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IMPACT ASSESSMENT OF CLIMATE CHANGE ON RICE PRODUCTION IN KHON KAEN PROVINCE, THAILAND

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ABSTRACT

Global climate change can affect crop yield of rice in the future. In the northeast region of Thailand, farmers faced both floods and drought and low soil fertility, leading the low rate of food self-sufficiency. Based on the questionnaire survey conducted in eleven districts of Khon Kaen Province as the Mid-Northeast, this paper aims to analyze the impacts of climate change on rice production, profitability of rice farming, and adaptation practices to climate change for rice farmers. Many rice varieties were grown in different paddy soil series of Khon Kaen Province. Impact assessment of climate change revealed production of major rice varieties in different paddy soil series under levels of N fertilizer application: three types of non-glutinous rice were KDML 105, Suphanburi, and Chainat; and glutinous rice were RD6 and Sanpatong. KDML 105 rice had high yields in Phon Phisai soil during the years 2010-2019, while RD6 could not grow well in Roi Et soil. Other rice varieties (Suphanburi rice, Sanpathong rice, and Chainat rice) could grow very well in Roi Et and Nam Phong as major soil series of Northeast Thailand. Yield of all tested rice varieties appear to decrease during the years 2050-2059 and 2090-2099, which was presumably due to the difficulties in rice cultivation under the unpredictability of climate. Chang rice variety was considered to maintain rice yields under future climatic conditions. For example, KDML 105 will have high yield during the dry season of years 2050-2059 and will increase during the years 2090-2099, if it will be planted on July. RD6 will grow very well during rainy season of the years 2090-2099 with planting done on June and July for both of Re and Pp soil series. Area, solar radiation and temperature were the most important factors in improving rice production. As solar radiation and temperature increased, rice yield would decrease.

Key words: Adaptation, rice farming

INTRODUCTION

Rice has long been Thailand's traditional food crop and the country's main export product. Over 80% of the Thai population eats rice as their main meal, with annual per capita consumption totaling 101 kg. Nonetheless, Thailand suffered more than USD $1.75 billion in economic losses related to floods, storms, and droughts from 1989-2002, the main share of that (USD $1.25 billion) was from crop yield losses (ADB, 2009). Climate change directly affected precipitation and temperature, with rise in temperatures leading to water deficit and floods in the future, changing soil moisture status, and pest and disease incidence (Chinvanno, 2010). Thailand will see drier spells in the middle of the wet season which can damage young plants, and floods at the end of the wet season that will affect harvest. Furthermore, increasing temperature or hotter night temperatures can cause increased spikelet sterility in rice and reduce grain yield (Wassmann and Dobermann, 2007).

The impacts of climate change on rice production in Thailand have been assessed by several research groups. For example, Agarwal (2008) estimated that the yield of Thai rice was expected to decline about 18% in the 2020s because of alterations in temperature and rainfall cycle and through changes in soil quality, pests and diseases as the impacts of climate change. Results from the Mekong Wetlands Biodiversity Conservation and Sustainable Use Programme (MWBP) (2005) indicated that many rice growers in the basin area faced the risk of losing paddy fields from floods and droughts due to climate change. The government of Thailand prepared an action plan on global warming mitigation and raised public awareness on the impacts of climate change (Setsiroot, 2007). In fact, many farmers need to be better informed of the consequence of climate change on their rice production and efficient management of their farms. Individual farmers may adapt in different ways to climate change based on their capability and individual adaptation scheme would differ from governmental policy that considered a much larger scale. This study tried to assess the impacts of future climate change on major rice varieties of Khon Kaen Province, and how rice farmers adapt to climate change through changing crop calendar and levels of N fertilizer application. Khon Kaen Province is one of the main rice growing areas of Thailand, while it faces extreme drought and flood. The analysis is based on a farm management questionnaire survey in eleven districts of Khon Kaen Province (Fig. 1), which covered all rice producing areas was conducted from February to March 2010. The selection of the surveyed districts was based on agro-climatic zones in order to capture the spatial distribution of climatic variability across the province.

The study sought to assess impacts of climate change on rice production and to clarify profitability of rice farming and possible ways for adaptation to climate change

