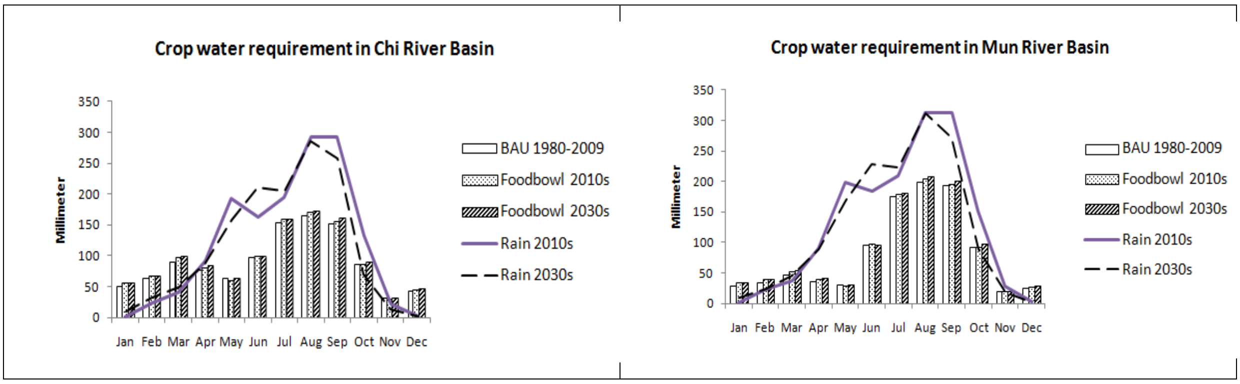


Figure 11: Future crop water requirement compares with rainfall distribution – land-use change - Food Bowl scenario

However, in case that there would be change in agricultural structure which lead to change in cropping pattern to focus on annual crop to produce ethanol for renewable energy, the land use for sugarcane and cassava will expand significantly while rain-fed rice production will reduce. This change in cropping pattern together with impact from future climate change would affect water demand pattern. Crop water requirement in dry season will increase significantly and would be of great concerns for the feasibility of future strategy to produce renewable energy from annual crop as well as concern on water management policy in the watersheds. (see Figure 12)

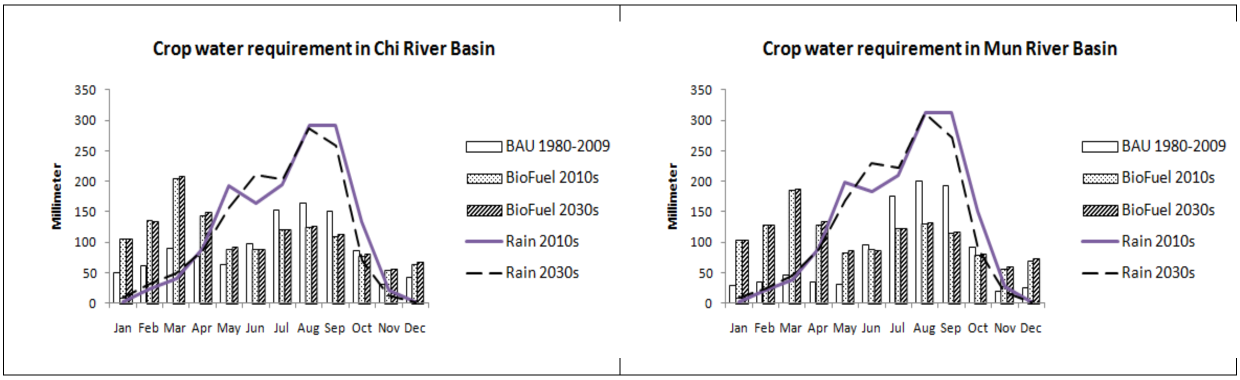


Figure 12: Future crop water requirement compares with rainfall distribution – land-use change – Green Energy/Bio-fuel scenario

Concerns on water resource under different cropping pattern scenarios and future climate: Concerns on water resource to support irrigated agriculture.

For the irrigated agriculture system, there are 3 major dams and number of smaller dams/dikes in the watersheds which can store excess water during the rainy season to support agricultural activity during the dry season (Dec. – Mar.) The river basin discharge in the future under influence of climate change can be used to assess change in water supply from irrigation system. In this regard, the average annual discharge was simulated using Variable Infiltration Capacity (VIC) hydrological model. Result from the model shows trend of increasing discharge in both Chi and Mun river basin. However, in the near term, during the decade of 2010s, the water supply in both river basins might decrease slightly with higher fluctuation during the decade. (See Figure 13)

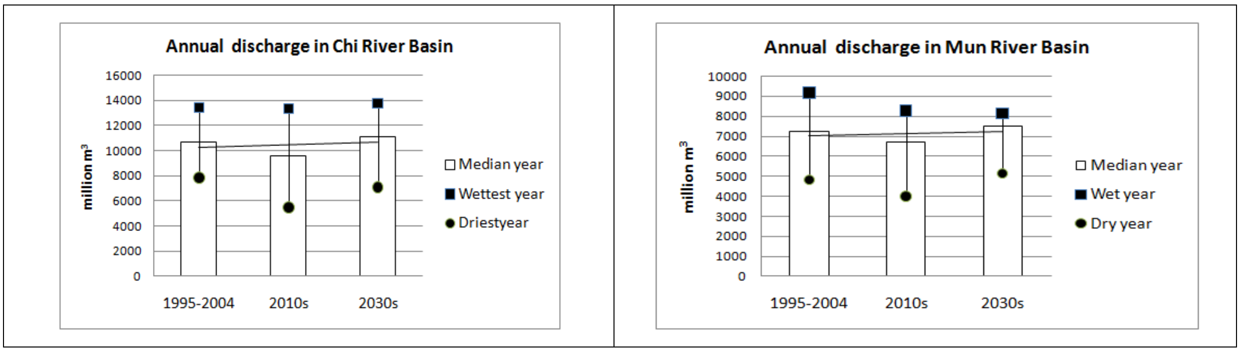


Figure 13: Future discharge of Chi and Mun River basin (under influence of climate change) in median / wettest / driest year (1980-2009 VS 2010s VS 2030s)

This implies that if the cropping pattern in the Chi and Mun river basins remain the same (Business as Usual scenario) or change toward maximizing rice production, the water resource in the watersheds should not be of high concern, except in the dry years during the decade of 2010s. However, the great concern would be the case of changing cropping pattern toward more sugarcane-cassava for renewable energy production (Green Energy – Bio-Fuel scenario) which would significantly increase demand for water in the dry season and the water supply from irrigation system may not be able to cope with such demand.

Conclusion & Discussion

In conclusion, under this climate scenario, impact of climate change alone may not threaten food production in the Chi and Mun river basins. Water resource may not be seriously affected by climate change. However, there is concern on changing cropping pattern if there would be higher demand for sugarcane and cassava to produce ethanol for renewable energy. This would significant change water demand during dry season and large scale irrigation improvement program/project would be put in place or new technique in plantation management that would increase yield while be more water efficient need to be implemented basin-wide.

2.4 Risk, vulnerability and adaptation of farmer community to climate change in Chi River basin, Thailand: Pilot case study Lao-Oi District

Suppakorn Chinvanno and Vichien Kerdsuk

Lao-oi district is located in Kalasin Province in the northeastern region of Thailand. The community's livelihood mainly depends on rice production, however, experiencing frequent flood upto 8 times over the past decade. Flood destroys almost half of rice productivity, or in other words, approximately 1,300 ha of rice paddy out of 3,200 ha would damage each time flood occurs. Figure 13 shows location of Lao-oi district and flood prone area.

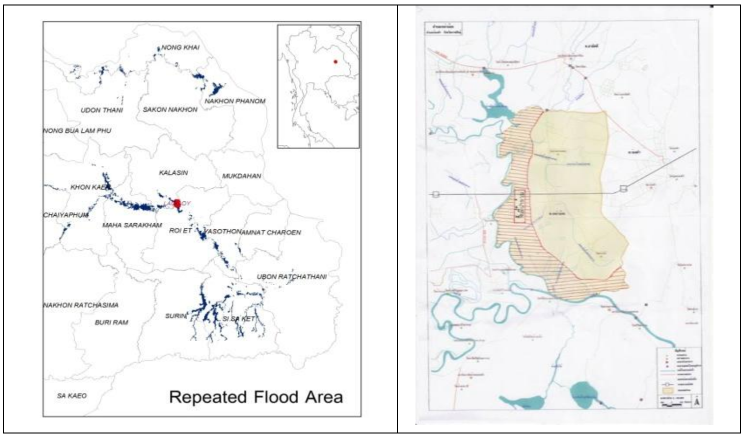


Figure 14: Location of Lao-oi district and flood prone area

Figure 15: Flood in Lao-oi district (Date?)

Scope: Assess future risk from climate change and identify adaptation strategy by mainstreaming adaptation and climate change to current development plan.

Method

- Analyze flood risk based on future change in magnitude and frequency of flood under future climate change influence, based on Gumbel distribution method using data from hydrological analysis with future climate scenario as input.

$$Q_{Tr} = \overline{Q} - 0.45S - 0.78S \ln\left(-\ln\left(1 - \frac{1}{Tr}\right)\right)$$

Q_{Tr} is the river flow at the flooding time (m3/sec), $\overline{Q}$ is mean value of flow, S is Standard deviation and Tr is cycle of return period

- The climate change adaptation assessment focus on mainstreaming future climate projection into community's strategic planning as an alternative approach in coping with uncertainty in climate change adaptation planning.

Result

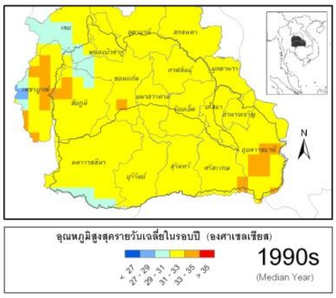
The analysis of future risk shows that Lao-oi District will face more severe flood as well as more frequent flood in the future.

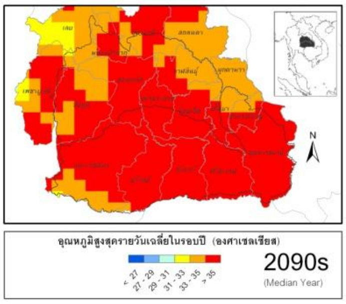
The adaptation to cope with future risk was based on assessing the strategy that the district is planning to cope with current flood risk under future climate condition and suggests alternative solution that would be a viable solution and operational under future climate change.

The Lao-oi District has put up strategy to switch from wet-season rice production to dry-season rice production by improve and enhance irrigation system in order to have sufficient water supply. The plan is to deploy additional pump stations in the river and distribute water to rice paddy via underground piping system (See Figure 16)

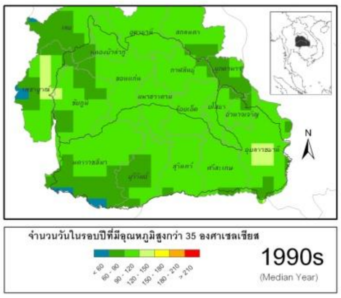
Figure 16: Existing pump station and water distribution system in Lao-oi District

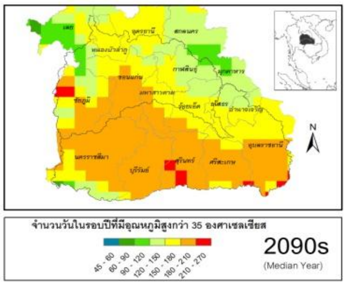
When taking future climate projection into consideration, this plan may not be a viable option under future climate condition. Increasing in temperature and longer summertime in the river basin may raise water demand of other sectors as well as agriculture sector in the downstream. In addition, more water may be required to maintain environmental flow of the river. Therefore, drawing more water from the river stream during dry season may lead to conflict with other sector and downstream as well as affect ecosystem integrity which may require more water to cope with warmer and longer summertime (see Figure 17)





Agerage maximum temperature in Chi and Mun River basins tends to increase in the future





Number of 'hot-day' over the year (max. temperature >35ºC) tends to increase in the future

Figure 17: Data from climate model shows that the study area tends to be warmer with longer summertime

Adaptation option was proposed as alternative plan to the planned development strategy toward enhancing irrigation system by harvesting water during rainy season, which annual rainfall tends to increase, and use the stored water to support dry-season agriculture instead of using water from main river stream. In this regard, the natural reservoir locate in the north of the district could be used for water harvesting. The adaptation recommendation is to invest in improving the reservoir to be capable of storing more water rather than enhancing pump station and pipe system. (See Figure 18 and Figure 19)

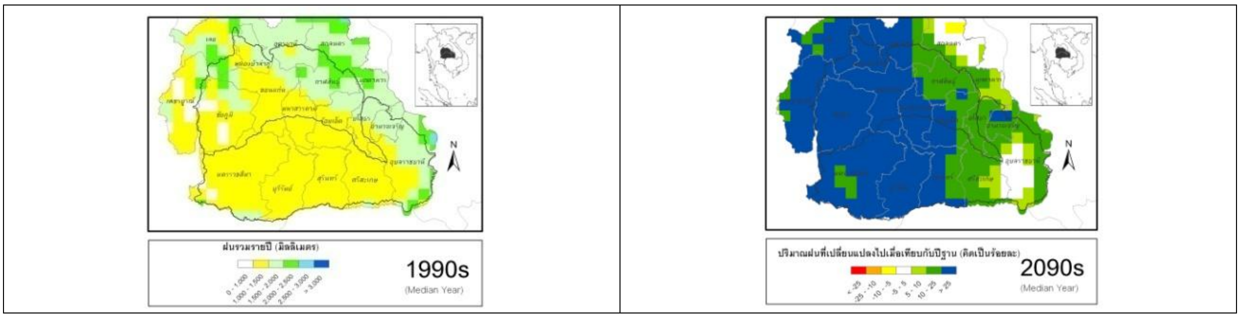


Figure 18: Data from climate model shows that the study area tends to have higher annual precipitation in the future

Figure 19: Adaptation to climate change by improving natural reservoir for dry-season rice production

2.5 Climate change risk assessment and adaptation of farmer community in Se Bang Hieng River basin, Lao PDR

Suppakorn Chinvanno, Bounyaseng Sengkhammy and Jutatip Thanakitmetavut

Champhone is the second biggest district of Savannakhet province, locates about 54 Km from Savannakhet city with total land area of 1,114 square kilometers and population of 105,415 (2008) in 102 villages. The area is one of the major rice production areas in Lao PDR, however, the farming productivity has been affected by climate from repeated flood and drought. Moreover, sand depositing caused by upstream erosion and flood in the area also cause land degradation which in turn affected rice productivity. In addition, salted soil in rice field has become severe problem in the exceptional dry year. (See Figure 20 & Figure 21)

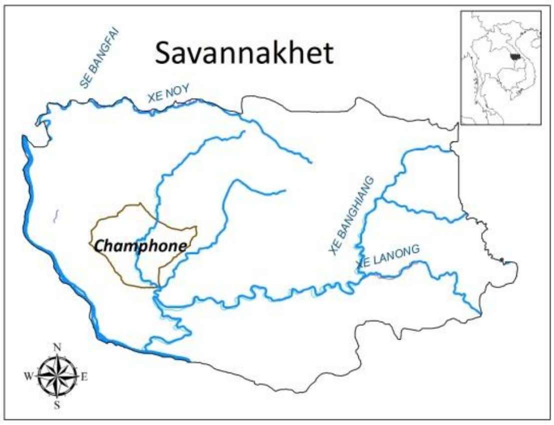


Figure 20: Location of Champhone District, Savannakhet Province, Lao PDR

Figure 21: Rice paddy in the flood prone and area affected by sand depositing from flood and upstream erosion

Scope: Assess future risk to farmer community at Champhone district, Savannakhet Province from impact of climate change using set of indicators from climate scenario and expert judgment on other changes from future socio-economic dynamic. Adaptation options to cope with future risk were assessed based on focus group discussion.

