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The Preliminary Study of Climate Change Impact on Rice Production and Economic in Thailand

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Abstract

Climate change affects crop production in two ways: changes in GDP and population and changes in climate variables, especially temperature and precipitation. This study aims to investigate preliminary effects of climate change impacts on Thailand's rice production, consumption, and export capacity by integrated EPIC model and the world and Thai rice market models. Therefore, the Biophysical process model (EPIC model) and Economic processes model are employed as the research methodology of this study. Main findings of the comparison showed both rice production and export in the base year (2007) are likely to expand until 2027, and there will be a sufficient amount of rice surplus for export, which is nearly the same level as that of domestic consumption in A2 scenario. In 2017, the amount of rice production will be only slightly higher than the domestic demand, leaving a small rice surplus of up to 2 million tons for export, compared to 14 million tons in 2016. However, in B2 scenario, the rice production capacity will be much lower than the domestic demand, meeting only half of it in 2017. From 2017 to 2019, the rice production capacity will undergo a constant fall and no longer meet the market demand as a result; it is estimated that there will be a shortage of approximately 0.038 to 0.218 ton. It is therefore important to note that if B2 scenario became reality in 2017, the rice production capacity of Thailand would nearly fail to meet the minimum level of domestic demand. However, we assure that Thailand still have land where can be converted to rice production with multiple cropping through irrigation investment, while comprehensive technical adaptation and mitigation to enhance farmer benefits are required.

Keywords: climate change, economic impact, rice production, Thailand

1. Introduction

Thailand is a major exporter of agricultural products with rice as one of its most important crops. Rice has not only played a part in contributing to food security of the world but also been an essential part of the Thai society and its culture for a very long time. Rice is the heart of the way of life of farmers in Thailand. However, there are many factors that have contributed to food insecurity these days. One of the factors is climate change, which has brought negative impacts to food production throughout the world. It has resulted not only in the increased temperature and decreased productivity but also in greater numbers of less predictable disasters such as drought. For decades scientists have agreed on the list of greenhouse gases – including carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) – that lead to the change of global temperatures and amounts of rainfall (IPCC, 2007). Studies have been conducted on climate change's impacts on several aspects as well as the plausible ways of minimizing such impacts in the future. There are also studies on climate change's impacts on rice production at national and international scales. According to the reports of the International Panel on Climate Change (IPCC) in 2007 and the Food and Agriculture Organization of the United Nations (FAO) in 2008, humid tropical zones will suffer negative impacts of the climate change, which definitely affects the way of life and food production. Various studies have been conducted to measure the effects of climate change impacts on net farm revenue such as integration of the Environment Policy Integrated Climate (EPIC) model and International Food Policy and Agricultural Simulation (IFPSIM) model (Wu et al., 2007), ORYZA 2000 (Vaghefi et al., 2011), Global circulation model (GCM) (Tumbo et al., 2010), Ricardian model (Fleischer et al., 2007; Ajetomobi, 2010; Thapa and Joshi, 2010; Mendelsohn, 2014), Statistical approaches were used to analyze the relationships between observed yield and climate (Chen et al., 2013; Huang et al., 2013; Wang et al., 2014). Mostly, their outcome found that rice production will decline with increase in temperature and decrease in precipitation, with decrease the net revenue per hectare, especially in dry land and non-irrigated areas. However, some results were inconsistent among studies due to differences of the empirical models, regional scale and the confronting effects of non-climate factors such as rice management practices, market mechanisms, policies and technology.

In Thailand, irrigation infrastructure covers only 21.82% of the entire agricultural area of the country, leaving 78.18% of the area to the hands of farmers themselves. Rice accounts for as much as 60% of the country's agricultural area, and most rice growing areas are in the northeastern region of Thailand (Isvilanonda & Bunyasiri, 2009), most of which are dependent on rainfall. The impact caused by climate change will bring in domino effects into people's lives, possibly starting from bio-physical system to their economy, society, and way of life, thus making them more vulnerable. The degree of the impact depends on adaptability of each community. Despite the impact that climate change could potentially bring, few integrated studies have been conducted to reach a greater insight into the situation in Thailand. In this study, therefore, the EPIC model was used in predicting rice production under two climate conditions – A2 and B2 – in the next 10 years (2017). 2007 was set as the base year (BY), and the analysis was anticipated to show the potential loss in rice production in the future.