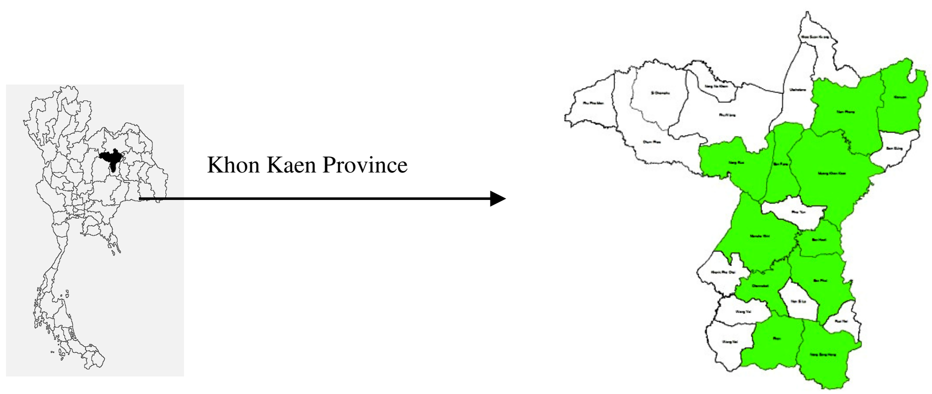


Fig 1. Map of studied area in eleven districts, Khon Kaen Province, Thailand

GENERAL INFORMATION OF THE AREA AND FARMERS STUDIED

Khon Kaen Province is located in the northeastern part of Thailand at 16°26′N 102°50′E with an elevation of 100-200 meters from sea level. It is comprised of 26 districts, with a total area of 10,886 square kilometers, and approximately 1.76 million inhabitants, 24% of whom are engaged in farming. Temperature ranges from 19 to 37 °C, with the average annual rainfall being about 1,040 millimeters with 104 rainy days (Khon Kaen Meteorological Station, 2010). There are several tributaries and irrigation canals from Nam Pong River, Chi River, and Ubolratana Dam. The total rainfed area in Khon Kaen was approximately 539,913 ha or nearly 82% of total farmland in 2010. Of the total farming area, nearly 65% is of naturally low fertility. Rice is the main food product in Khon Kaen Province.

During the past 30 years, the total planted area in Khon Kaen Province increased by 22%, but it was small increase in rice by 13%. In fact, there were high growing demand of field crop (sugarcane and cassava) due to higher price from the world market, and some farmers also preferred for faster cash crops of vegetables (Table 1).

Table 1. Land resources in Khon Kaen Province.

Year	Area cultivated (ha)			
	Rice	**Field crop**	**Fruit and vegetables**	**Total**
1978	2,228,701	714,247	79,360	3,215,196
2009	2,527,699	895,211	222,241	3,928,425
Growth ratio (%)	13.42	25.34	180.04	22.18

Source: Khon Kaen Provincial Statistical Office, 2010

In the study area, average operated land of households was 2.35 ha, most of whom were owner farmers (Table 2). More broadly, each farm area was divided more than 2 parts for paddy field, field crops, vegetables or fruit trees, and livestock. The average age of the heads was 55 years, while their farm experience was more than 40 years. The majority of farmers graduated only from primary school, which was the basic formal education. Most of the household income came from farm activities. The average annual household income was around USD $ 4,286, 48 % was engaged in farm income (USD $ 2,054).

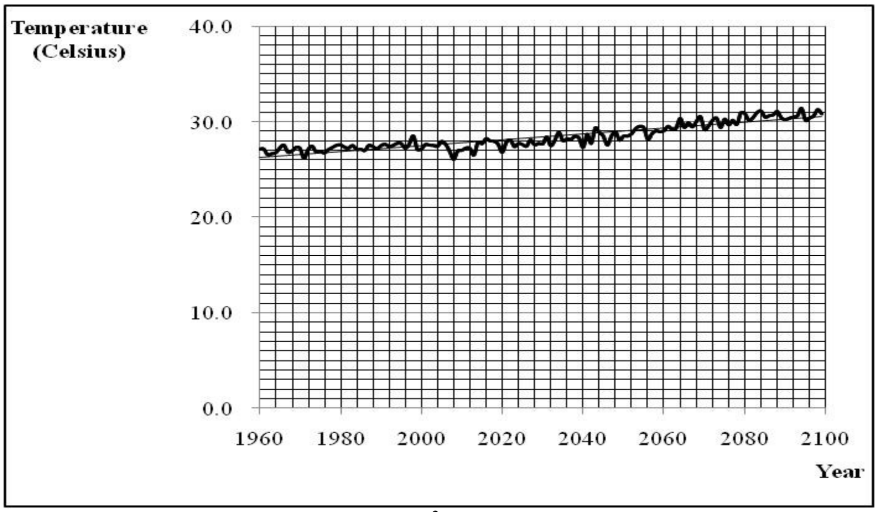
Table 2. Profile of farmers interviewed in Khon Kaen Province, 2010.