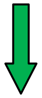
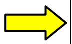
Method

Risk assessment was based on indicators which were selected by experts and key informants from the study area. Data from climate scenario was used to indicate the plausible risk in the future from impact of climate change. Potential social and economic change that might affect risk profile of the community in the future was also taken into consideration.

Result

Change in risk profile at Champhone District in the future from impact of climate and socio-economic change as well as recommendations on adaptation are summarized as follows:

Risk	Sector at risk	Impact from climate change		Impact from socio-economic change		Coping mechanism - Adaptation	Other recommendations
Flood (Month 8-9)	Farmer Wet season rain-fed system	↑	High annual rainfall cause more water availability in the watershed Indicator: 1) Trend of annual rainfall in Savannakhet - If increase in annual rainfall = higher flood risk + higher sand depositing risk *(see Figure 1 – Appendix 7)* 2) Total rainfall in month 5-8 - If increase in annual rainfall = higher flood risk + higher sand depositing risk *(see Figure 2 – Appendix 7)* *3)* Number of years that annual rainfall is > baseline average – If increase = higher flood risk *(see Figure 3 – Appendix 7)* 4) Change in discharge of Se Bang Hieng during August - October – if	↑	Higher erosion from higher rainfall cause more sediment deposit in Se Champhone – waterway shallow	• Flood tolerance rice variety (>15 days) • Change crop – flood tolerance • Adjust cropping technique – free seedling technique • Improve flood control infrastructure • Harvest NTFP • Handicraft – weaving • Fishing	• Need support from agronomist to identify flood tolerance crop • Need more survey / budget – flood control system • Need more survey on natural eco-system services • Improve in technique / design on handicraft production & assistance in marketing (may require establishment of community group to strengthen in marketing community products)

			increase = higher flood risk *(see Figure 4 – Appendix 7)* 5) Change in discharge of Mekong River at Savannakhet during August - October – if increase = higher flood risk *(see Figure 5 – Appendix 7)*				
Dry spell (Month 6-7)	Farmer Wet season rain-fed system		Low rainfall in early rainy season Indicator: Number of days with daily rainfall < 2mm during month 6-7 in Champhone If increase = higher dry spell risk *(see Figure 6 – Appendix 7)*			Improve support irrigation / improve natural reservoir (water harvesting)	Need further survey
Low flow in dry season (Month 12 – 4)	Farmer Dry season irrigated system		Low annual rainfall cause less water availability in watershed Indicator: 1) Monthly discharge of Se Bang Hieng during month 12-4 – if decrease = higher risk *(See Figure 7 – Appendix 7)*		Change in upstream land-use: Deforestation / more sugarcane plantation / rubber tree plantation / expansion of urban area (more water usage)	• Improve reservoir • Expand water distribution canal – use water from reservoir (existing - Nong Sui reservoir) • Improve water distribution system (pump) • Change crop to	• Need more survey / budget • Need support from agronomist to identify flood tolerance crop

						less water required variety	
Heat stress in dry season crop (Month 3)	Farmer Dry season irrigated system	↑	High temperature in middle of crop season Indicator: Number of days with daily maximum temperature > 37ºC in March in Champhone - If increase = higher heat stress in dry season crop *(See Figure 8 – Appendix 7)*			• Heat tolerance rice variety • Change crop to other potential annual crop and Eucalyptus • Livestock	Need support from agronomist
Salted soil	Farmer Dry season semi-irrigated system	↓	Low annual rainfall Indicator: 1) Trend of annual rainfall in Savannakhet - if decrease in annual rainfall = higher low flow risk *(See figure 1- Appendix 6)* 2) Number of years that annual rainfall is < baseline average – If decrease = higher salted soil risk *(See Figure 9 – Appendix 7)*	↑	Salt production may spread salinity	• Soil improvement • Change crop to other potential annual crop and Eucalyptus • Livestock • Shrimp aquaculture • Handicraft	Need support from soil scientist / agronomist Need market for other agricultural products Need technical support / marketing support – handicraft
Sand depositing	Farmer Dry season semi-irrigated system	↑	High rainfall cause more soil erosion Indicator: Trend of annual rainfall in	↑	Change in upstream land-use: Deforestation / more sugarcane plantation / rubber tree plantation	• Soil improvement plan • Change crop to other potential	• Need support from agronomist • Need more survey on water way and source of erosion

			Savannakhet - If increase in annual rainfall = higher sand depositing risk *(See Figure 1 – Appendix 7)*		(more water usage)	annual crop and Eucalyptus • Change to livestock • Infrastructure to prevent sand depositing	

3.0 Discussion

High resolution future climate projection is critical and essential component for climate change impact, risk and adaptation assessment. As of the time when this project started, there was very limited number of climate scenario available for climate change impact, risk, V&A assessment. The climate scenarios developed under this study has supported the climate change study in the region to move forward. However, the downscaled future climate projection is scenario, which is only plausible future under certain circumstances and assumptions. Therefore, it has to be carefully interpreted and used in the context of climate and this requires proper communication with the users of climate scenario. Moreover, multiple projections usually required to cope with the uncertainty on the long-term projection. The study on climate change needs to base on scenario-based approach, which does not rely on definite future in single pathway and this requires thinking paradigm shift in most of policy planner.

The future climate projection shows regional climate change in various aspect and dimensions. The changes occur not only in term of magnitude of change but also in time and space. According to the climate projection, the region tends to get warmer, which would be warmer at more rapid rate in the second half of the century. Annual precipitation will also increase, when consider the region in general. However, the spatial distribution of the area where temperature and precipitation will change would differ from sub-region to sub-region and change is not linear across the region. Moreover, the region would not only get warmer, but the warm period over the year will also extend longer with higher fluctuation from year to year. Seasonal shifting is detected in various sub-regions in the Southeast Asia.

Field experiment on rice production was conducted. In this report, the research team showed and compared the results a rice experiment and potential for increasing the rice yields in the wet season even with no additional mineral fertilizer. Moreover, the result from field experiment shows result of higher yield from wet season rice which is contradicting with common belief that the dry season rice would give higher yield. The research team has also demonstrated the use of CropDSS, databases and DSSAT-CSM-Rice model to simulate rice yields under A2 SRES scenarios under management of green manure and mineral fertilizer.

Change in climate pattern in the future will affect various systems and sectors in the region. This study focuses the study on rice production and water resources in the pilot study site, the Chi and Mun River basin. Under future climate scenario, which is based on downscaled ECHAM4 - A2 GCM, climate change may not have serious effect on rice production in the Chi-Mun River basin and water resource should not be of concerns. However, there is tendency of impact of climate change in the years which may have extreme weather condition that would require further analysis.

However, climate change is slow process and would take long period of time to clearly detect the change and it is not the only change in the society that would have effect on agricultural system and water resource. Therefore, risk analysis as well as assessment on vulnerability and adaptation to climate change need to take other changes, which are driven by social and economic dynamic, into consideration. Change from social and economic dynamic could have more abrupt impact on the agriculture system in the study site and may affect risk profile of the sector to climate. In this regard, scenario of future cropping patterns in the Chi and Mun River basin was developed and it showed that under direction toward producing more sugarcane and cassava for renewable energy production, water resource could be of concern and there would be high potential for water shortage during dry season, unless large scale irrigation would be planned with water diversion from outside the river basins as rainfall in the Chi and Mun River basin would change slightly under influence of climate change and would not be able to support such change in agriculture system.

Adaptation to climate change should also be taken into consideration in multiple aspects. Adaptation to climate change could be action with physical tangible solution, e.g. infrastructure, or alternative livelihood or institutional arrangement. At the river basin scale with focus on agriculture system, the adaptation to future change would be making decision on strategic direction toward agriculture strategy under future conditions, which climate change is a factor to consider along with others. At community level, due to conception and perception on risk and time-span of their concern on risk and actions to be taken to manage such risk, adaptation to climate change may need to focus on how the community is planning to cope with risk that they are facing now, however, using climate change to assess such risk in the future as well as to assess appropriateness of the development plan to ensure its sustainability in the long-term under climate change condition. This concept was demonstrated in the case study at Lao-oi District in Thailand.

4.0 Conclusions

The activity under this study has initiated development of high resolution regional climate scenarios for Southeast Asia by technical team in Vietnam and Thailand. The future climate projection is based on dynamic downscaling of ECHAM4 GCM A2 & B2 GHG scenario using PRECIS regional climate model. The future climate scenario data is available for public access for further climate change study in the region at http://cc.start.or.th.

Pilot study on soil fertility and rice productivity under different climate conditions was conducted at the experimental field at Chiang Mai University, Thailand. The result shows potential for increasing the rice yields in the wet season even with no additional mineral fertilizer. Moreover, the result from field experiment shows result of higher yield from wet season rice which is contradicting with common belief that the dry season rice would give higher yield.

Pilot study on impact of climate change on food production and hydrological regime in major watersheds in Southeast Asia was conducted in Chi & Mun watersheds, which is large watershed in the northeastern region of Thailand and also is major annual crop production area of Thailand. Scenario-based assessment on impact of climate change on rice production and water resource was assessed based on future climate scenario as well as cropping area pattern scenarios. The study shows that food production may not be seriously affected by influence of climate change, however, if agriculture structure in the study watershed may change toward producing more sugarcane and cassava for renewable energy, water resource in the watershed during dry season would be of high concern.

Risk and adaptation options to impact of climate change were also assessed at community level at the pilot study sites in northeastern region of Thailand, Lao-oi District, and also at Champhone District in central region of Lao PDR.

The activities under this study also provide support for other major climate change study in the region and the outcomes were also used to support numbers of policy planning for the countries in the region.

5.0 Future Directions

- In this study, we had initiated the development of high resolution regional climate scenario, but the study on climate change would need multiple scenarios in order to cope with uncertainty from long term climate projection. Diversity of scenarios would enhance robustness in the assessment on impact, risk, vulnerability and adaptation to climate change. Future direction would be to develop additional high resolution climate scenario for the Southeast Asia region. Moreover, access to high resolution global climate model, which would require no downscale process e.g. the climate projection which is being developed at National Institute of Environmental Sciences - Japan, and make the dataset accessible to the researchers and policy makers would be future direction of the research team.
- In this report, we present the accomplishments from the first 2 years of the APN-funded project rice experiment at the Multiple Cropping Center, Chiang Mai University, Thailand,

providing details of completed experiment and ongoing simulation studies. Future directions of our group in Chiang Mai University will continue on long-term rice experiment and to further improve the crop modeling - CropDSS interface shell to allow studies in other locations.

- Assessment on impact, risk, vulnerability and adaptation to climate change should be expanded to cover wider range of system / sectors in other key area in the region using different climate and socio-economic scenarios. The assessment should base on integrated multiple sectors with area-based V&A assessment approach which take inter-relationship between and among sectors into consideration with linkage to sustainable livelihood framework in order to provide holistic view of the vulnerability and adaptation of the area at risk. Moreover, the combined ecosystem-based adaptation and community-based adaptation should also be further explored in the area where livelihood of the community depends on ecosystem integrity.
- More capacity research building should be further pursued to increase number of researchers who would work on the subject. The capacity building on climate change study should be planned as continuous short-course training program as well as embedded into formal education program in the longer term.
- Pilot implementation in disseminating knowledge on climate change to local stakeholders to initiate community long-term visioning process and strategic planning that take climate change into consideration.