Climate change results in a set of long-term effects – involving demography, environment, economy, public health, politics, and technologies, as well as food and water security. To be specific, climate change is much likely to have a negative impact on the agricultural sector and their productivity, which will further affect the farmers' incomes as a result. There have been very few studies about the climate change's impact on the agricultural sector in Thailand, especially on rice. In this study, the data on the loss in rice production caused by climate change was analyzed to find the preliminary impact on the economy using world and Thai rice market models and EPIC model to make suggestions on policy to prepare for the changes to come.

2. Methodology

2.1 Biophysical Process Models: EPIC Model

In the early 1980s, EPIC, also known as the Environmental Policy Integrated Climate was created by teams of scientists of the U.S. Department of Agriculture, belonging to the following services: Agriculture Research Service (ARS), Soil Conservation Service (SCS), and Economic Research Service (ERS) (Sharpley & Williams, 1990). EPIC was designed to simulate biophysical processes and the interaction of cropping systems over long periods of time, during which changes in the environment occur at a relatively slow rate. A wide range of soils, climates, and crops can be simulated, using predefined management practices, in an efficient and convenient manner (Smith, 1997). EPIC is able to simulate processes such as weather, soil erosion, hydrological and nutrient cycling, tillage, crop management, crop growth potential and crop yield. Crop growth is calculated on a daily basis with the required weather inputs, precipitation, maximum and minimum temperature, solar radiation, wind speed and crop parameters such as morphology, phenology, physiology etc. (Gassman et al., 2003, 2005; Zhang et al., 2010; Rinaldi and De Luca, 2012). It can calculate the potential daily photosynthetic production of biomass, which depends on radiation, water, nutrients, temperature, and soil aeration. Crop yield is simulated using the harvest index concept, which is affected by the heat unit factor and includes the amount of the crop removed from the field as well as the above-ground biomass. (Brown et al., 2000; Izaurralde et al., 2006; Rinaldi & De Luca, 2012).

In this study, the EPIC0509 version was used and run using i-EPIC interface. The i-EPIC model is a program that is linked to the EPIC model, an upgraded model that provides more accurate analysis (Willams et al., 2006). The input information and display of results are accomplished in Microsoft Access software. The i-EPIC model and its user manual can be downloaded fromhttp://www.public.iastate.edu/~tdc/i_epic_main.html. The current EPIC community code can be downloaded from http://epicapex.brc.tamus.edu (Arunrat & Pumijumnong, 2014; Arunrat et al., 2014).

2.2 Preparation and Data Collection

Base on the studies of Pumijumnong and Arunrat (2012; 2013) and Arunrat and Pumijumnong (2014) and Arunrat et al., (2014). The assumptions for the simulation are as follows; (1) the cropping calendar is fixed, (2) crop management is fixed (rice variety, fertilizer, pesticide and herbicide), (3) each simulation unit (SU) with similar environmental conditions (topology, soil property and weather data), (4) the climatic variables directly affect crop yields, (5) all parameters are fixed, and (6) current trade policy is not changed. We used the essential data and information for i-EPIC Model includes:

(1) Soil data

From the survey of soil nutrient status in Thailand during 2004-2008, 6,422 soil nutrient test results (pH, organic matter content, available phosphorus, and available potassium contents) were collected in the laboratory of the Office of Science for Land Development, Land Development Department.

(2) Weather data

Monthly weather data was obtained from the Thai Meteorological Department for the period 1988–2007 and weather data of A2 and B2 scenarios (IPCC SRES) for the next 10 years (2017) from Southeast Asia START Regional Center (SEA START) (www.Start.or.th). i-EPIC requires monthly weather variables such as precipitation, minimum/maximum air temperature, solar radiation, wind speed and relative humidity.

(3) Crop management

In this study, relevant crop parameters and rotation operation (Table 1 and Table 2) were modified on the basis of the measured and published data. In the EPIC model, potential evaporation was calculated by the Penman-Monteith method. In addition, the period of plantation used in this research follows the Land Development Department planting calendar. The general chemical fertilizers were 16-20-0 and 46-0-0, which are considered appropriate for rice growth (Department of Agricultural Extension, 2010). Meanwhile, soil losses were computed using the Universal Soil Loss Equation (USLE).

Table 1. Important crop parameters for the EPIC model based on the measured and published data.