Items	
No. of farmers (HH)	300
Average age of household heads (HHH) (years)	55
Formal education of HHH (years)	4
Farming experience of HHH (years)	40
Distribution of the HHH by occupation	
Farmer	285
Non-farm labor	15
Distribution of households by tenurial status	
Owner farmers	299
Tenant farmers	1
Average farm size (ha)	2.35
Annual household income (USD per household)	
Farm income	2,054
Non-farm income	2,232

IMPACTS OF CLIMATE CHANGE ON RICE PRODUCTION IN KHON KAEN PROVINCE

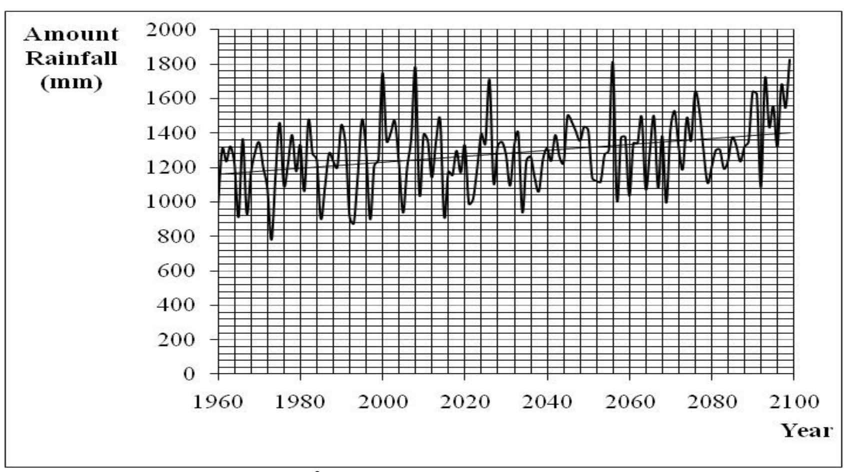
Impact Assessment of Climate Change

The climate impact on rice production was simulated by using the Decision Support System for Agro-technology Transfer Model (DSSAT) under different climatic conditions in Khon Kaen Province. The climatic factors for running this model included maximum temperature, minimum temperature, rainfall, and solar radiation from year 1960 to 2099 based on ECHAM4-PRECIS climate models under SRES B2 GHG Scenarios (The Southeast Asia START Regional Center, 2010). This weather dataset was used to simulate yields for the near future (the years 2010-2019) and the far future (the years 2050-2059 and 2090-2099). Trends of temperature and rainfall from 1960 to 2099 were an increasing at the level of 14% temperature and rainfall fluctuations (Fig. 2).



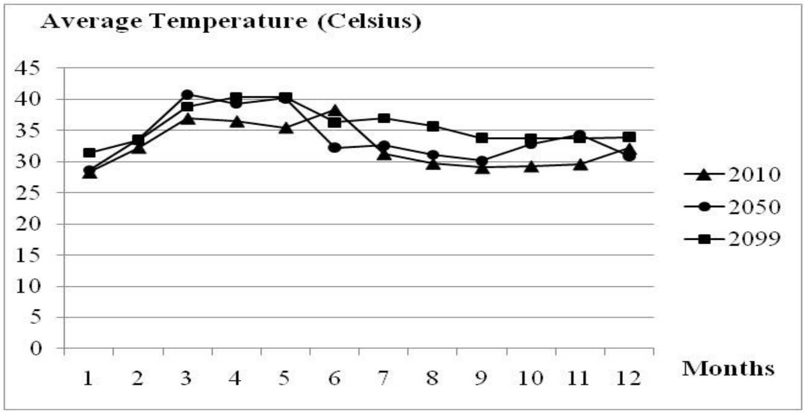
Temperature = 0.03 Year + 26.27, R^2 = 0.82

(a) Average temperature trend

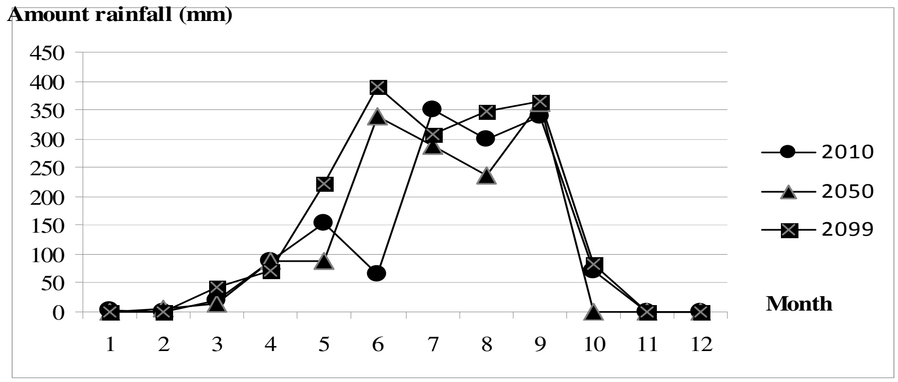


Rainfall = 1.74 Year + 1160, R^2 = 0.61

(b) Average amount rainfall trend



(c) Average temperature per month during 2010, 2050, 2099.



(d) Average amount of rainfall per month during 2010, 2050, 2099.

Fig. 2. Temperature and amount rainfall trends in Khon Kaen Province, 1960-2099.

