CLIMATE CHANGEG IMPACTS ON FOOD SECURITY IN LOWER MEKONG BASIN

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ABSTRACT

The Mekong River in Southeast Asia is among the greatest rivers in the world. The Lower Mekong Basin (LMB) covers an area within Cambodia, Lao PDR, Thailand, and Viet Nam. Agriculture is the single most important economic activity in the LMB. The livelihoods and food security of most of the basin rural inhabitants are closely linked to the Mekong River and its waterway. Climate change in the LMB is expected to result in an increase in the frequency and severity of floods, droughts, and saltwater intrusion. Such changes are expected to affect natural ecosystems, agriculture and food production, and also exacerbate the problems associated with supplying the region's increased demand for food. Mekong River Commission (MRC) has implemented a study to facilitate the long-term planning and policy-making in the crop production sector towards a food secured and poverty-alleviated future for the LMB under the climate change. Rice yield for Northeast Thailand was simulated by using the ecology specific data under the SWAT (soil and Water Assessment Tool) model. The result of the SWAT model showed the reduction of rice yield 9-24 percent in 2020-2029, 20-30 percent in 2050-2059, and 31-32 percent in 2080-2089. However, for the long-term insecurity, risks and vulnerabilities other than the direct impact of climate change on rice yield also need further investigation.

Keywords: Mekong River, Climate Change, Food Security, SWAT model, Regional Water Management.

1. INTRODUCTION

Agriculture is the single most important economic activity in the Lower Mekong Basin (LMB). More than 10 million hectares of the LMB's total cultivated land is used to produce rice. While continued economic growth has led to a significant improvement in living standards in recent years, many of the basin's population still live in poverty. The livelihoods and food security of most of the basin's rural inhabitants are closely linked to the Mekong and its water ways.

The diversity and productivity of the LMB is driven by a unique combination of hydroclimatic features that define the timing and variability in water inputs, transport and discharge through the watershed. The Southwest monsoon divides the calendar year into the wet and the dry seasons. During the wet season, floods sometimes occur and affect agriculture crop production. During the dry season, droughts sometimes occur and cause water shortage for agriculture and irrigation.

The impacts of climate change in the LMB will further affect agriculture and irrigation, crop yields, livelihoods, and food security, in addition to the complexity of the Mekong water availability especially for agriculture and irrigation.

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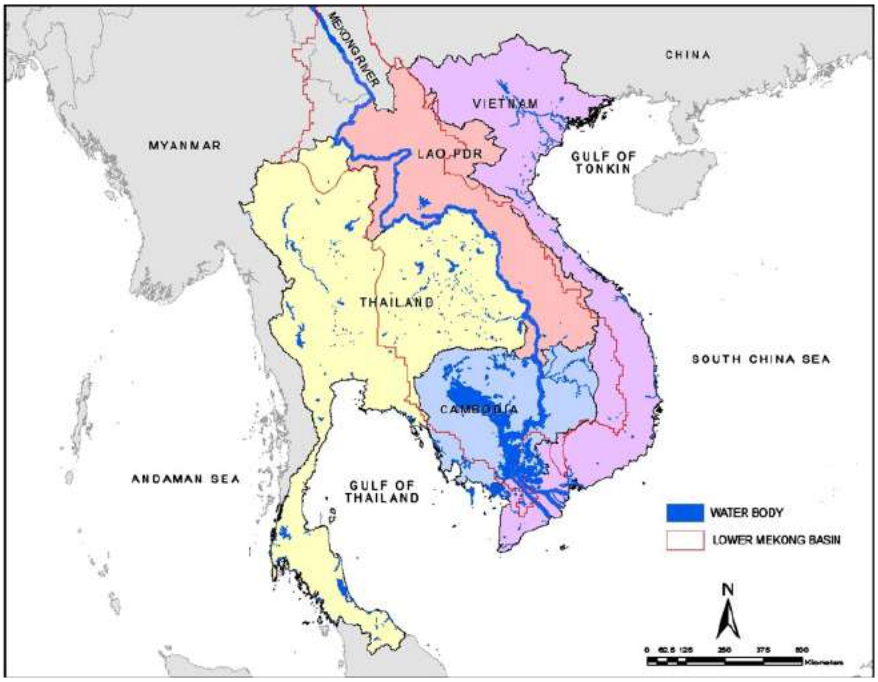

Figure 1. Lower Mekong Basin.

2. STUDY METHODS

2.1 Assessment of rice yield using SWAT model

The rice yield for Northeast Thailand was simulated by using the ecology specific data under SWAT (Soil and Water Assessment Tool) model. Three different future period, 2020-2029, 2050-2059, and 2080-2089, were chosen for the future projection and climate change impact assessment in three provinces of Northeast Thailand.