Input variable	Explanation	Value
WA	Biomass-Energy Ratio	25
HI	Harvest index	0.5
TOPC	Optimal temperature for plant growth	33
TBSC	Minimum temperature for plant growth	15
DMLA	Maximum potential leaf area index	6
DLAI	Fraction of growing season when leaf area declines	0.8
DLAP1	First point on optimal leaf area development curve	30.01
DLAP2	Second point on optimal leaf area development curve	70.95
RLAD	Leaf area index decline rate parameter	0.5
RBMD	Biomass-energy ratio decline rate parameter	0.5
ALT	Aluminum tolerance index	3
GSI	Maximum Stomatal Conductance	0.008
CAF	Critical aeration factor	1
SDW	Seeding rate	50
HMX	Maximum crop height in m	0.8
RDMX	Maximum root depth in m	0.9
WAC2	CO_2 Concentration /Resulting WA value (Split Variable)	660.31

Table 2. Rotation operation of rice in Thailand

Rotation operation	*Major rice*		*Second rice*	
	Date	*Month*	*Date*	*Month*
Tillage	1	June (06)	1	January (01)
Planting	15	June (06)	15	January (01)
Fertilizer	1	September (09)	1	February (02)
Harvest	31	December (12)	30	April (04)
Kill	31	December (12)	30	April (04)

(4) GIS data

(i) land utilization of 2007, (ii) digital elevation model (DEM), (iii) slope, (iv) sets of soil data in a form of GIS digital file, (v) location of 81 weather stations, and (vi) simulation units (a polygon type of data): In this study, a 0.1° x 0.1° SU is created and each grid covers an area of 11.11 x 11.12 km. Since rice production land is emphasized in this study, we separated the rice production area from land used for other utilization purposes by overlapping the Land Utilization data of 2007 provided by the Land Development Department with the developed simulation unit. The selected simulation unit of the study is an overlapping area that covers more than 50% of the rice production area, which consists of 1219 SU.

2.3 Model Validation and Statistical Analysis

The validation process focused on the rice yield using the observed values of yield that were collected from the Agricultural Statistics of Thailand for years 1996-2012, which were generated by the Office of Agricultural

Economics (OAE), Ministry of Agriculture and Cooperatives (MOAC). A statistical measure was calculated to represent different aspects of model performance. Mean Absolute Percentage Error (MAPE) was computed for each of the regional models. MAPE is the most commonly used to evaluate cross-sectional forecasts, because of its simplicity to calculate and easiness to understand (Rayer, 2007; Wilson, 2007). Basically, it is a measure of forecast accuracy, which compares forecasts of a variable against actual values. ITSMF-NL (2006) noted that the forecasting model with MAPE below 40 % might be considered reasonably reliable (See in Table 3). The formula used in calculating MAPE is as follows:

$$\text{MAPE} = \frac{1}{n}\left[\sum_{t=1}^{n}\left|\frac{e_t}{A_t}\right| \times 100\right] = \frac{1}{n}\left[\sum_{t=1}^{n}\left|\frac{(A_t - P_t)}{A_t}\right| \times 100\right]$$

Where: A_t = actual value at time t; P_t = predicted value at time t; e_t = forecast error; n = total number of periods; t = time period

Table 3. Rule for MAPE values

Interpretation	*Range of MAPE values*
Highly accurate forecasting	< 10 %
Good forecasting	10 - 20 %
Reasonable forecasting	20 - 50 %
Inaccurate forecasting	> 50 %

2.4 Economic Processes Model

Based on the concept of supply and demand Equation (Alston et al., 1995; 1998), this study employed both world and Thai rice market models to predict amounts of rice production, consumption and export capacity in two scenarios (A2 and B2) in the next 10 years from 2007 onwards. The A2 scenario assumes that each country holds its own culture and trade, labor movement, and that technology transfer is restricted. Temperature will be changed likely range 2.0-5.4 ºC. The atmospheric CO_2 concentration reaches at 432 and 549 ppmv in 2020 and 2050, respectively (IPCC, 2007). Given these constraints, per capita GDP grows slowly and the annual average per capita income is 7,200 US$ in 2050, while the world population reaches 11 billion people (Garnaut et al., 2008). The B2 scenario assumes that trade is restricted and the cultural practices of each country are maintained such as those in the A2 scenario. However, low CO_2 emission energy technology is developed. The atmospheric CO_2 concentration reaches 432 in 2020 and 549 ppmv in 2050 for this scenario, with a projected temperature increase in the range of 1.4-3.8 ºC. The per capita income is 12,000 US$ in 2050 while the world population reaches 9.4 billion people (IPCC, 2007).