Levels of rice yields depended not only on the climatic conditions, but also on field soils and capability of management (crop, irrigation, fertilizer, tillage and harvest). An experimental dataset of crop management and soil series for major rice varieties of both glutinous and non-glutinous rice from the Ministry of Agriculture and Cooperatives were used for this study. Two types of glutinous rice were RD6 and Sanpatong, and non-glutinous rice were KDML 105 (Jasmine Rice), Suphanburi, and Chainat. The majority of the farmers preferred to plant glutinous rice for their household consumption, while non-glutinous rice for cash. Over 50 paddy soil series were found in Khon Kaen Province, three paddy soils were selected in this assessment based on the high ranking areas of rice cultivation and available data including Roi Et-Re (20%), Nam Phong-Np (8%), and Phon Phisai-Pp (5%) (Khon Kaen Rice Experiment Station, 2006). Therefore, this study shows yields of five rice varieties in three soil series during the rainy season (May-November) and the dry season (December-May) under climatic conditions and three levels of N fertilizer application, 25, 50, and 75 kg per ha to improve yield.

Simulated rice yields in three soil series (Re, Np, and Pp) of Khon Kaen Province during the years 2000-2009 under three levels of N fertilizer application are shown in Table 3. Based on data obtained from the questionnaire survey of 300 farmers in Khon Kaen, major glutinous rice (RD6) and non-glutinous rice (KDML105) were used to simulate. It is obvious that levels of N fertilizer affected rice production. Nitrogen fertilizer at 75 kg per ha provided higher rice yields than 25 and 50 kg per ha of N fertilizer for RD6 rice and KDML 105 rice during both rainy and dry season.

Climatic variability determined crop yield. Near future climate scenarios for the years 2010-2019, and future climate scenarios, for the years 2050-2059 and 2090-2099, were used to compare impacts of climate change on five varieties of rice crop production including KDML 105, RD6, Suphanburi, Sanpatong, and Chainat at 75 kg per ha of N fertilizer application.

Table 3. Comparison of simulated rice yields in three soil series of Khon Kaen Province with different levels of N fertilizer application during the years 2000-2009.

	Soil Series	Level of N Fertilizer (kg per ha)	Type of Rice / Yield (kg per ha) KDML 105 Mean	KDML 105 Std. Dev.	RD6 Mean	RD6 Std. Dev.
Rainy Season	Roi Et (Re)	25	677.3	484.5	663.8	520.5
		50	541.7	472.5	612.3	516.7
		75	957.2	656.5	818.6	625.0
	Nam Phong (Ng)	25	1,632.8	694.4	1,641.2	668.7
		50	1,225.6	688.7	1,100.1	614.3
		75	1,934.7	922.7	1,865.2	857.4
	Phon Phisai (Pp)	25	2,544.2	916.9	2,596.8	936.5
		50	2,766.7	821.0	2,638.4	755.8
		75	2,923.7	1,159.0	2,935.7	1,189.9
Dry Season	Roi Et (Re)	25	2,363.1	1,683.3	1,466.2	1,382.7
		50	1,718.3	1,534.3	1,197.2	1,315.7
		75	3,186.3	1,717.9	2,103.7	1,356.6
	Nam Phong (Ng)	25	2,696.6	1,846.8	2,036.9	1,689.6
		50	2,636.2	2,087.3	1,828.1	1,629.8
		75	3,568.7	1,888.9	2,765.2	1,680.3
	Phon Phisai (Pp)	25	3,432.1	2,374.9	2,280.1	1,769.8
		50	3,302.1	2,632.7	2,322.7	1,994.3
		75	4,206.7	2,247.3	2,923.7	1,765.7

Possible adaptation of crop yields through a change in month of planting under major soil series and climate conditions during the years 2010-2019, 2050-2059, and 2090-2099 were evaluated (Tables 4-6). KDML 105 had high yields in Pp soil during rainy season, while Suphanburi, Sanpathong and Chainat could grow very well in Ng, and Pp soil series for the dry season of the years 2010-2019 with planting done on December or January (Table 4). RD 6 had high yield in Ng and Pp soil series during both rainy and dry seasons. All of the rice varieties appear to show a decreasing trend during the years 2050-2059 and 2090-2099, which is presumably due to the difficulties in rice cultivation under the unpredictability of climate. The results show KDML 105 will have higher yield during the dry season of the years 2050-2059, RD 6 has high yield during the rainy season when planted in May, June or July, while other rice varieties (Suphanburi, Sanpatong, and Chinat) will decrease in yield during both the rainy and dry seasons (Table 5).

Rice farmers need to change rice variety under climate change in the future. Yields of five rice varieties will be reduced during dry season of the years 2090-2099 (Table 6). If farmers will choose to plant non-glutinous rice (KDML 105 and Suphanburi) from July, they will get high yield. RD6 for glutinous rice will grow very well during the rainy season, it appears advantageous to start planting on June and July for both Re and Pp soil series.