SWAT can simulate the hydrological process (stream flow), soil carbon, crop production and water quality. In this study, only stream flow and crop production was extracted from the model. The SWAT model was calibrated for both stream flow and crop production, and using the temperature and precipitation from the downscaling process.

2.2 Study area

The study basin comprises almost 19 provinces located in Northeast Thailand. These provinces lie between latitude 14.5 to 17.5 N and longitude 102.12 – 104.9 E. Mekong River enters to the area after running along the borders of Lao PDR; run along Thailand border in Eastern part of the country and then runs to Cambodia.

The three Provinces – Khon Kaen, Roi Et, and Ubon Ratchathani in Northeast Thailand, were selected for this study because they represent the different regions in that part of the country. The two major Rivers namely the Chi and the Mun Rivers, which are also tributaries of the Mekong River, flow through these Provinces.

2.3 Data collection and crop modelling

This study required several data items, which include topographic (Digital Elevation Model or DEM), soil, land use, meteorological, hydrologic (stream flow) and agronomic data. The DEM was extracted from the U.S. Geological Survey with the resolution of 90m. The soil data was extracted from the FAO global soil database as well as the land use data. The data has been extracted for the study area and processed using the ArcGIS9.3.

The future climate dataset and agronomic data were collected from previous research. Agronomic data on the effect of planting dates, fertilizer application, rain fed versus irrigation watering, management practices, etc., and on yield and yield components, were retrieved from field experiments conducted by the Rice Research Center in Khon kaen, Roi Et and Ubon Rathcathani. The cultivars used in the field experiment and KDML105 and RD6 in Roi Et Province in 2004, and KDML105 in Roi Et and Ubon Ratchathani in 1996.

The information on the physical and chemical properties of the soil was collected from the Land Development Department (LDD). There are 44 established soil types in Northeast Thailand. The major soil types used for rice cultivation are Roi Et, Ubon, Udon, Renu and Si Thon. The soil typoe data collected for modeling include slope, runoff potential and drainage type, soil texture and the soil water capacity.

2.4 Creation of climate change scenarios

Future climate scenario constructed by Southeast Asia START Regional Centre at Chulalongkorn University, Thailand was used as the input to the SWAT model for forecasting future rice yield. The future climate was predicted using the Global Circulation Model (GCM) ECHAM4 developed for the global resolution of 280 x 280 km by Max Plank Institute, Germany. These data were developed with consideration of world growth forcing a level of atmospheric CO2 according to the IPCC SRES A2 scenario. The A2 scenario which is one of the most pessimistic scenario, describes the future world as very heterogeneous with regionally oriented economic development. Thus A2 scenario assumes a large increase in greenhouse gas emissions and thus significant negative impacts on climate. To increase the resolution from global to local extent, dynamic downscaling using regional climate model (RCM) was applied. The GCM output was further downscaled at the regional level using the RCM PRECIS (providing regional climates for impact studies) for the study area at 25 x 25 km. The downscaled data for the periods of 2020 – 2029, 2050 – 2059, and 2080 – 2089 for the grid that includes the study site were used for each of the three study sites respectively located in three provinces.

The predicted future climate scenario was applied to the calibrated SWAT model for the study site to estimate the rice yield during the three future periods. The impacts were then assessed by computing the changes in the yield averaged for each of the three future decades (2020 – 2029, 2050 – 2059, and 2080 – 2089), with respect to the yield obtained for the actual daily weather data collected for ten consecutive years from 1997 to 2006 for each of the three sites.

3. RESULTS AND DISCUSSION

3.1 Calibration and validation

The model was calibrated for the period of 1981-1990 and followed by the calibration for the period of 1991-2006. The calibration parameters were constrained with the range of each parameter. Model outputs were calibrated to fall within the percentages of average measured values; and then monthly regression statistic, Nash-Sutcliffe Efficiency coefficient (ENS), and the coefficient of determination (R^2) were evaluated. If measured and simulated mean values met the calibration criteria but ENS and R^2 did not, then additional checking was performed to ensure that rainfall variability and plant growing season were properly simulated overtime. If all the parameters were pushed to the limit of their range for the model output, and the calibration criteria were still not met, then the calibration was stopped for that output.

Streamflow was the first output to calibrate. The streamflow was extracted as the surface runoff (SR) and base flow (BF). SR was calibrated until the average simulated and observed SR has the bias within 15 percent and the monthly ENS > 0.5 and R2 > 0.6. The same criteria were applied to calibrate the base flow.