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Appendix 1: Conferences/Symposia/Workshops

1) Training Workshop on PRECIS Regional Climate Model

(Note: Workshop was organized by Malaysia Meteorological Dept. and Hadley Centre, UK Met Office. The project sent 3 participants to attend the training in this workshop)

Date: 6-11 August 2006

Venue: Kuala Lumpur, Malaysia

Agenda:

Date	Session
Monday 7 August 2006: Morning session	• Welcome Session • Introduction to the PRECIS system • Regionalisation techniques and regional climate modelling
Monday 7 August 2006: Afternoon session	• Demonstration of PRECIS • "Hands-on" session using the PRECIS user interface to set up and run experiments.
Tuesday 8 August 2006: Morning session	• Modelling the climate system and climate change: The PRECIS regional model
Tuesday 8 August 2006: Afternoon session	• Demonstration of PRECIS data storage system and data processing/display • "Hands-on" session on processing and analyzing results from PRECIS.
Wednesday 9 August 2006: Morning session	• Uncertainties in the development of climate scenarios • Designing RCM experiments
Wednesday 9 August 2006: Afternoon session	• Presentations from participants on plans for the projects where PRECIS is to be used • "Hands-on" session continuing experimenting with the PRECIS interface and analyzing results of experiments.
Thursday 10 August 2006: Morning session	• Validating and evaluating a regional climate model • Scenario construction for impacts assessment • Discussion on data requirements for impacts assessments planned by participants
Thursday 10 August 2006: Afternoon session	• Installation of PRECIS • "Hands-on" session - more work with the user interface, working with sample output data or the installation procedure
Friday 11 August 2006: Morning session	• Detailed workplans presented by participants • Discussion on details of project work, linked impacts work and publications
Friday 11 August 2006: Afternoon session	• Plans for follow-up meetings and activities • Feedback from participants and formal close

Participants

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Thailand	
3) Mrs. Theeraluk Pianmana	The Thai Meteorological Department, Bangkok, Thailand

2) Roundtable Meeting – CAPaBLE project: Research on Climate Change in Southeast Asia and Assessment on Impact, Vulnerability and Adaptation on Rice Production and Water Resource

Date: 12-13 March 2007

Venue: Chiang Mai University, Chiangmai, Thailand

Agenda:

12 March	**Presentation and discussion**	
0900 – 0915	Welcome Address	Associates Prof. Dr. Boonserm Cheva-issarakul – Director, Multiple Cropping Center and Dean, Faculty of Agriculture
0915 – 0945	Opening Address	Dr.Attachai Jintrawet – Principle Investigator
0945 - 1030	Overall research project presentation • Scope of study • Concept behind the study • Timeline • Mode of operation • Research partners • Challenge ahead • Discussion	Mr. Suppakorn Chinvanno – Project Coordinator
1030 – 1045	Coffee break	

1045 - 1145	Regional climate scenario development
	• Tool and method
	• Domain coverage & time period for the simulation
	• Output parameters
	• Preliminary finding
	  ○ Baseline climate simulation summary
	  ○ Future climate simulation summary
	  ○ Output data format
	  ○ Plan for completion
	• Etc.
		Mrs. Pham Thi Thanh Huong and Mr. Nguyen Dinh Dung – Institute of Meteorology and Hydrology

1145 – 1215	Discussion on climate simulation result post processing – climate scenario validation and adjusting	
1215 – 1315	Lunch	
1315 – 1345	Study of climate change impact on rice cultivation Field experiment: • Purpose of field experiment	Dr. Attachai Jintrawet – Multiple Cropping Center, Chiang Mai University

	• Concept & method • Expect finding & use of finding • Scope of experiment • Current activity and status Modeling approach: • Introduction to crop model • Changwat DSS – decision support system on rice production • Example of result from crop model on rice yield simulation • Linkage between field experiment and crop model • Use of climate model simulation data in crop modeling process • Discussion	
1345 – 1445	Study of climate change impact on water resource – Modeling approach • Purpose • Concept & method • Expect finding & use of finding • Scope of experiment • Timeline and activity • Using climate data in hydrological modeling simulation process • Discussion	• SEA START RC • Dr. Juha Sarkkula – WUP-Fin Mekong River Commission Secretariat • Representative from Environmental Research Institute – Lao PDR
1445 – 1500	Coffee break	
1500 – 1600	Open discussion: Use of climate scenario on climate change impact study – PRECIS regional climate model output for impact study (input to crop model and hydrological model) • Data format requirement • Climate parameters requirement • Expected data availability schedule • Etc.	
1615 – 1645	Rice field experiment visit	
	Day 1 meeting adjourned	
13 March	**Brainstorm session**	
0900 – 0930	Implication of climate change impact on future agriculture and water resource • Concerned climate risk and impact from the regional climate scenario	
0930 – 1015	Plan on risk and vulnerability assessment • Target systems / sectors	

	• Concept of vulnerability • Indicator(s) of coping capacity • Indicator(s) of vulnerability • Scope of assessment – system / sector / sites • Potential partners	
1015 – 1045	Plan on climate change scenario dissemination: Report on Southeast Asia climate change study – Regional climate change scenario • Conclusion on climate change trend and major issues from climate change scenario • Sensitive issues and areas	
1045 – 1100	Coffee break	
1100 – 1200	Wrap up • Conclusion on year 1 deliverables – timeline for wrap-up activity and completion schedule • Summary on year 2 plan and timeline • Project communication	

Participants

	Name	**Organization**	**Contact**
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10	Prachinburi Mr. Chitnucha Buddhaboon	Prachinburi Rice Research Center	chitnucha@yahoo.com

3 Workshop on the Southeast Asia Climate Change Scenarios Development and Initial Climate Change Study in Vietnam

Date: 5 April 2007

Venue: National Institute of Meteorology, Hydrology and Environment (IMHEN)

Agenda:

	Presentation and discussion	**Presenters**
08.30 – 08.35	Opening ceremony	Tran Thuc, Director, IMHEN
08.35 – 08.50	Activities of IMHEN on climate change impact and adaptation studies	Tran Thuc, Director, IMHEN
08.50 – 09.05	Overview of climate change and possible impacts	Le Nguyen Tuong, Chief, Division of Science, Training and International Cooperation, IMHEN
09.05 – 09.20	Implementation of the UNFCCC in Viet Nam	Nguyen Khac Hieu, Deputy Director General, Department for International Cooperation, MONRE
09.20 – 09.35	Some new information from the IPCC Fourth Assessment Report	Suppakorn Chinvanno - Southeast Asia START Regional Center
09.35 – 09.50	Needs for regional collaboration to develop climate change scenarios	Suppakorn Chinvanno - Southeast Asia START Regional Center
09.50 – 10.05	Development of climate change scenarios for Viet Nam	Nguyen Van Thang, Center for Meteorology and Climatology, IMHEN
10.05 – 10.15	Coffee break	
10.15 – 10.30	Impact of climate change on water resources in some river basins of Viet Nam	Hoang Minh Tuyen, Center for Hydrology and Water resources, IMHEN
10.30 – 10.45	Possible impacts of sea level rise on coastal erosion and flooding in Viet Nam coast	Vu Thanh Ca, Center for Advanced Technology Application, IMHEN
10.45 – 11.00	Consideration of climate change impacts in environmental management	Duong Hong Son, Center for Environmental Research, IMHEN
11.00 – 11.15	Impact of climate change on agriculture and its adaptation measures	Nguyen Van Viet, Center for Agricultural Meteorology, IMHEN
11.15 – 11.30	Overview of methodological frameworks for adaptation assessment in agriculture	Ngo Tien Giang, Center for Agricultural Meteorology, IMHEN
11.30 – 12.00	Discussion and Recommendation for further study and cooperation	

Participants

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1.	Tran Thuc	Director of National Institute of Metrology, Hydrology and Environment, Hanoi, Vietnam
2.	Nguyen Cong Thanh	Deputy Minister, Ministry of Natural Resources and Environment Hanoi, Vietnam
3.	Nguyen Duy Chinh	Deputy Director of National Institute of Meteorology, Hydrology and Environment Hanoi, Vietnam
4.	Nguyen Khac Hieu	Deputy Director General, Department for International Cooperation, MONRE Hanoi, Vietnam
5.	Nguyen Trung Nhan	Director of Hydro-Meteorological Department, MONRE
6.	Suppakorn Chinvanno	SEA START RC Bangkok, Thailand
7.	Le Cong Thanh	Deputy Director of Hydro-Meteorological Department, MONRE Hanoi, Vietnam
8.	Nguyen Le Tam	Deputy Director of Science and Technology Department, MONRE Hanoi, Vietnam
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12.	Nguyen Trong Hieu	Center for Hydro-Meteorological Science, Technology and Environment Hanoi, Vietnam
13.	Hoang Xuan Nhuan	Center for Marine technology and Economy Hanoi, Vietnam
14.	Luong Hoang Tung	Department of Environmental Protection

		Hanoi, Vietnam
15.	Nguyen Ngoc Ha	Department of Water Resource Management Hanoi, Vietnam
16.	Ha Dong	NhanDan Newspaper Hanoi, Vietnam
17.	Nhat Tan	Water Resource Newspaper Hanoi, Vietnam
18.	Quang Hau	Water Resource Magazine Hanoi, Vietnam
19.	Phuong Minh	Vietnamese Television (VTV1) Hanoi, Vietnam
20.	Hai Linh	Vietnamese Television (VTV2) Hanoi, Vietnam
21.	Nguyen Son Ha	Ha Noi Television Hanoi, Vietnam
22.	Le Kim Huyen	Ha Noi Television Hanoi, Vietnam
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41.	Nguyen Van Thang	Director of Center for Meteorology and Climatology Hanoi, Vietnam
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43.	Nguyen Van Viet	Director of Center for Agricultural Meteorology Hanoi, Vietnam
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52.	Nguyen Dinh Dung	Hanoi, Vietnam
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61.	Vu Thi Hien	Center for Meteorology and Climatology
62.	Truong Duc Tri	Hanoi, Vietnam
63.	Nguyen Thi Thanh Hai	Center for Meteorology and Climatology
64.	Dao Xuan Linh	Administrative Office
65.	Tran Quang Vin	Administrative Office
66.	Le Dinh Diep	Administrative Office

4 Workshop Climate Scenario development Meeting: Setting up PRECIS Model

Date: 19-20 April 2007

Venue: SEA START RC, Thailand

Agenda:

Thursday 19 April 2007:	

Morning session	• Introduction briefing
	  o Objective of the experiment and expected outcome of the meeting
	• Discussion
	  o How to properly PRECIS set up
	    ▪ Reviewing new data harddisk – what is available? For what period of time?
	    ▪ Selecting proper options in PRECIS for simulation
	• Installing new version of PRECIS on pilot machine (4 computer systems are prepared with SUSE LINUX installed)
	• Test run PRECIS (for short period)
	• Further discussion (while waiting for output of the test run)
	  o Previous problems encountered and Hadley's response
	    ▪ Unable to locate daily output files
	    ▪ Strange result from previous simulation – extremely high temperature
	    ▪ Regular system crash while running simulation (Fredolin)
	    ▪ etc.

Afternoon session	• Review output file structure (main objective is to locate the daily output file for each key parameters – Tmax, Tmin, Tmean, Precipitation, Solar Radiation, wind speed, moisture, etc.) • Understanding data format (main objective is to get idea on how to further manipulate / convert the output from PRECIS – from pp to grib, netcdf and further to other format for other applications, preferably text file with lat., lon. coordinate) • Installing new version of PRECIS on additional machines (if there is not enough time – adjourn for the next day)
Friday 20 April:	
	• Discussion on lesson learned • Conclude solution to previous problems • Summarize unsolved problem(s) for reporting to Hadley Center • Final set up the systems for simulation

Participants

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4. Mr. Wiriya Laung-aram	Royal Thai Navy Sattahip, Thailand viriya.navy@gmail.com

5 Workshop Climate Scenario development Meeting: climate scenario verification

Date: 28-29 July 2007

Venue: SEA START RC, Thailand

Agenda:

28 July 2007	
• Introduction: update situation, purpose and expected outcome of the workshop	Suppakorn
• Comparison: 1980-89 observed data (3 parameters: precipitation / tmax / tmin) VS baseline simulation ERA40 (Vietnam simulation 1980-89) and ECHAM4 (START simulation 1980-89) Thailand (24 locations) / Lao PDR (8 locations – precipitation only) / Vietnam (15 locations) / Malaysia (11 locations) • Monthly comparison – 10 years • 10-year monthly average	Viriya All participants to work together.
• Analysis – analysis of variance, R^2	Viriya & All participants to work together.
• Conclusion: synthesize the comparison together – put together all graphs ready for report preparation & conclude how precise the simulation result is	Viriya & Suppakorn
• Summary decadal change – 10-year monthly average: ECHAM4 A2 1980s VS 2010s / 2020s / 2030s (selected 9 locations) - precipitation / tmax / tmin	Thanat
29 July 2007	
• Introduce conversion script – PP format to text file	Viriya
• Introducing data extraction script	Viriya
• Summary decadal change: ERA40 A2 1980s VS 2070s / 2080s / 2090s	Viriya
• Working with Vietnam data – ERA40_A2_2070-2100	All participants to work together.

Participants:

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Thailand	
4. Mr. Wiriya Laung-aram	Royal Thai Navy Sattahip, Thailand viriya.navy@gmail.com

6 Workshop on rapid assessment of impact, vulnerability and adaptation to changing climate and flood regimes in the Mekong River Delta

Note: Organized in collaboration by: Can Tho University, Southeast Asia START Regional Center (SEA START RC), Water and Development Research Group, Helsinki University of Technology (TKK), Finland, and WWF-Greater Mekong.

Co-sponsored by: Asia-Pacific Network for Global Change Research, Ministry of Foreign Affairs – Finland and MacArthur Foundation

Date: 3-4 March 2009

Venue: Can Tho University, Vietnam

Agenda:

Tuesday 3rd March 2009	
0800 – 0810	Opening address *By Prof. Dr. Le Quang Tri, Vice Rector of Can Tho University and Director of DRAGON institute - Mekong - Can Tho University*
0810 – 0820	Welcome participants *By Mr. Bao Thanh, Director of Sub-Institute of Hydrometeorology and Environment of South Vietnam (SIHYMETE) and Deputy Director of Institute of Meteorology Hydrology and Environment (IMHEN)*
0820 – 0840	Introduction to climate change and climate risk *By Dr. Luong Quang Huy, IUCN Vietnam*
0840 – 0900	Overview on workshop process *By Dr. Duong Van Ni, Can Tho University*
0900 – 0940	Key climate change and future flood risk in the Mekong River delta *By Dr. Le Anh Tuan, College of Environment and Natural Resources (CENRes), Can Tho University*
0940 – 1000	Coffee break
1000 – 1045	Group discussion: Identify sectors at risk, local context and current climate risk
1045 – 1130	Group discussion: Future risk of each sector under future changes
1130 – 1300	Lunch break
1300 – 1400	Group discussion: Responses to climate risk – now and future (suggested options and enabling condition)
1400 – 1500	Carousal session: Review adaptation options – harmonizing VS conflict

	among options
1500 – 1530	Coffee break
1530 – 1630	Plenary session: Report from group discussion
1630 – 1650	General discussion
1650 – 1700	Closing remark *By: Dr. Nguyen Hieu Trung, Dean, College of Environment and Natural Resources (CENRes), Can Tho University and Vice Director of DRAGON institute - Mekong - Can Tho University*
1830 – 2000	Reception dinner
Wednesday 4th March 2009	
Morning session	Discussion among resources person and partners to synthesize results of the stakeholder breakout sessions to determine issues learned from the meeting. Expected outcome is to have draft synthesis report from stakeholders' discussion on climate risks and adaptations – now and future.
Afternoon session	Planning for follow-on activity (e.g. in-depth assessment, science-policy linkage activity, pilot action on resilience enhancement at community level, etc.), contribution from each partner and potential collaboration, network establishment, etc. Discussion will be among academics, international civil society, and policy planner e.g. SEA START RC, TKK, Can Tho University, Nong Lam University, AIT-HCMC, WWF-Greater Mekong Programme, IUCN-Vietnam, MONRE – SIHYMETE, Mekong River Commission Secretariat, others.