2.4.1 World Rice Market Model

Amounts of rice in the world market are calculated using supply Equation (1).

$$\boldsymbol{SW = \alpha P_{-1}^{\beta} or\ lnSW = ln\alpha + \beta lnP_{-1}} \quad (1)$$

Farmers usually base their decision about the amount of rice to be produced each year on the rice price of the previous year. $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ are coefficients in the supply Equation as explained in Table 4, and the data used for the world rice market model are presented in Appendix A; Table A1.

Table 4. Description variables for world rice market model

Variable	*Description*
SW	World market supply
DW	World market demand
P	Rice price in the world market
QW	Rice price equilibrium in world market
P_{-1}	Rice price at previous year (current year-1)
PO	Crude oil price in the world market
PP	Potato price in the world market
WP	World population

$$P = aDW^{b}WP^{c}PO^{d}PP^{e}$$

$$or \ln P = \ln a + b\ln DW + c\ln WP + d\ln PO + e\ln PP \quad (2)$$

In the demand Equation, the rice price depends on the market demand, the size of population, and crude oil and potato prices. In theory, market demand and price have an inverse relationship; the population size and production size have a positive relationship. The higher price of crude oil will lead to the higher market demand for agricultural products, thus increasing the rice price. As rice can be replaced by potato, rice price depends partly on the potato price as well.

Equation (3) determines the market equilibrium

$$QW = SW = DW \tag{3}$$

2.4.2 Thai Rice Market Model

The rice market in Thailand is structurally similar to the world rice market in that the rice price is the same. This is due to the fact the rice price is not determined at the national scale but at the global scale under the free trade policy. Supply Equation is shown in Equation (4) and rice price of the previous year is taken into account when the production size is determined.

$$\boldsymbol{ST = xP_{-1}^{y} or lnST = lnx + ylnP_{-1}} \tag{4}$$

Equation (5) shows the relation between domestic market demand and related factors such as rice price, population size, prices of crude oil and substitute goods. Equation (6) shows the amounts of rice exported by Thailand. Equation as explained in Table 5.

$$DT = fP^{g}TP^{h}PO^{i}PP^{j}$$

$$or \ln DT = \ln f + g \ln P + h \ln TP + i \ln PO + j \ln PP \tag{5}$$

$$E = ST - DT \tag{6}$$

Table 5. Description variables for Thai rice market model

Variable	*Description*
DT	Domestic market demand
ST	Domestic market supply
E	Amounts of domestic rice exported
TP	Thailand Population

3. Results

3.1 Impacts on Climate Change

According to the Special Report on Emissions Scenarios (SRES) by IPCC, the scenarios in 2017 will be as follows.

1. Temperature (ºC)

The highest average temperatures of 2007, A2 and B2 scenarios are 32.74, 33.13 and 33.20 ºC, respectively. The lowest average temperatures of 2007, in A2 and B2 scenarios are 22.99, 24.18 and 22.52 ºC, respectively. It is found that in A2 and B2 scenarios the highest average temperature will become higher in 2017, and will become highest under B2 scenario, which is slightly higher than A2 scenario. Also, the lowest average temperature will become higher in 2017 in A2 scenario and will decrease by 1-2 ºC in B2 scenario.

2. Rainfall (mm)

From the comparative analysis, it is found that the amounts of rain in 2007, and under A2 and B2 scenarios are 141.24, 129.39, and 125.60 mm respectively as shown in Table 6. It shows that in 2017 the amount of rain will decrease in both A2 and B2 scenarios, and the amount of rain in A2 scenario will be lower than that in B2 scenario. Table 7 shows that in A2 scenario, the amounts of rain in the central, northern, northeastern, and western regions of Thailand will decrease in the future whereas the amounts of rain in the eastern and southern regions will increase. Also, the amounts of rain in the central and northeastern regions in A2 scenario will be higher than those in B2 scenario while the amounts of rain in the other regions – especially the eastern and southern regions – in A2 scenario are lower than those in B2 scenario.

3. Number of rain days (day)

From Table 6 show the numbers of rain days in 2007, A2 and B2 scenarios – which are 10.93, 18.73, and 18.49 respectively. It is found that in both scenarios there will be more rain days in 2017. The number of rain days in B2 scenario is slightly lower than that in A2 scenario. Table 7 shows that in A2 scenario, the number of rain days increases in every region, and when compared with B2 scenario, there will be more rain days in the A2 scenario.