In the validation processes, the model was run with the parameters identified in the calibration process for different time series data from the calibration period. On the hydrological component, the average streamflow, peal flow and volume was between the observed and simulated and the statistic value of Nash-Sutcliffe Efficiency coefficient (ENS) and the coefficient of determination (R^2) was calculated.

For the crop model component, since the availability of crop production data is limited, the model was calibrated based on the result of field experiment in 1996. The simulated crop production was compared with the experiment result and the statistic value (coefficient of determination and bias) was calculated.

3.2 Stream flow

The simulated streamflow agreed with the observed value with the accuracy about 77 per cent. The simulated flow was substantially underestimated for September – October, but has the high accuracy for the other months. The simulated monthly flow of the SWAT model reached the R^2 of 0.78 and Ens = 0.85.

In the validation period, the predicted peak flows and the time to peak matched well with the observed value. Though the peak flow in October was underestimated, the result shows close correspondence. The simulated flow shows good agreement with the observed data with the value of r^2 =0.82 and E_{ns} = 0.887.

In most cases, monthly stream flows were reasonably predicted by SWAT for the study area during calibration and validation periods. However, stream flows were quite underestimated in the wet months through the period of study.

3.3 Rice Yield

Rice yield was simulated with SWAT model. Data from three locations (Khon Kaen, Ubon and Roi ET) were used to calibrate the model. The results show that rice is simulated with r = 0.71 along the calibration periods (Figure 2). However, the model slightly over predicted the yield in Khon Kaen and Udon provinces where models slightly underestimated the yield in Roi ET province.

The observed and simulated yield at Ubon Ratchathani indicated the model results are in agreement with the observed data. Calibration was done for the seeding in the normal date (8 August 1996) and a later date (28 August 1996). The yields were simulated with the bias of 1.3 percent in Khon Kaen, 1.24 percent in Ubon and -5.7 percent in Roi ET. However, the error is still acceptable and the model was used to project future rice yield in the following section.

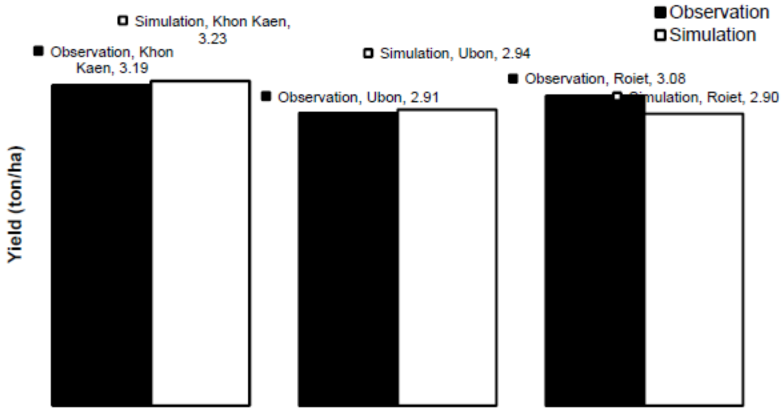

Figure 2. Observed and simulated rice yield in Khon, Ubon and Roi ET provinces during calibration.

3.4 Future climate projection

The projected future change of carbon dioxide concentration, precipitation, maximum and minimum temperature average for the decade for the provinces of the study area for the periods of 2020 - 2029, 2050 – 2059 and 2080 – 2089 as relative to baseline (1980 – 1990) are shown in the table below.

Table 1. The increasing of temperature and precipitation of future climate projection based on baseline (1980 – 1989).

		Ubon			Khon Kaen			Roi Et		
Period	CO_2 (ppm)	Tmax (°C)	Tmin (°C)	Precipitation (%)	Tmax (°C)	Tmin (°C)	Precipitation (%)	Tmax (°C)	Tmin (°C)	Precipitation (%)
2020-2029	437	1.47	0.93	10.1	0.32	2.14	5.9	0.35	2.21	19.2
2050-2059	555	1.72	2.14	45.2	3.3	3.15	2.6	1.59	3.2	40.5
2080-2089	732	3.51	3.06	2.98	3.25	5.19	5.2	3.2	5.1	20.1

The result of future climate projection shows that the temperature will increase in the future in all locations and all time periods. However, the variation of temperature in the future at Ubon will be higher than two other areas. On the other hand the precipitation will increase at all areas. The precipitation will increase higher in the near future but lower in the far future.

3.5 Future crop yield under climate change scenario

The future crop is estimated by applying the projected future climate as inputs to the model. To assess the impact of climate change on future crop yield, future land use is assumed to be the same with the current period. The result of future projection is shown in the figure below.