Participants

No.	**Name**	
1	Mr. Suppakorn Chinvanno	Advisor to research group, Southeast Asia START Regional Center, Thailand suppakorn@start.or.th
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3	Ms. Jutatip Thanakitmetavut	Research Assistant, Southeast Asia START Regional Center, Thailand

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14	Ms. Dang Thuy Trang	Mekong River Ecoregion Coordinator WWF Greater Mekong Programme Vientiane, Lao PDR Trang.dangthuy@wwfgreatermekong.org

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30	Dr. Le Quang Tri	Director of DRAGON institute - Mekong - Can Tho University, Vietnam lqtri@ctu.edu.vn

Appendix 2: Funding sources outside the APN

1. Thailand Research Fund – co-funding through project "Simulation of future climate scenario for Thailand and surrounding countries" with budget USD42,500.-. Additional collateral fund was also support for the development of CropDSS shell for crop modeling.
2. Science & Technology Postgraduate Education and Research Development Office (PERDO), Thailand – co-funding through project "Preparation of Climate Change Scenarios for Climate Change Impact Assessment in Thailand" with budget of USD16,200.-

Appendix 3: List of Young Scientists

Research assistants in the Project

<u>Lao PDR</u>

1. Mr. Soulideth Souvannalath (souli2002@hotmail.com), Water Resource Coordinating Committee. His involvement in the project is to support the development of the climate scenario, especially in the rescaling process which requires local data from each country in the region. This has enhanced understanding on the concept of climate scenarios, technique in rescaling regional climate model output and general understanding about plausible future climate change in the Southeast Asia region, especially in the Lao PDR.
2. Ms. Bounyaseng Sengkhammy (bounyaseng@wrea.gov.la / bounyaseng@gmail.com) Water Resource and Environment Administration / Water Resources and Environment Research Institute. Ms. Bounyaseng is the team leader of Climate Change Adaptation Initiative in Lao PDR, which conducts pilot assessment on climate change risk and adaptation at community level. Collaboration between her work and this project has enhanced her to the dataset and concept of using various indicators, which is derived from climate scenario to assess community risk to climate change.

<u>Thailand</u>

1. Mr. Chitnucha Buddhaboon (chitnucha@yahoo.com), a Ph.D. candidate of the Agricultural Systems program at Chiang Mai University, Faculty of Agriculture, Chiang Mai University, Thailand is working on the DSAT-CSM-rice model for his research focusing on the deep-water rice ecosystem areas in Prachinburi province. Mr. Buddhaboon is expected to complete his study in 2011 calendar year and will resume his official post at Prachinburi Rice Research Center of the Rice Research Dept. Mr. Buddhaboon will resume his research on climate change and rice production and will be the key person in this field for the Rice Department of Thailand.
2. Mrs. Kanita Ueangsawat, a Ph.D. candidate of the Soil Science and Conservation at Chiang Mai University, Faculty of Agriculture, Chiang Mai University, Thailand. Mrs. Ueangsawat is using the ECHAM4 A2 and B2 climate scenarios with the SWAT model and will be presenting her findings at the SWAT SEA II Conference in Vietnam during January 4-8, 2011. Mrs. Ueangsawat is expected to complete her study in 2012 calendar year and will resume her official post at Crop Science and Natural Resources Dept., Faculty of Agricultural at Chiang Mai University and will be continue her research works in the area of climate change and water resources.
3. Mr. Tupthai Norsuwan is a young researcher of the Multiple Cropping Center and will pursue his Master of Science degree in the area of integrated soil fertility management under rice production systems.
4. Mr.Viriya Luang-aram (viriya.navy@gmail.com) is officer at Hydrographic Department, Royal Thai Navy. He had worked on the setting up the regional climate modeling and supervising the simulation process of future climate projection. His involvement had enhanced his skill in climate modeling technique and the development of climate scenarios.
5. Mr. Chalermrat Saengmanee (chalermrat@start.or.th) is research assistant at Southeast Asia START Regional Center. He had work closely with Mr.Viriya in developing the regional climate scenario. His involvement in the project has made him gain knowledge in the re-scaling process of the regional climate model output. Moreover, he also gain experience and knowledge in the assessment of climate change impact on hydrological regime in the Mekong River Basin and also concerns on water resource in the Chi & Mun River basin from his work in using data from future climate projection on hydrological analysis under this project.

6. Ms. Jutatip Thanakitmetavut (jutatip@start.or.th), is research assistant at Southeast Asia START Regional Center. Her involvement in the project is primarily on the spatial analysis of climate scenario. This enhance her knowledge on the analyzing various aspects of future climate change and the patterns of change in the region. Moreover, her work is also to create linkage between science and policy people as well as public through result of her spatial analysis.

Vietnam

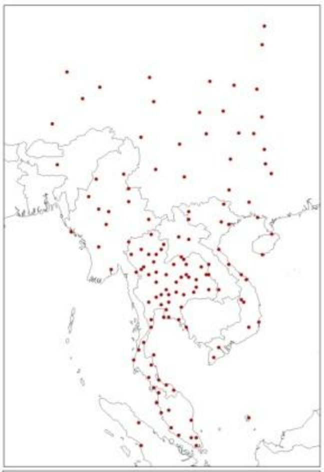
1 Mrs. Pham Thi Thanh Huong (huongKH@vkttv.edu.vn), Institute of Meteorology, Hydrology and Environment (IMHEN) Mrs. Huong is technician at IMHEN and was supported by this project to attend PRECIS regional climate model training at Malaysia Meteorological Department, which conducted by the Hadley Centre, the UK Met Office. This has enhanced her knowledge in climate model and development of regional climate scenario for climate change assessment.

2 Ms. Nguyen Thi Lan is technician at Institute of Meteorology, Hydrology and Environment (IMHEN) and assist Mrs. Huong at IMHEN in the development of regional climate scenario for climate change assessment. Her involvement has enhanced her in the knowledge on regional climate model and climate change scenario.

3 Mr. Nguyen Dinh Dung is technician at Institute of Meteorology, Hydrology and Environment (IMHEN) and assist Mrs. Huong at IMHEN in the development of regional climate scenario for climate change assessment. His involvement has enhanced her in the knowledge on regional climate model and climate change scenario.

Appendix 4: Developing regional climate scenarios using rescaling technique on regional climate model output

Rescaling raw output from regional climate model is an effort to develop climate scenario to better match actual climate characteristic in the region. The rescaling process is the process to ‘suppress’ and ‘lift’ the simulated data throughout the simulation domain by using coefficient value that was calculated from different of average values of key weather parameters between simulated and observation data during 1980s at number of station grids in the simulation domain and those values at the station grids were interpolated using kriging technique to get the coefficient value for every grids that will be used to rescale the simulated result of each climate grid throughout the simulation domain over the period of the simulation.



Weather station locations for rescaling process

Fig.1: Locations of weather observation station used for the rescaling process

The rescaling process in the development of this climate scenario covers 3 variables: precipitation / maximum temperature / minimum temperature and based on calculation of coefficient value at each grid.

- Calculating coefficient value for precipitation rescaling is based on ratio between average annual rainfall over the decade of simulation and observation at each station

$$k_i = \frac{\overline{P_{simulated}}}{\overline{P_{Observed}}}$$

k_i is coefficient for rescaling at grid i, and $\overline{P}$ is decadal average annual rainfall at grid i

The coefficient from each location will be used in interpolation process in order to derive coefficient value for every grid to be used in the rescaling process, which the coefficient is used to multiply with the figure from simulation process to correct model bias.

$$P_i^{'} = k_i \cdot P_i$$

$P_i^{'}$ is daily precipitation after rescale process, k_i is coefficient for rescaling at grid i, and P_i is daily precipitation before rescale at grid i

- Calculating coefficient value for maximum temperature rescaling is based on difference between decadal average daily maximum temperature of simulation and observation at each station

$$k_i = \overline{Tx_{simulated}} - \overline{Tx_{Observed}}$$

k_i is coefficient for rescaling at grid i and $\overline{T}$ is decadal average decadal maximum temperature at grid i

The coefficient from each location will be used in interpolation process in order to derive coefficient value for every grid to be used in the rescaling process, which the coefficient is used to multiply with the figure from simulation process to correct model bias.

$$Tx_i^{'} = k_i + Tx_i$$

$Tx_i^{'}$ is daily maximum temperature after rescaling process, k_i is coefficient for rescaling at grid i and Tx_i is daily maximum temperature before rescaling process at grid i

- Rescaling minimum temperature uses the same coefficient value as the maximum temperature and the rescaling is based on the following equation

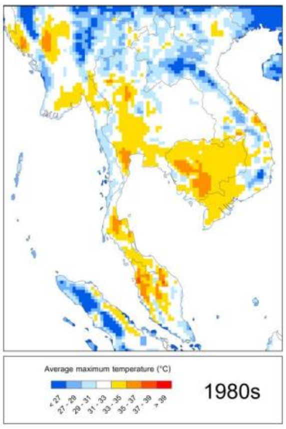
$$Tn_i^{'} = k_i + Tn_i$$

$Tn_i^{'}$ is daily minimum temperature after rescaling process, k_i is coefficient for rescaling at grid i and Tn_i is daily minimum temperature before rescaling process at grid i

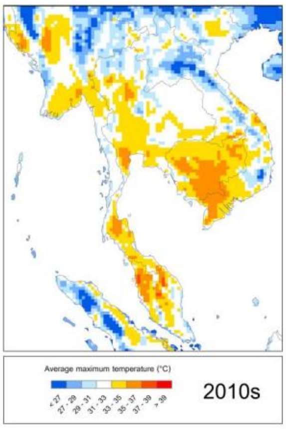
Appendix 5: Future climate projection – climate change scenario for Southeast Asia

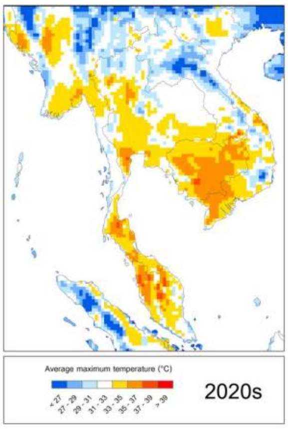
This climate scenario is result of dynamic downscaling of ECHAM4 GCM A2 and B2 GHG scenarios using PRECIS regional climate model at spatial resolution of 20km x 20km.