4. Solar Radiation (MJ/m^2)

Table 6 shows amounts of solar radiation in 2007, A2 and B2 scenarios – which are 114.81, 198.78, and 200.17 MJ/m^2. It is found that the amount of solar radiation will increase and become higher in 2017 in both scenarios, and the amount in B2 scenario will be higher than that in A2 scenario. Table 7 shows that in A2 scenario the amount of solar radiation increases in every region of Thailand, and that the amounts of solar radiation in B2 scenario are higher than those in A2 scenario in every region.

Table 6. Summarized climate changes in Thailand

Parameter	*2007*	*A2 scenario*	*B2 scenario*
1) Temperature (ºC)			
Air Temperature Average Max	32.74	33.13	33.20
Air Temperature Average Min	22.99	24.18	22.52
2) Precipitation Average (mm)	141.24	129.39	125.60
3) Rain days Average (day)	10.93	18.73	18.49
4) Solar Radiation (MJ/m^2)	114.81	198.78	200.17

Table 7. Summarized climate changes divided according to regions of Thailand

Region	*Temperature (ºC)*						*Precipitation Average (mm)*			*Rain days Average (day)*			*Solar Radiation (MJ/m^2)*		
	Temperature Average Max			*Temperature Average Min*											
	2007	*A2*	*B2*	*2007*	*A2*	*B2*	*2007*	*A2*	*B2*	*2007*	*A2*	*B2*	*2007*	*A2*	*B2*
C	32.90	33.96	34.07	22.76	24.60	22.69	122.46	114.36	113.32	10.40	17.47	17.07	114.81	108.17	108.19
E	32.73	33.16	33.46	22.97	25.89	24.30	138.87	144.11	155.37	10.82	20.47	20.41	114.81	112.86	112.84
N	32.52	32.99	32.94	22.64	21.81	21.01	117.86	116.66	117.28	10.14	18.25	17.76	114.81	199.02	100.74
NE	32.69	32.78	32.80	23.11	24.03	22.38	149.92	134.44	128.40	11.18	19.13	18.97	114.81	193.59	195.60
S	32.42	33.70	34.88	23.41	25.71	26.11	177.07	114.33	124.47	11.90	23.24	22.75	114.81	124.62	125.79
W	32.98	33.83	34.94	22.57	25.90	24.97	135.55	129.46	131.08	11.07	19.37	18.99	114.81	122.37	122.91

C = Central: E = Eastern: N = Northern: NE = Northeastern: S = Southern and W = Western

3.2 Climate Change Impacts on Rice Production

3.2.1 Comparison of Rice Production between Irrigated and Non-Irrigated Areas

This study investigated rice production in two kinds of area: irrigated and non-irrigated. EPIC model assumed that the area is ploughed and there is no weed or pest. The study period was set in accordance with the cropping calendar of the Rice Department. It is found that the average production capacity of second rice season in irrigated areas in 2007 is 3.65 ton/ha. It is estimated that in 2017 the production capacity of second rice season in irrigated areas in A2 and B2 scenarios will be 0.93 and 0.39 ton/ha, respectively. The production capacity of major rice season in irrigated areas in 2007 is 2.33 ton/ha. It is estimated that in 2017 the production capacity of major rice season in irrigated areas in A2 and B2 scenarios will be 1.76 and 0.79 ton/ha, respectively, as detailed in Table 8. In total, the amount of rice produced in A2 scenario will be higher than that in B2 scenario in 2017 over both irrigated and non-irrigated areas, yet such amounts in both scenarios drop from those in 2007.

Table 8. Comparison between irrigation and non-irrigation conditions with the change of rice production (ton/ha)

Water condition	*Major rice yield*			*Second rice yield*		
	2007	*A2 Scenario*	*B2 Scenario*	*2007*	*A2 Scenario*	*B2 Scenario*
Irrigation	2.33	1.76	0.79	3.65	0.93	0.39
Non-irrigation	2.30	1.47	0.58	3.78	0.70	0.26

3.2.2 Total Domestic Rice Production

The entire rice growing areas of the country consist of 1219 simulation units, covering both major and second season rice growing areas. Of this number, 322 units are in the central region, 29 units in the eastern region, 48 units in the northern region, 793 units in the northeastern region, 12 units in the southern region, and 15 units in the western region. From analyses on the comparison between the amount of rice produced in 2007 and the estimated amount of rice to be produced in 2017 in A2 and B2 scenarios, the findings are as follows.