Adaptation to Climate Change

The common problems of rice production in the villages studied were inadequate water supply in the dry season, floods in the rainy season, inadequate labor during harvest and transplanting, high pest and disease occurrence, and low soil fertility. Adaptation technical issues based on some interviews with local farmers and available information are summarized in this sub-section.

First, most farmers grow glutinous rice for household consumption. If they had a larger land area, they would grow Jasmine rice (KDML 105), Suphanburi, and Chainat on a commercial basis. The adaptation of rice cultivation was carried out through various factors, including new rice varieties, fertilizers, pesticides and labor. Farmers used seeds from the previous year and new varieties. The new rice varieties provided high yield, temperature resistance and consumed less water. Khao Dok Mali Thon Nam Thum, a new Jasmine rice variety and RD 12 for glutinous rice, could survive complete submergence for 20 days.

Second, rice was mostly transplanted or direct seeded depending on water supply and labor. The planting season was around June and the harvest was from November to January. There were many farmers who apply chemical fertilizers to increase yield. Although adaptation technology relied on increasing use of chemical fertilizers to attain higher yield, resulting in higher costs and lower profits. Therefore, green management of soil fertility becomes an alternative way of adaptation.

Third, many young villagers were engaged in nonagricultural employment in the city. Agricultural machinery was used more for production and transport of products to market. As agricultural labor is limited, most farmers interviewed had tractors for land preparation, water pumps and sprayers for the dry season. Land preparation for rice farming included soaking, plowing, and puddling through mechanized means. It seems there was a high demand for labor for crop care and harvest processing. If agricultural machines provided high cost of oil and CO_2 pollution, it was thus necessary to develop the hybrid cultivation technology to reduce CO_2 emissions and fuel consumption.

Fourth, most villages studied were located in rainfed areas. High temperature increased evaporative demand, rice needs more water supply, and irrigation and drainage facilities were very important. Paddy fields were flooded with 7-10 centimeters of water during the crop growth and 2 weeks before harvest. While there was the possibility of farmers facing extreme floods and drought, many farmers in drought areas had transformed their rice farm to planting of drought resistant crops using less water such as soybean, cassava, and sugarcane. The irrigation technologies of dam and water channels need to be developed more, and constructed to enable water to be drawn onto the fields. The traditional weir was called Fai, it was constructed from stones and earth, and easily destroyed by floods. The operation and maintenance of Fai required the cooperation of the local community.

Fifth, many soil series were found on paddy field, the major suitable area for rice cultivation was located north of Khon Kaen Province due to high fertility and adequate water supply from the Ubolratana Dam (Fig. 3). It seems the soil environment was affected by the severity of weathering and erosion, in particularly sandy soil and clay soil area. The sandy soil does not have high drainage capacity, while over 50 millimeter per hour per day of rainfall could not permeate the clayey soil but runs off the surface while stripping away the fertile soil (Hattori and Kyuma, 1978). Soil fertility management was important to improve rice crop. The maintenances of soil fertility included the use of various organic wastes/ manure, crop rotation practicing, and reducing burn agriculture.

Sixth, many farmers could not afford seeds of high yielding varieties, the most commonly used adaptation techniques was a change in crop calendar and cropping pattern. Another important consideration was promoting drought-tolerant rice varieties of local communities, which were selected for high yield under water shortage. Risk transfer mechanisms should be included in adaptation strategy from the national to the household levels. This can include crop insurance and more diversified livelihood. An example of integrated aquaculture and agriculture systems allowed farmers to shift in response to change in the suitability of land and availability of water to produce food.

Finally, the government of Thailand worked on an action plan for global warming mitigation, and provided information to raise awareness about climate change. As part of the plan, the government promoted new genetically modified (GM) varieties of deep water rice, and also constructed embankments to protect rice farms from flood damage. However, the government could not provide enough seeds of new high yielding varieties to distribute to all farmers, while many rice growers had inadequate knowledge for the efficient management of their farms under the impacts of a transformed climate. Therefore, the implementation of climate adaptation in Thai rice production needs to be improved.