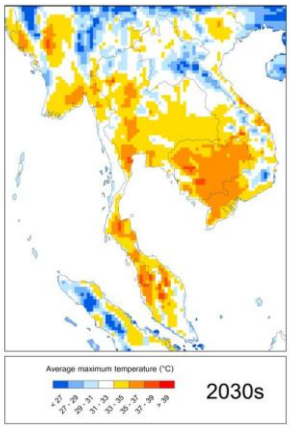
- **Average maximum temperature**

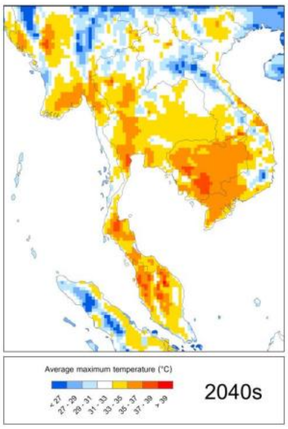


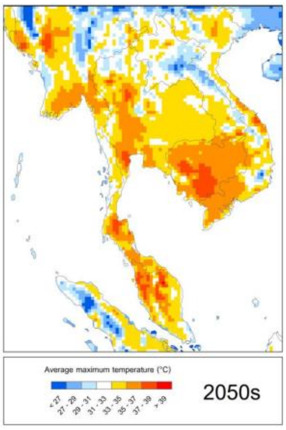
Future projection – A2 GHG scenario

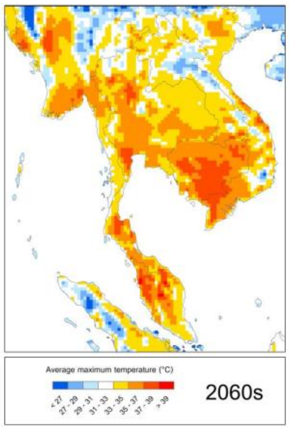


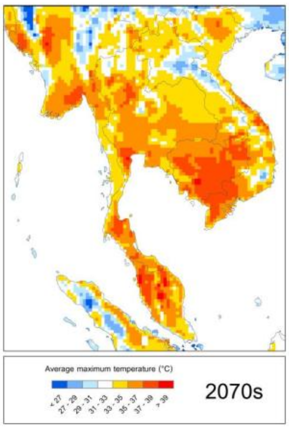
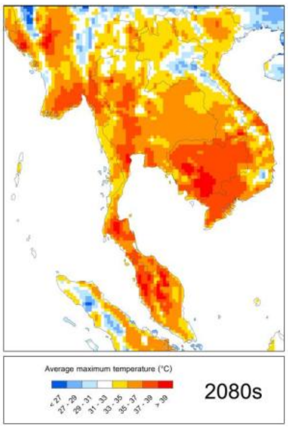
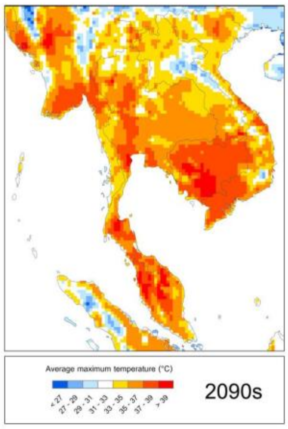
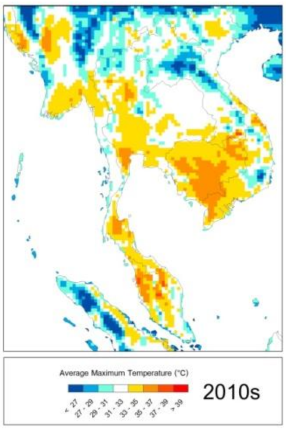
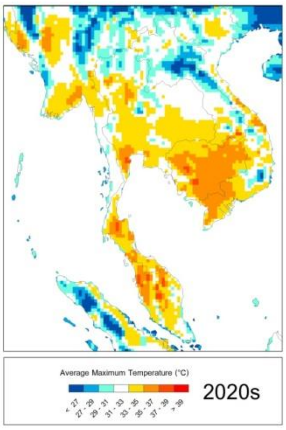
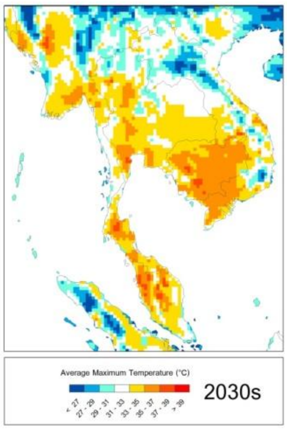
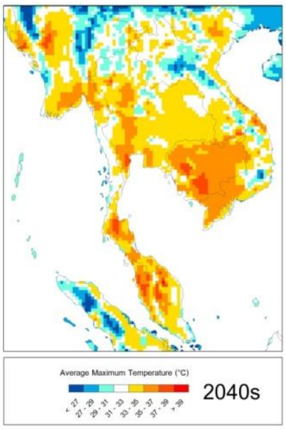
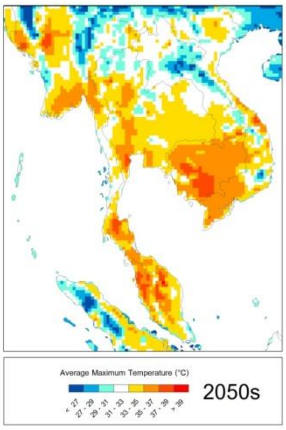
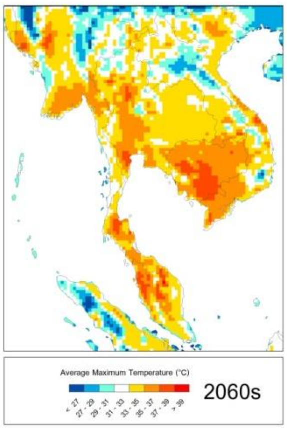
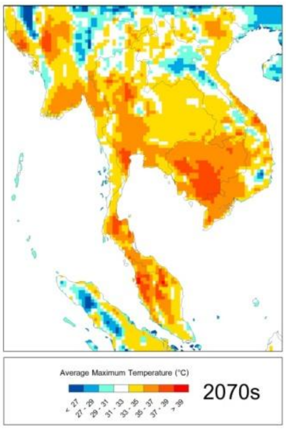
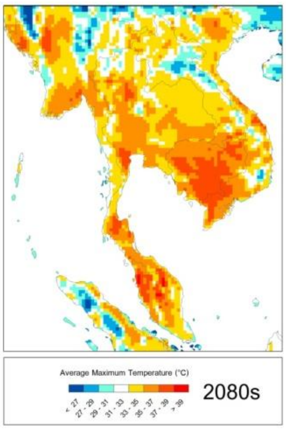
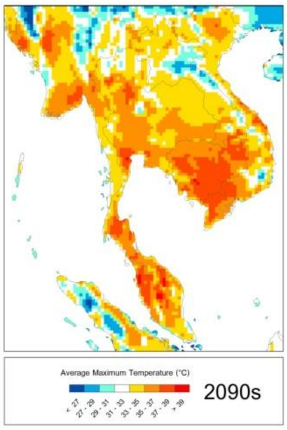




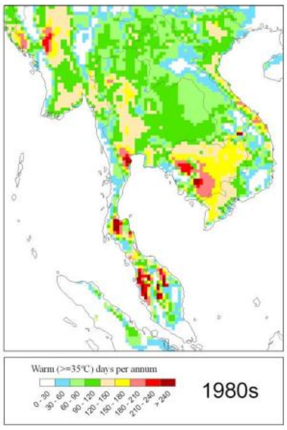




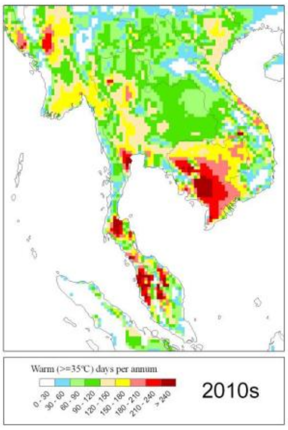


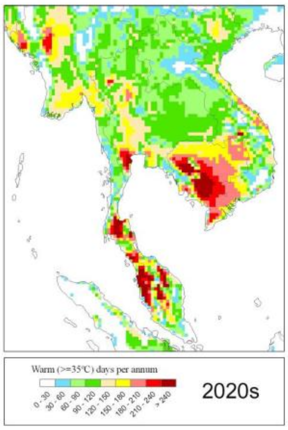
		
Future projection – B2 GHG scenario		
		
		
		

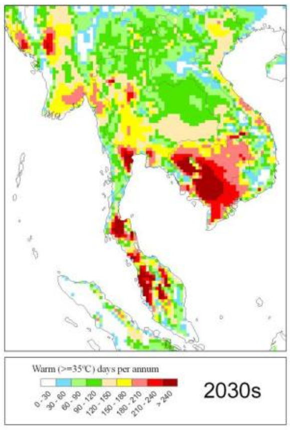
- **Number of 'hot day' (>35ºC) in a year**

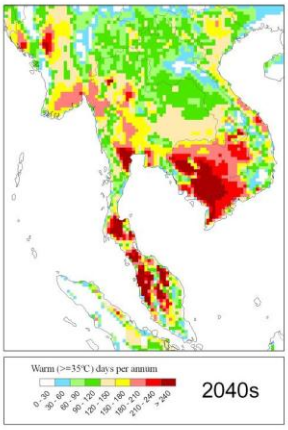


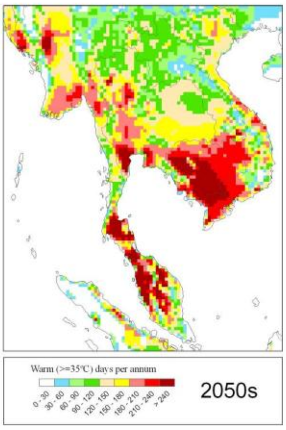
Future projection – A2 GHG scenario

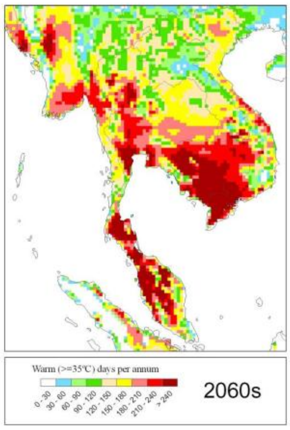


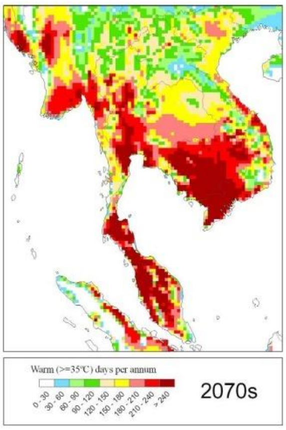


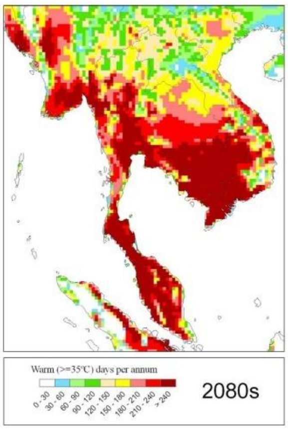


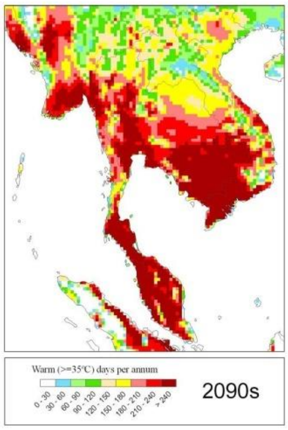




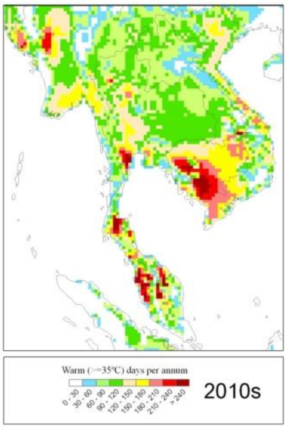


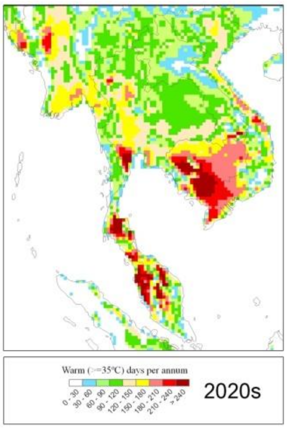


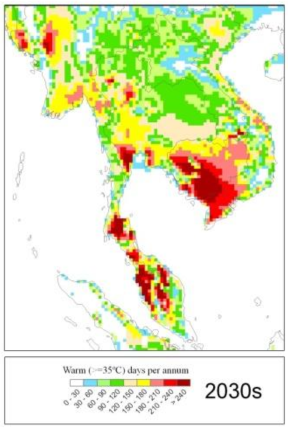


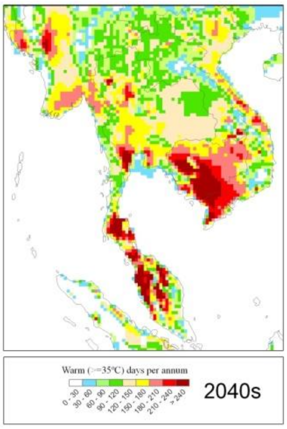


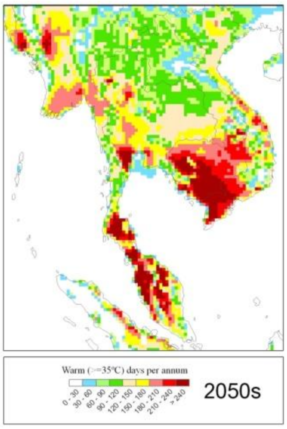
Future projection – B2 GHG scenario

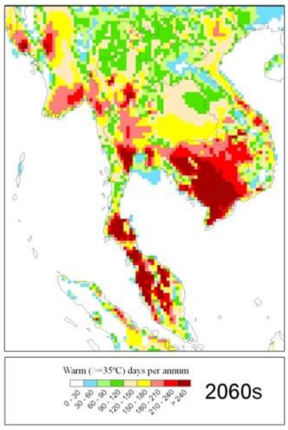


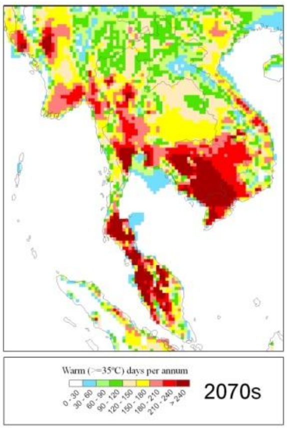


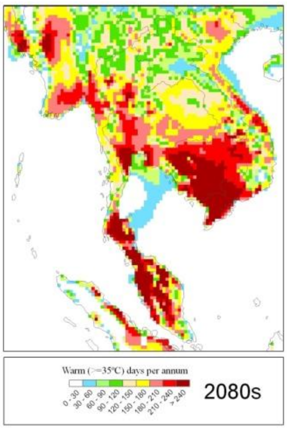


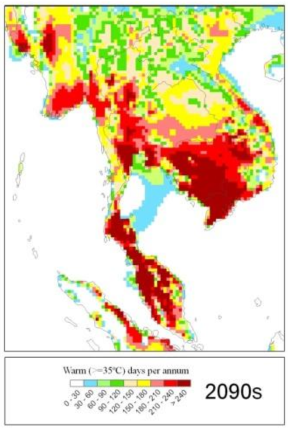




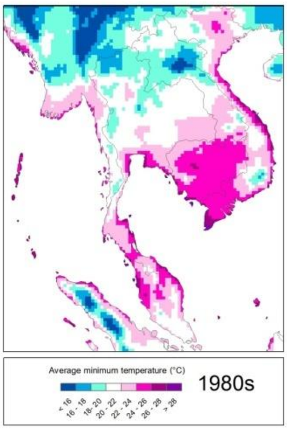
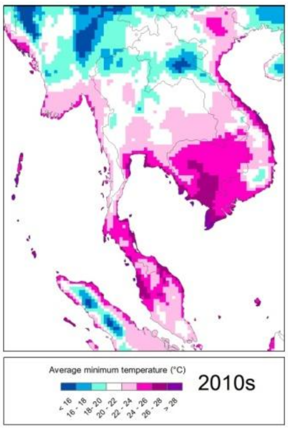
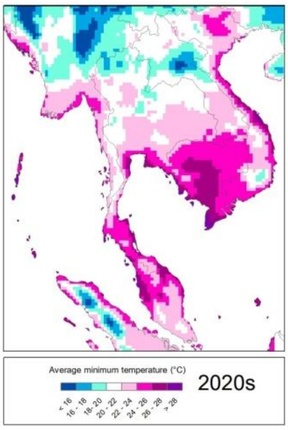
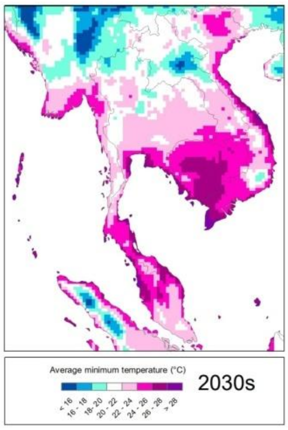
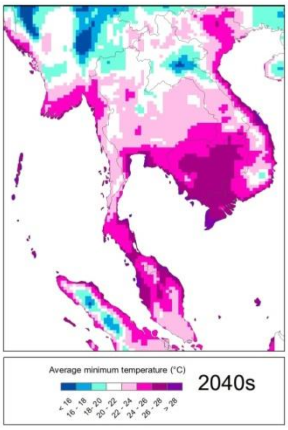
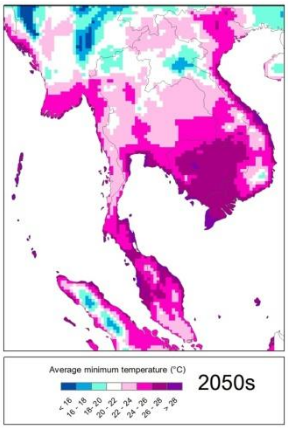
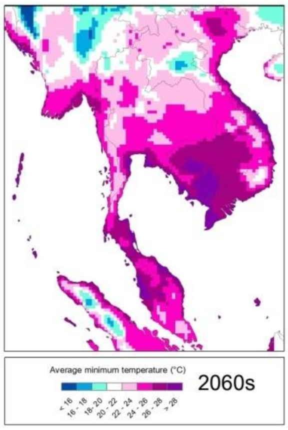