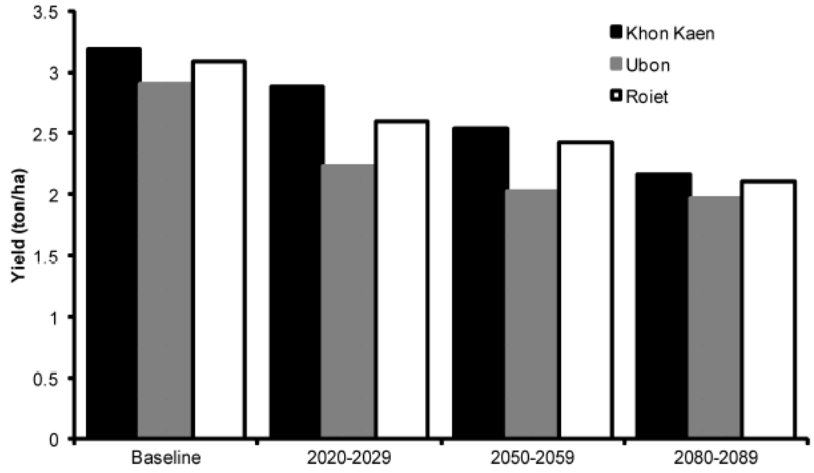

Figure 3. Rice yield in Khon Kaen, Ubon and Roi Et provinces under future climate scenarios.

The simulated rice yield is shown in the Table 2. The result shows the reduction of yield in all location about 9 – 24 percent in the period of 2020 – 2029. The percentages of reduction will increase to the range of 20 – 30 percent and 31 – 32 percent respectively in the period of 2050 – 2059 and 2080 – 2089. This reduction was caused by the rise in temperature, which would decrease the grain-filling duration. Increasing temperature will reduce the duration between anthesis and maturity in the future, which would affect spikelet sterility and, hence, reduce the final yield. The harvest index was also reduced for future periods. This condition indicates that, although the total biomass yield remained almost the same, the grain yield will decrease significantly in the future periods.

Table 2. Simulated and percentage change of rice yield under future climate change scenarios.

	Rice Yield (tonne/ha)			
Location	Baseline	2020-2029	2050-2059	2080-2089
Khon Kaen	3.186	2.876	2.544	2.165
		(-9.73)	(-20.15)	(-32.05)
Ubon	2.908	2.233	2.027	1.975
		(-23.22)	(-30.3)	(-32.1)
Roi Et	3.081	2.597	2.426	2.104
		(-15.7)	(-21.26)	(-31.7)

3.6 Result summary

This sample study assessed the impact of climate change on rice yield in Northeast Thailand using SWAT model and PRECIS dynamic downscaling. The SWAT model simulates the water availability in the study area and the crop production using the Erosion-Productivity Impact Calculator (EPIC) plant growth model. The simulated weather data downscaled via RCM PRECIS was in good agreement with the observed weather in terms of seasonal pattern, indicating that PRECIS provided acceptable weather data for future periods. The results show the increasing temperature and decreasing precipitation in future periods. It predicted a useful input to effective planning of water resources of the study area.

The simulated yields of rice in the three provinces of NE Thailand for 2020 – 2029 and 2050 – 2059 under SWAT model are in line with the projected rice yields for entire Thailand using econometric model for the 2025 and 2050. The decline in the yield is higher under SWAT model about 9 to 24 percent decline in the rice yield by 2020 – 2029 and about 20 – 3o percent decline in rice yield by 2050 – 2059 compared to rice yield projection by the econometric model that indicates 4 percent and 10 percent decline in the yield by 2025 and 2050 respectively.

4. CONCLUSIONS

Food security becomes a predominantly rural and also local issue in the LMB, which is amongst the major food sources in the world. Food insecurity concentrates mainly in remote mountain areas with low levels of rice production in the LMB. Though food shortages would occur from a range of factors, local crop failures remain the key factor where limited access to markets and poverty remains significant. Where local crop failures threat food security, importance of capture fishery would hold as well.

Pilot exercise of crop yield modeling showed varied levels of future reduction in the yields in the projected climate change scenarios. An econometric and SWAT models predict rather clear reduction in the rice yield. Combined with the result of gross margin analysis and observations in the field, actual trends of average rice yield will likely continue to increase in the near future. For the long-term insecurity, risks and vulnerabilities other than the direct impact of climate change on plant physiology, also need investigation. Various risks in crop production are not taken into account in the yield simulation by crop models.

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