In the central region, the average amounts of major rice season in 2007, A2 and B2 scenarios are 3.67, 2.54, and ton/ha respectively. The numbers for second rice production are 4.68, 1.06 and 0.39 ton/ha respectively. Details are provided in Table 9.

Table 9. Comparison between major and second rice production (ton/ha)

Region	*Major rice production*			*Second rice production*		
	2007	*A2 Scenario*	*B2 Scenario*	*2007*	*A2 Scenario*	*B2 Scenario*
C	3.67	2.54	0.84	4.68	1.06	0.39
E	3.58	3.74	1.84	4.63	1.81	1.03
N	2.87	1.04	0.44	4.12	0.26	0.16
NE	1.67	0.84	0.42	3.41	0.45	0.19
S	5.58	14.02	6.02	5.18	12.20	3.57
W	3.16	6.24	2.19	2.50	2.13	0.89

In 2007, the rice production in the Central, Northern, and Northeastern parts of Thailand showed a decreasing rice production in both A2 and B2 scenarios (Table 9). In contrast, rice production in the Eastern, Southern, and Western regions showed an increasing level of rice production under the given conditions of both A2 and B2 scenarios. The major rice production also increased in the A2 scenario and decreased in the B2 scenario. When comparing the A2 and B2 scenarios, it was found that the A2 scenario had a higher level of major rice production in every region of Thailand. The second rice production under the A2 and B2 scenarios in 2007 decreased in the Central, Eastern, Northern, Northeastern, and Western parts of Thailand, with the exception of the Southern part of Thailand. According to the results, the second rice production of in Southern provincial areas increased under the A2 scenario, whereas under the B2 scenario, it decreased. The A2 scenario also resulted in a second rice production in every region of Thailand.

3.3 Climate Change Impacts on Rice Production, Consumption, and Export

3.3.1 Analysis Based on World Rice Market Model

From the world rice market model based on Equation 1-3 as shown in Table 4, Equation (1) was tested with regression analysis. Table 10 shows that R^2=0.614; t-statistic is high; the coefficient is significant, making the Equation nearly completely reliable. Therefore, Equation (7) would be used in the next step.

Table 10. Statistics of Equation (1)

coefficient	*value*	*t-statistic*	*p*
$\ln\alpha$	17.592	60.910	0.000
β	0.481	7.879	0.000
	R^2 = 0.614		

$$ln\ SW = 17.592 + 0.481\ ln\ P_{-1} \tag{7}$$

Table 11 shows how Equation (2) was tested with regression analysis. Moreover, Table11shows that R^2= 0.672; t-statistic is high, the significance level of 95% for the coefficient. The constant and coefficient of WP have significance levels of 91.5% and 94.9% respectively, standing above 90%.

Equation (5) shows that the price elasticity of rice demand is -0.317$\left(\frac{1}{-3.154}\right)$, implying that rice has the elasticity value of lower than 1.

Table 11. Statistics of Equation (2)

coefficient	*value*	*t-statistic*	*p*
ln a	9.610	1.694	0.085
b	-3.154	-4.430	0.022
c	3.574	1.970	0.051
d	0.193	3.236	0.003
e	0.513	2.810	0.008
	R^2 = 0.672		

$$\ln P = 9.610 - 3.154\ \ln DW + 3.574\ \ln WP + 0.193 \ln PO + 0.513 \ln PP \tag{8}$$
$$or\ \ P = 14{,}913\ DW^{-3.154} WP^{3.574} PO^{0.193} PP^{0.513}$$

It is found that Equations (7) and (8) which are structural Equations used in predicting equilibrium quantity and rice price during 2007-2017 and next to 2027 are reliable only for the first four years. Equation (9) which is a reduced form is, as a result, used for estimation instead of Equation (8).