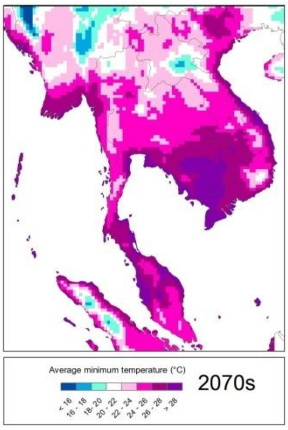


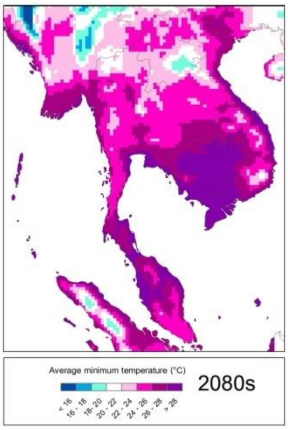


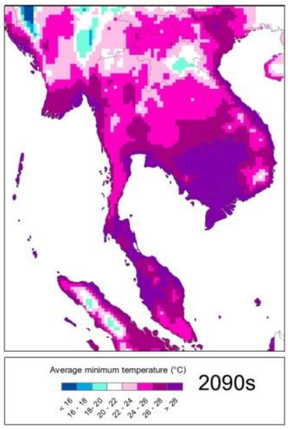


- **Average minimum temperature**

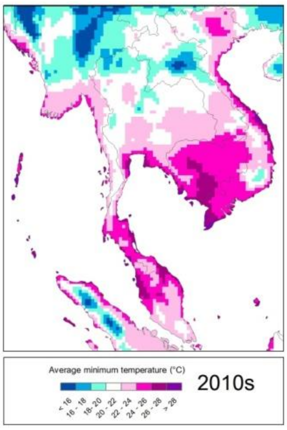
		
Future projection – A2 GHG scenario		
		
		

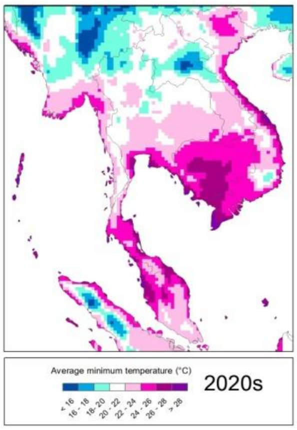


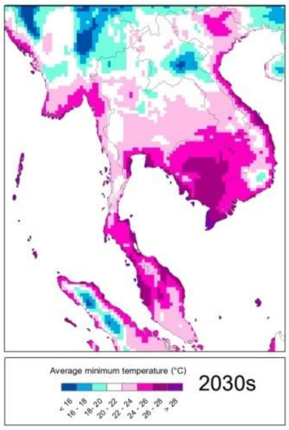


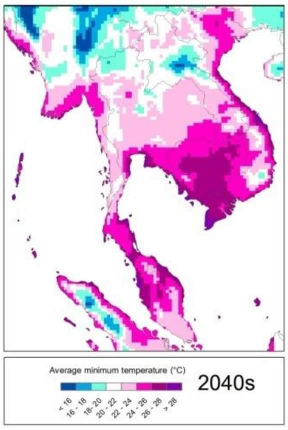


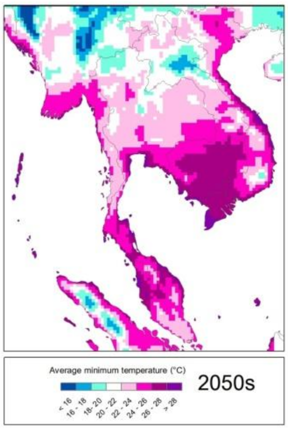
Future projection – B2 GHG scenario

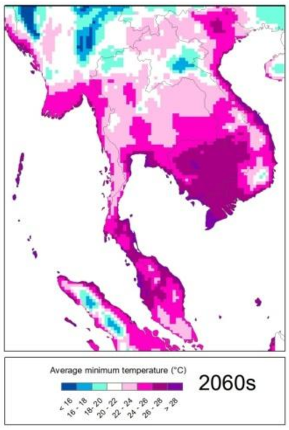


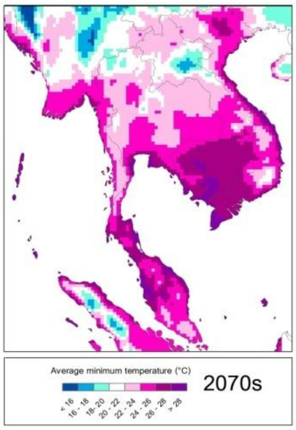


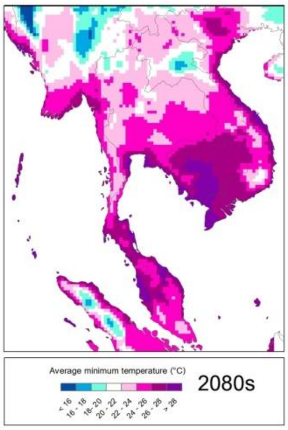


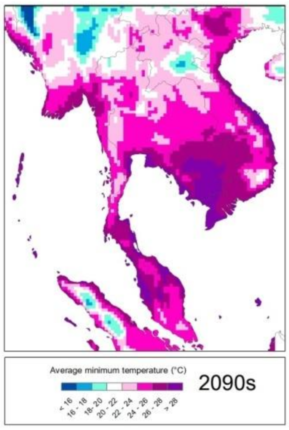




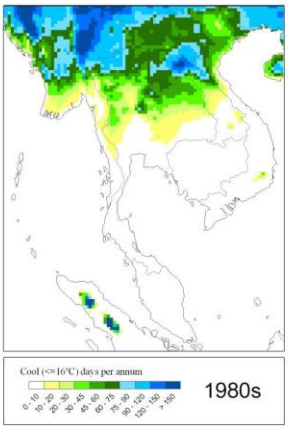




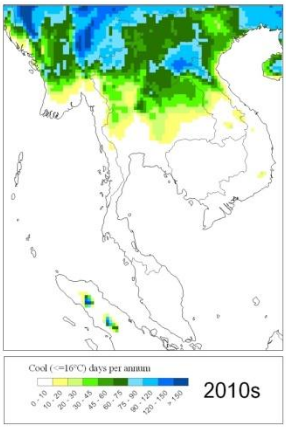


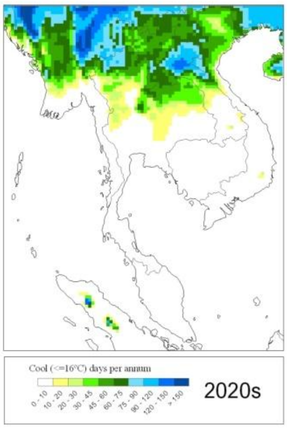


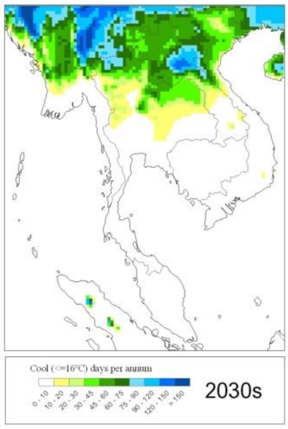
- **Number of 'cool day' (<16ºC) in a year**