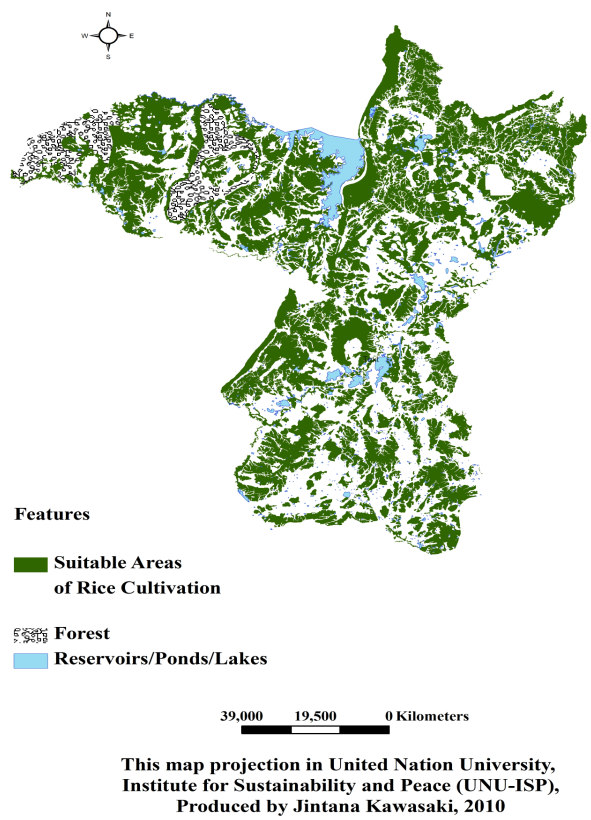


Fig. 3. Suitable area for rice cultivation in Khon Kaen Province, 2010.

ECONOMIC ANALYSIS

Costs and Returns

The data collected from the questionnaire survey were used to estimate costs and returns per hectare for rice production during the rainy season and dry season. Costs have been classified into variable costs such as seeds, fertilizers, and labor, and fixed costs such as depreciation, interest on capital and rental payment of land. Total revenue was measured by price and yield for each crop. Net profit was obtained by deducting total cost from total revenue.

Average costs per hectare of rice for two seasons, rainy season and dry season, are presented in Table **7.** Rice crop per hectare in the rainy season had the highest total production cost of USD $598.6, labor constituted the largest expense of USD $335.3. Input costs during the dry season such as seed, fertilizer and pesticides, were higher than in the rainy season.

The profitability of rice production per ha is shown in Table 8. Normally, rice prices depended on the demand and growing time, but price of rice production during the rainy season was guaranteed with higher prices by the government policy. The average farm price per kg of rice ranged from USD $0.25- 0.39 for the rainy season, and USD $0.22-0.32 for the dry season. Although rice in the dry season had lower price, farmers had the highest revenue with higher yields contributing to higher profits. It seems most farmers preferred to grow new rice high yielding varieties in the dry season for selling, while they planted the traditional variety from the previous year in the rainy season for their household rice consumption. The net profit per ha was the highest at USD $811 for dry season, followed by USD $575 for the rainy season. The profitability of rice production was also evaluated by the ratio of benefit to cost. The benefit-cost ratio (B/C ratio) during the rainy season and dry season were greater than one, especially the highest B/C ratio of dry season was 2.41. These benefits and costs were estimated without adaptation cost to climate change. However, level of rice yields in the future will more fluctuate, depending on climatic conditions and production efficiency. The adaptation and crop damage cost to climate change need to further understand for policy makers and farmers. The government should also provide advices on adapting production technology to become more resilient to climate change.

Production Function Analysis

In order to examine the mechanism of rice production in Khon Kaen Province under unpredictability of climate, the production function of the Cobb-Douglas type was estimated for the farmers studied. The dependent variable (Y) is total production of rice in Khon Kaen Province during 1960 to 2010 (kg per year), and four independent variables were used: X_1 refers to rice's total planted area per year (ha), and physical factors of rice production including X_2 is annual temperature (Celsius), X_3 refers to annual rainfall (millimeter), and X_4 is solar radiation (mega joule).

The results of the estimation of rice production function under climatic conditions of Khon Kaen Province during the years 1960-2010 are presented in Table 9. The regression coefficients of planted area, temperature, and solar radiation were significant at the 1% level. The coefficient of determination (R^2) was 85%, indicating a reasonable explanatory power of the variables included in the estimation.

Table 4. Simulated rice yields of five rice varieties in Khon Kaen Province during the years 2010-2019.