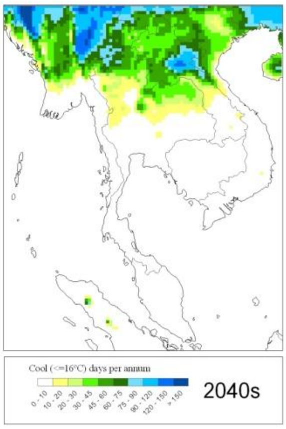


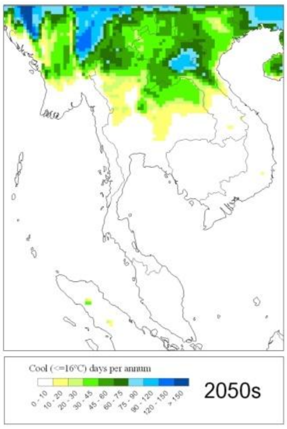
Future projection – A2 GHG scenario

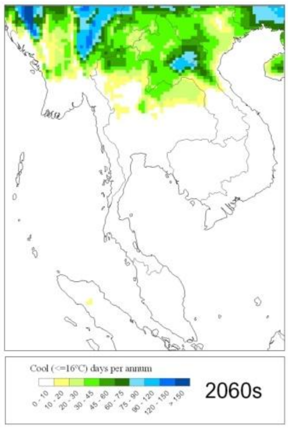


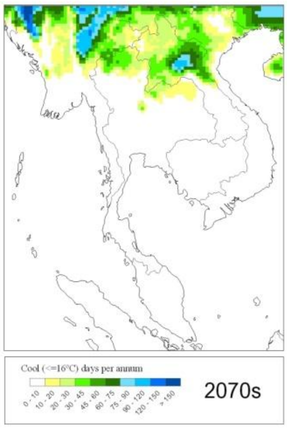


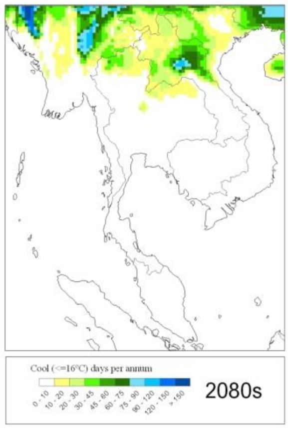


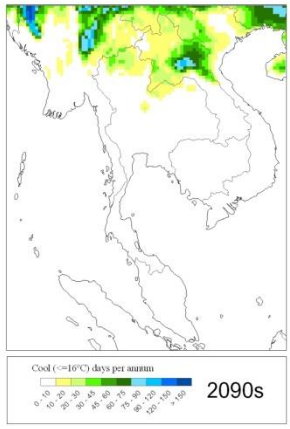




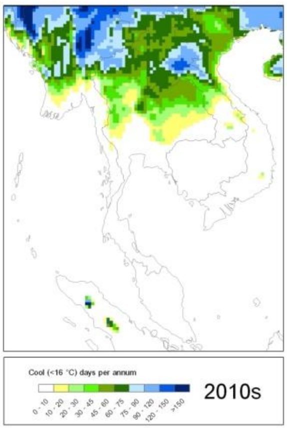


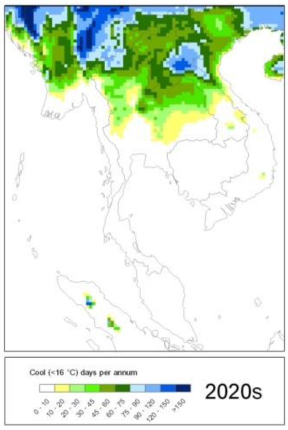


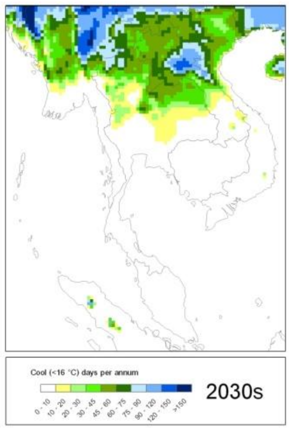


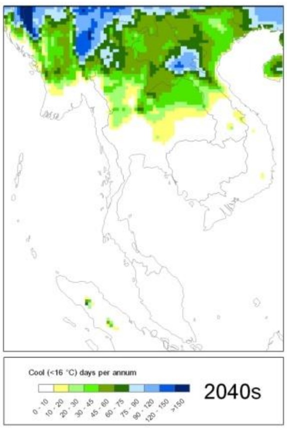


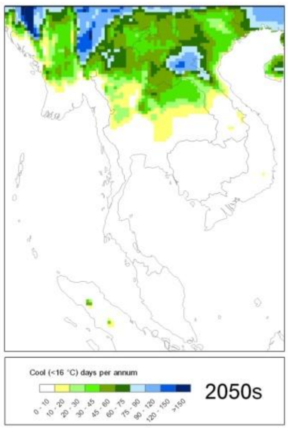
Future projection – B2 GHG scenario

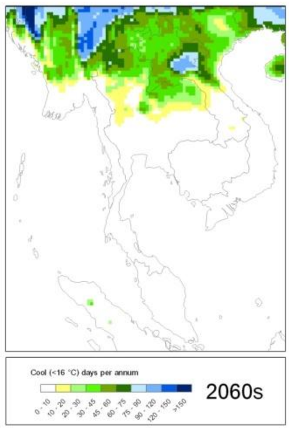


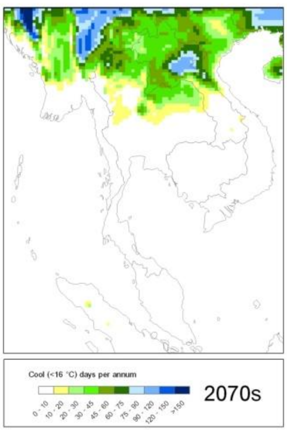


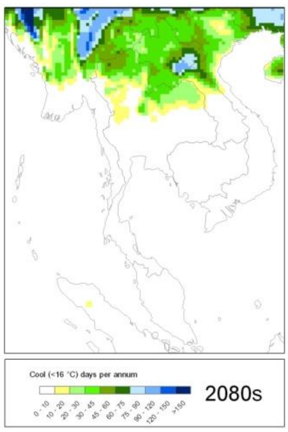


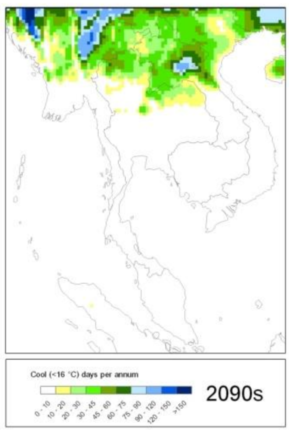




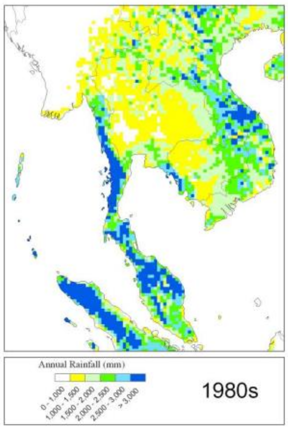




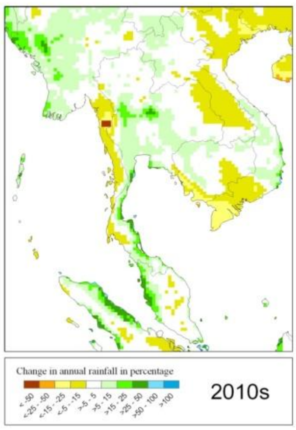


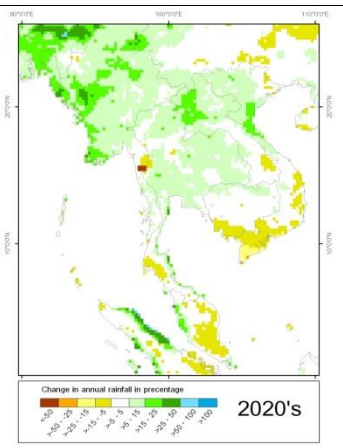


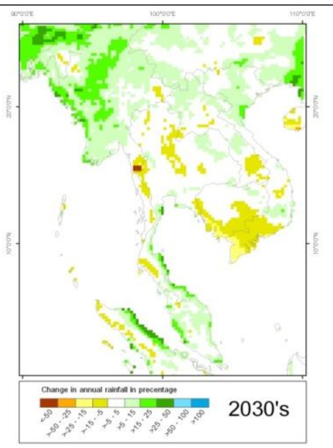
- **Average annual precipitation and future change in %**

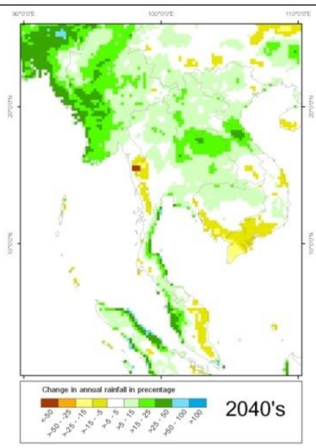


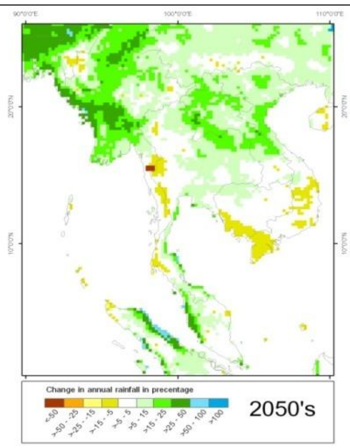
Future projection – A2 GHG scenario

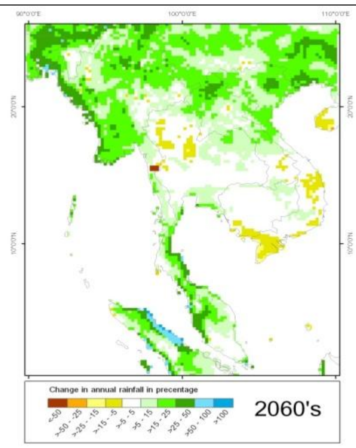


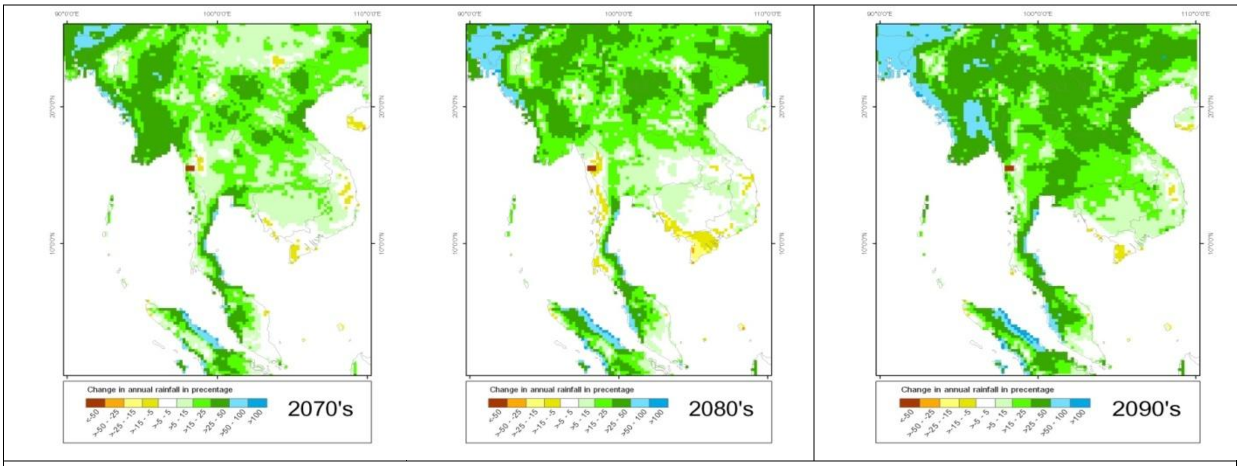




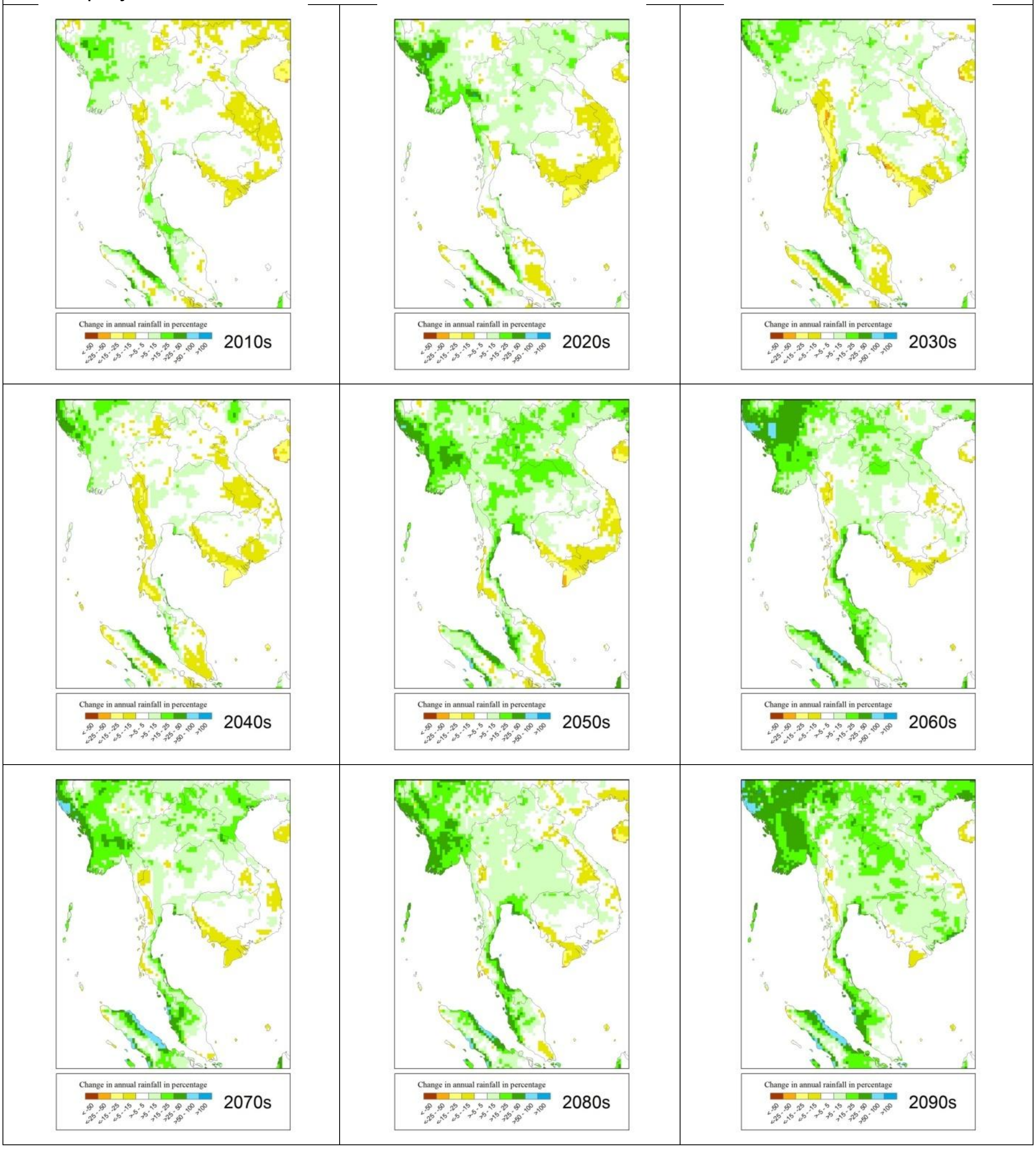






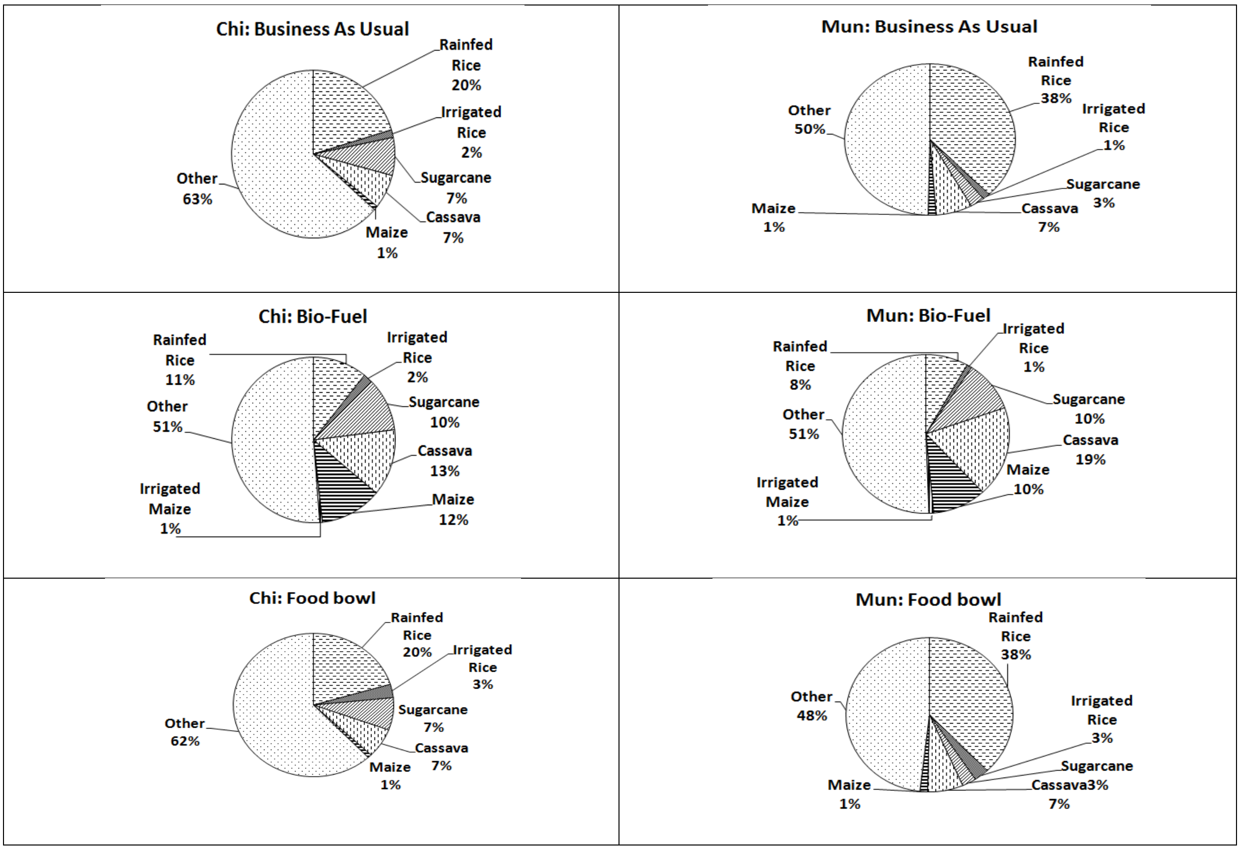


Future projection – B2 GHG scenario



Appendix 6: Future land-use scenarios (cropping pattern) and rice production area in the Chi-Mun river basin

Change in future social and economic condition may drive land-use pattern in the Chi and Mun River basin to change. Set of scenarios was developed under assumptions that future cropping pattern may change toward maximizing rice production (Food Bowl scenario) and change toward more focus on sugarcane and cassava production for ethanol producing (Green Energy – Bio-fuel scenario). Under these scenarios, ratio of major annual crop production area could change as follows:



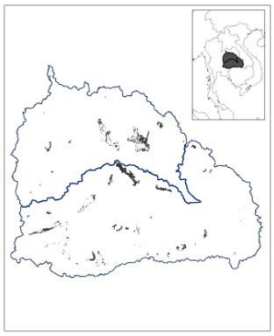
Under assumptions in these scenarios, rice production area could change as follows;

Chi watershed

Total crop area : Chi River Basin (x1,000 ha)	BAU	Bio-fuel	Difference (%)	Food bowl	Difference (%)
Rainfed rice	997.25	651.49	(-34.67)	997.25	0
Irrigated rice	72.65	72.61	(-0.06)	149.22	105.40
Sugarcane	361.20	411.69	13.98	361.20	0
Cassava	325.13	631.75	94.31	325.13	0
Maize	40.16	409.91	920.61	40.16	0

Mun watershed

Total crop area : Mun River Basin (x1,000 ha)	BAU	Bio-fuel	Difference (%)	Food bowl	Difference (%)
Rainfed rice	2,726.48	1,523.65	(-44.12)	2,756.24	1.09
Irrigated rice	98.06	77.02	(-21.46)	203.91	107.95
Sugarcane	192.01	824.76	329.54	192.01	0
Cassava	483.46	1,347.62	178.74	483.46	0
Maize	104.24	903.54	666.59	104.24	0

	 Irrigated rice Decreasing crop area Bio-fuel	 Irrigated rice Increasing crop area Food Bowl

Appendix 7: Indicators for climate change risk assessment at Champhone District, Savannakhet Province, Lao PDR

These indicators were analyzed based on future climate projection data from climate scenario, which is result from dynamic downscale of ECHAM4 GCM SRES A2.

Figure 1: Trend of change in annual rainfall in Savannakhet

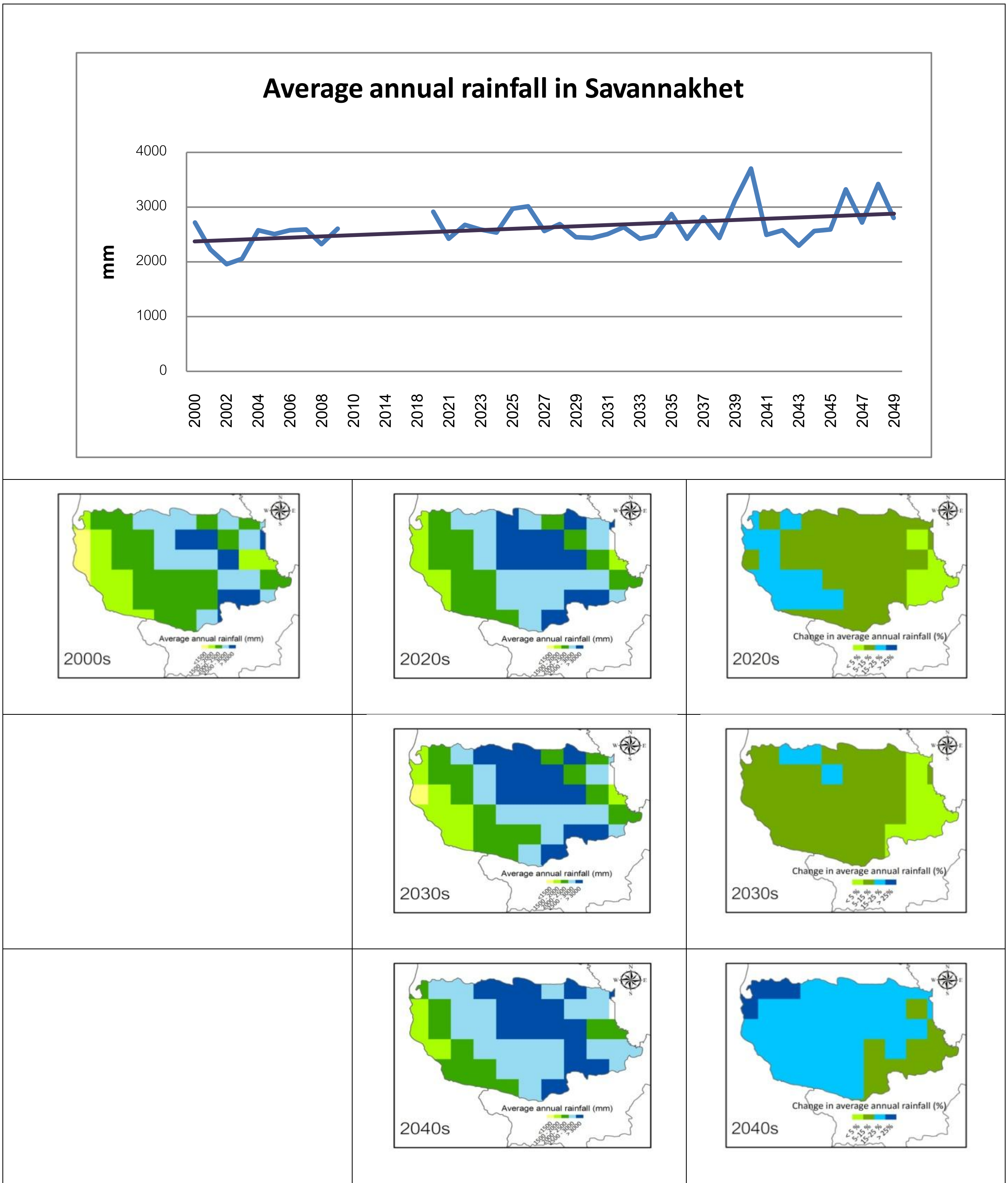


Figure 1: Trend of change in annual rainfall in Savannakhet - Decadal average annual rainfall and change in future (%)

Figure 2: Trend of change in annual rainfall in Savannakhet during May – August

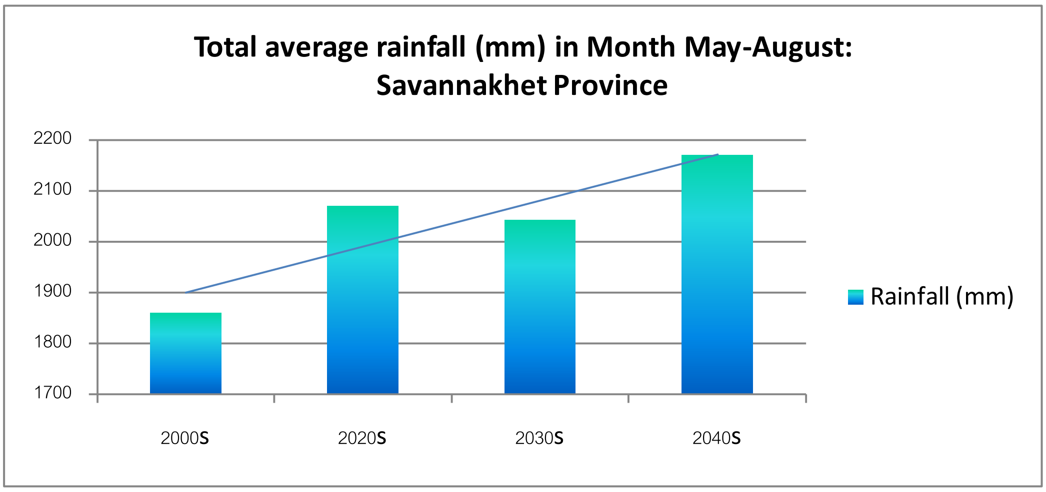


Figure 3: Number of years that annual rainfall is > baseline average – If increase = higher flood risk

Number of years	Annual rainfall >Baseline average
Baseline	6
2020s	10
2030s	10
2040s	9

Figure 4: Change in discharge of Se Bang Hieng during August - October

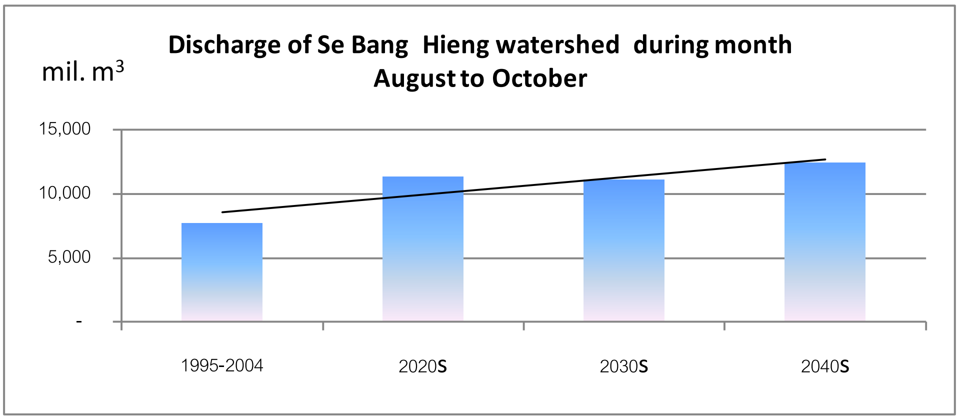


Figure 5: Change in discharge of Mekong River at Savannakhet during August - October

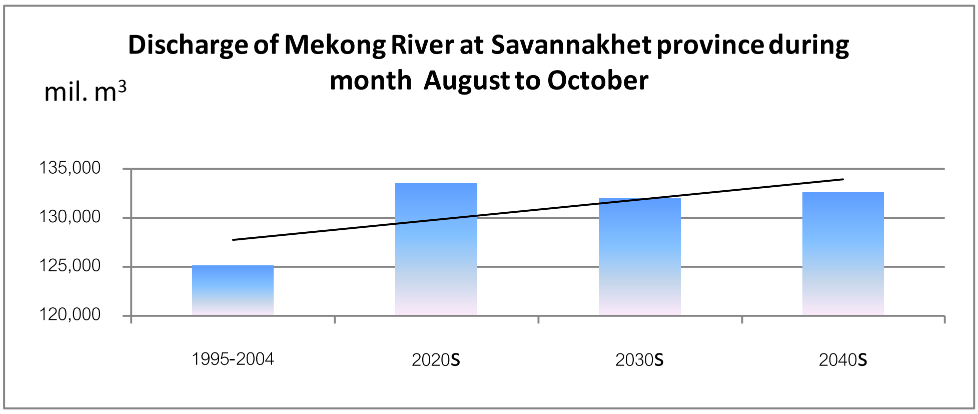


Figure 6: Number of days with daily rainfall < 2mm. during June-July in Champhone

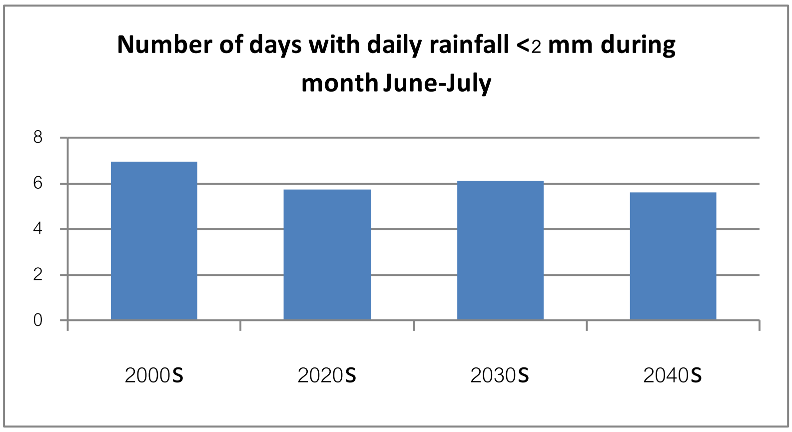


Figure 7: Monthly discharge during month December – April

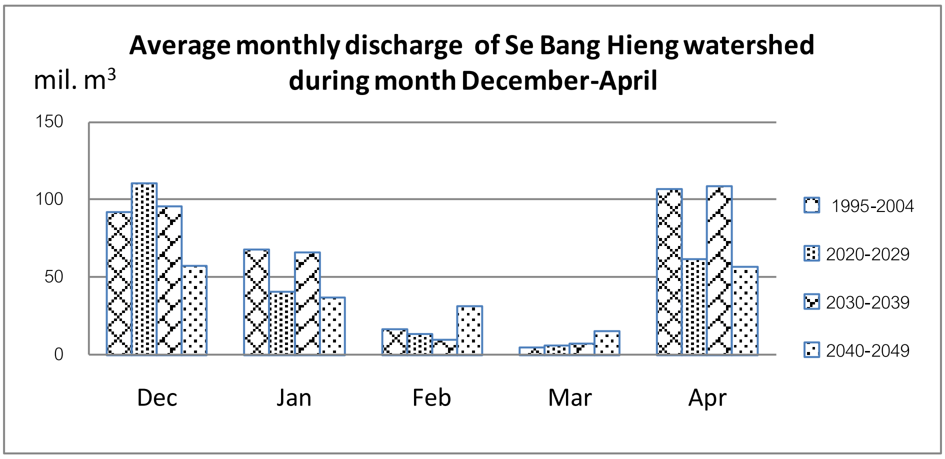


Figure 8: Number of days with daily maximum temperature > 37ºC in month of March in Champhone

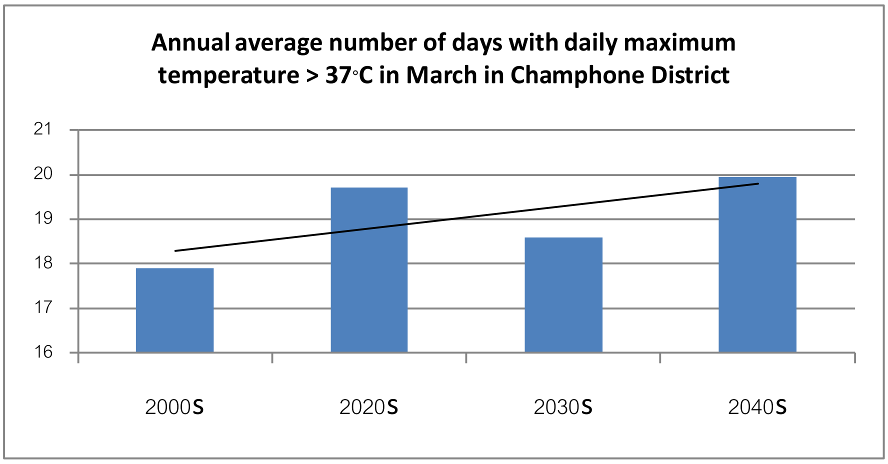


Figure 9: Number of years that annual rainfall is < baseline average

Number of years	Annual rainfall < Baseline average
Baseline	4
2020s	0
2030s	0
2040s	1