Soil Series	Planting Season	Type of Rice (kg per ha)									
		KDML 105		RD6		Suphanburi		Sanpatong		Chainat	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Roi Et (Re)	Rainy Season										
	May	649.0	356.9	620.0	523.8	1,627.0	1,443.2	1,426.0	1,415.7	1,152.0	1,008.4
	June	545.0	302.7	643.0	469.3	1,728.0	1,175.4	1,466.0	1,317.0	1,128.0	767.3
	July	645.0	413.2	829.0	439.0	2,485.0	1,763.3	1,903.0	877.4	2,078.0	1,638.3
	Dry Season										
	December	2,495.0	1,889.1	1,861.0	727.6	2,132.0	1,917.0	2,699.0	1,376.3	2,234.0	1,809.6
	January	3,205.0	1,809.2	1,454.0	616.7	3,006.0	2,716.2	2,270.0	1,689.1	2,589.0	1,575.1
	Rainy Season										
Nam Phong (Ng)	May	1,138.0	952.3	2,120.0	2,023.8	1,790.0	1,087.1	1,517.0	1,423.4	2,576.0	1,792.7
	June	1,580.0	672.1	2,531.0	2,133.2	2,423.0	1,453.2	1,638.0	1,540.7	2,375.0	1,401.8
	July	1,271.0	829.1	2,765.0	2,131.5	1,848.0	1,403.9	1,752.0	1,620.0	2,606.0	1,288.6
	Dry Season										
	December	2,476.0	2,020.1	2,303.0	1,677.6	2,623.0	1,910.8	2,168.0	1,579.3	3,104.0	2,989.6
	January	2,349.0	2,002.8	2,246.0	1,350.0	2,625.0	1,577.9	2,284.0	1,372.9	3,291.0	3,081.5
Phon Phisai (Pp)	Rainy Season										
	May	2,226.0	2,150.7	2,101.0	2,096.4	1,474.0	1,407.0	1,602.0	1,597.4	888.0	847.6
	June	2,451.0	1,305.5	2,309.0	2,092.3	1,372.0	929.4	1,564.0	1,426.6	965.0	653.7
	July	2,646.0	1,301.6	2,683.0	2,318.9	1,366.0	637.7	1,556.0	1,259.6	1,070.0	499.5
	Dry Season										
	December	3,231.0	1,513.4	2,282.0	1,909.7	1,479.0	1,049.5	2,365.0	1,968.6	2,479.0	1,759.0
	January	2,872.0	1,068.8	2,994.0	1,208.4	3,248.0	2,311.0	2,436.0	1,579.6	2,931.0	2,797.5

Table 5. Simulated rice yields of five rice varieties in Khon Kaen Province during the years 2050-2059.

Soil Series	Planting Season	Type of Rice (kg per ha)									
		KDML 105		RD6		Suphanburi		Sanpatong		Chainat	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Roi Et (Re)	Rainy Season										
	May	673.0	575.3	865.0	667.1	1,154.0	904.9	1,044.0	912.1	731.0	754.1
	June	419.0	317.0	867.0	717.7	1,863.0	1,267.2	1,345.0	1,234.7	1,088.0	740.1
	July	1,298.0	1,073.0	909.0	679.2	1,880.0	1,577.5	1,617.0	895.3	1,441.0	442.6
	Dry Season										
	December	2,298.0	2,073.0	1,808.0	833.2	1,880.0	1,554.1	2,593.0	1,490.2	1,380.0	1,140.7
	January	2,934.0	1,091.7	1,021.0	840.8	708.0	399.7	1,433.0	808.9	2,096.0	1,183.2
Nam Phong (Ng)	Rainy Season										
	May	1,673.0	886.3	2,795.0	2,349.6	1,511.0	703.2	945.0	550.5	2,439.0	1,604.1
	June	1,134.0	636.4	2,539.0	2,417.8	1,692.0	741.5	1,324.0	1,134.3	2,461.0	1,494.0
	July	1,252.0	972.4	2,979.0	2,856.3	1,603.0	1,287.2	1,420.0	676.4	2,396.0	1,188.6
	Dry Season										
	December	3,083.0	1,966.4	2,026.0	1,138.6	1,603.0	945.7	1,811.0	1,484.5	3,749.0	2,743.1
	January	2,028.0	1,866.6	2,203.0	2,119.7	1,567.0	974.6	1,522.0	1,400.8	3,272.0	2,091.1
Phon Phisai (Pp)	Rainy Season										
	May	2,517.0	1,480.7	2,408.0	2,138.2	1,071.0	1,022.3	1,310.0	959.0	687.0	655.8
	June	2,504.0	1,691.4	2,537.0	2,171.4	1,524.0	1,032.4	1,236.0	598.7	991.0	671.3
	July	2,080.0	1,137.3	2,112.0	2,052.3	1,140.0	532.2	790.0	880.4	747.0	348.7
	Dry Season										
	December	3,424.0	2,667.0	1,861.0	1,403.3	1,124.0	534.0	1,662.0	1,310.1	1,635.0	765.8
	January	3,856.0	2,690.7	2,190.0	1,815.0	1,203.0	755.5	1,359.0	505.7	2,193.0	816.1

Note: Yields during the years 2050-2059 with underlines are lower than yields during the years 2010-2019.

Table 6. Simulated rice yields of five rice varieties in Khon Kaen Province during the years 2090-2099

Soil Series	Planting Season	Type of Rice (kg per ha)									
		KDML 105		RD6		Suphanburi		Sanpatong		Chainat	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Roi Et (Re)	Rainy Season										
	May	922.0	622.7	735.0	636.1	1,205.0	1,002.2	920.0	632.4	864.0	791.3
	June	900.0	612.2	1,271.0	864.5	2,812.0	1,912.7	852.0	579.5	2,163.0	1,471.3
	July	2,307.0	1,708.7	1,379.0	730.8	2,100.0	1,952.3	1,091.0	642.3	1,117.0	650.3
	Dry Season										
	December	650.0	537.3	1,583.0	1,051.3	2,100.0	1,256.3	1,448.0	1,370.3	626.0	517.5
	January	790.0	445.9	866.0	771.1	1,668.0	1,506.1	713.0	402.5	880.0	496.8
Nam Phong (Ng)	Rainy Season										
	May	1,841.0	761.4	2,376.0	2,013.4	1,549.0	1,211.9	750.0	625.2	2,430.0	1,334.4
	June	1,750.0	653.6	2,365.0	2,169.6	1,500.0	1,350.8	950.0	535.8	2,410.0	1,439.3
	July	1,435.0	707.2	2,418.0	1,991.0	1,928.0	1,442.0	1,260.0	910.7	1,718.0	1,342.0
	Dry Season										
	December	2,734.0	1,151.2	1,830.0	887.0	1,455.0	955.5	1,360.0	854.9	3,649.0	1,017.9
	January	1,890.0	819.2	2,004.0	1,924.1	1,096.0	1,008.8	708.0	651.6	2,891.0	1,820.1
Phon Phisai (Pp)	Rainy Season										
	May	2,704.0	1,899.3	2,191.0	1,823.2	1,451.0	1,339.6	910.0	868.6	712.0	572.3
	June	2,530.0	1,359.0	2,662.0	2,448.4	2,196.0	1,487.6	814.0	583.6	640.0	412.0
	July	2,927.0	1,899.6	2,798.0	1,839.4	2,575.0	1,202.1	673.0	581.0	822.0	650.6
	Dry Season										
	December	2,762.0	1,356.9	1,269.0	1,260.0	755.0	613.7	1,448.0	1,209.8	1,717.0	1,335.8
	January	2,892.0	1,332.0	1,724.0	641.6	1,063.0	842.2	728.0	570.9	1,043.0	788.1

Note: Yields during the years 2090-2099 with underlines are lower than yields during the years, 2050-2059

Table 7. Cost of rice production per ha in Khon Kaen Province, 2009.

Unit: USD

Items	Rainy Season	Dry Season
Variable Costs :	498.3	496.1
Seed	42.4	44.2
Fertilizer	54.6	58.3
Pesticide	30.5	32.3
Labor	335.3	326.4
Opportunity cost of investment (1.7% per year)	2.9	3.1
Others	32.4	31.9
Fixed Costs:	100.4	79.0
Land tax and land rent	98.3	76.4
Depreciation of farm machinery	2.1	2.6
Total cost	598.6	575.1

Source: Survey February-March, 2010

Table 8. Profitability of rice production in Khon Kaen Province, 2009.

Items	Rainy Season	Dry Season
1. Production (kg per ha)	3,786	5,331
2. Average farm price (USD per kg)	0.31	0.26
3. Total revenue (USD per ha)	1,174	1,386
4. Total cost (USD per ha)	599	575
5. Net profit (USD per ha) (3)-(4)	575	811
6. Benefit-cost ratio (3)/(4)	1.96	2.41

Source: Survey February-March, 2010

Table 9. Estimates of rice production function under climatic conditions of Khon Kaen Province during year 1960 – 2010.

Variables	Reg coeff.		t value
Constant	-0.188	ns	-0.041
Area (ha)	1.946	***	7.519
Temperature (Celsius)	-0.663	***	-1.339
Rainfall (millimeter)	-0.077	ns	-1.001
Solar radiation (megajoule)	-0.830	***	-4.535
R square	0.855		
F value	67.819		
N	50		

Source: Survey January-March, 2010; the Southeast Asia START Regional Center, 2010

Note: ***Denotes significance at 1% level

** Denotes significance at 5% level

* Denotes significance at 10% level

ns Denotes non significance at 10% level

The results imply that area, solar radiation, and temperature were the most important factors for rice production. If the area increased by 10%, rice yield would increase by 19.46%. While a 10 increase in solar radiation and temperature would decrease rice production by 8.30% and 6.63% respectively. The increased temperature and solar radiation caused high percentages of spikelet sterility of rice, but reduced grain yield. Our study revealed that rainfall was not a significant contributor to the determination of rice production, presumably because responsible water management of local communities encouraged farmers to cultivate the drought-tolerant rice varieties with less water.

CONCLUSIONS

The common adaptation practices to climate change found in rice farming were selection of new rice varieties for higher yield and improving soil fertility, while many farmers shifted cultivating dates to avoid the drought hazard in that year. Trend of climate change in the future will affect rice yields. These results highlights the need to implement adaptation to climate change strategies for rice farmers, which are as follows: 1) develop rice growing techniques by using appropriate local rice varieties with higher yield under water shortage; 2) improvement of soil fertility by using crop residues from farms and green manure for farm environment and reducing CO_2 emissions; 3) operation and maintenance of irrigation systems for enough allocation of water demand in the dry season and water storage in the rainy season; and 4) insure crop yield for small farmers.

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