Table 12 shows how Equation (9) was tested with regression analysis. Table 12 shows that $R^2 = 0.873$; t-statistic is high, the significance level of 95% for the coefficient. The coefficient of PO has significance level of 93.5%, standing above 90%.

$$\ln P = \ln k + l \ln P_{-1} + m \ln WP + n \ln PO + o \ln PP \tag{9}$$

Table 12. Statistics of Equation (9)

coefficient	*value*	*t-statistic*	*p*
ln k	-18.510	-3.318	0.002
l	1.190	3.489	0.001
m	0.537	1.897	0.000
n	0.112	2.304	0.065
o	0.368	4.426	0.027
	$R^2 = 0.873$		

$$\ln P = -18.510 + 1.190 \ \ln P_{-1} + 0.537 \ \ln WP + 0.112 \ \ln PO + 0.368 \ \ln PP \tag{10}$$

For estimations of 2007-2027, the population size was based on the data from FAO; the real crude oil price was set to increase by 3.24% each year – which was the average rate of 1996-2007; and the real potato price was fixed at 176 dollars per ton.

Equations (7) and (10) were used in estimating the equilibrium quantity and rice price from 2007 to 2027. We found that both equilibrium quantity and rice price are likely to make constant increase in the future (See Appendix B; Table B1).

3.3.2 Analysis based on Thai Rice Market Model

Table 13 shows how Equation (4) was tested with regression analysis. Table 13 shows that $R^2 = 0.575$; t-statistic is high; the coefficient is nearly completely reliable. We also found that both equilibrium quantity and Thai rice price are increase in the future (See Appendix B; Table B2).

Table 13. Statistics of Equation (4)

coefficient	*value*	*t-statistic*	*p*
ln x	14.586	48.948	0.000
y	0.464	7.451	0.000
	$R^2 = 0.575$		

$$ln\ ST = 14.586 + 0.464\ ln\ P_{-1} \tag{11}$$

Table 14 shows how Equation (5) was tested with regression analysis. Table 14 shows that $R^2 = 0.706$; t-statistic is high; the coefficient is nearly completely reliable. Prices of rice, crude oil, and potato are excluded due to the fact that t-statistics are very low, and as a result, are assumed to be zero. It is then concluded that population size is the only factor that affects the domestic demand for rice, not prices of rice or any other products.

Table14. Statistics of Equation (5)

coefficient	*value*	*t-statistic*	*p*
ln f	9.683	10.326	0.000
h	0.618	4.796	0.000
	$R^2 = 0.706$		

$$\ln DT = 9.683 + 0.618 \ln P_{-1} \tag{12}$$

The estimation amounts of rice production, consumption, and export by Thailand from 2007 to 2027, based on the data from FAO in 2007. It is found that the amounts of rice production, consumption, and export are likely to increase in response to the increasing rice price and greater demand in the global market and the expanding population in Thailand (See Appendix B; Table B3).

3.4 Comparison of Situations in 2007, A2 and B2 Scenarios in 2027

Climate change's impacts on rice production in different scenarios are shown in Table 9. Statistical data about rice production (by region) and productivity in 2007 from the Office of Agricultural Economics is presented in Table 9. This data, together with estimations in Appendix B; Table B3, allows us to estimate the amounts of rice growing areas from 2007 to 2027 with an assumption that the amounts are growing at a constant rate. After the amounts of rice growing areas from 2007 to 2027 are successfully estimated, it is possible to compare climate change's impacts on rice production in different scenarios. In addition, the rice growing areas and rice productivity by region in different scenarios from 2007 to 2027 are shown in Appendix B; Table B4.

In terms of major rice season, it is found that the amounts of rice growing areas will be increasing steadily from 2017 to 2027. We found that the northeastern region has the largest rice growing area before the northern, central, southern, eastern, and western regions, respectively (See Appendix B; Table B4 and B5). The amounts of rice production appear to conform to those of rice growing areas in each region. Also, the amounts of rice production in A2 scenario are higher than those in B2 scenario in every region. In addition, it is found that in A2 scenario the yield rates are higher than those in the BY scenario in eastern, southern, and western regions, and that the southern region is the only region where yield rates in both A2 and B2 scenarios are higher than those in BY scenario. While, second rice season, it is found that the amounts of rice growing areas will be increasing steadily from 2017 to 2027. The central region has the largest rice growing area before the northern, northeastern, eastern, western and southern regions, respectively (See Appendix B; Table B4 and B5). The amounts of rice production appear to conform to those of rice growing areas in each region. Also, the amounts of rice production in A2 scenario are higher than those in B2 scenario in every region. In addition, it is found that in A2 scenario the yield rates are higher than those in the BY scenario in eastern, southern, and western regions, and that the southern region is the only region where yield rates in A2 scenario are higher than those in BY scenario. As our results, we can mention the results of economic analyses are in accordance with estimations from the physical models.

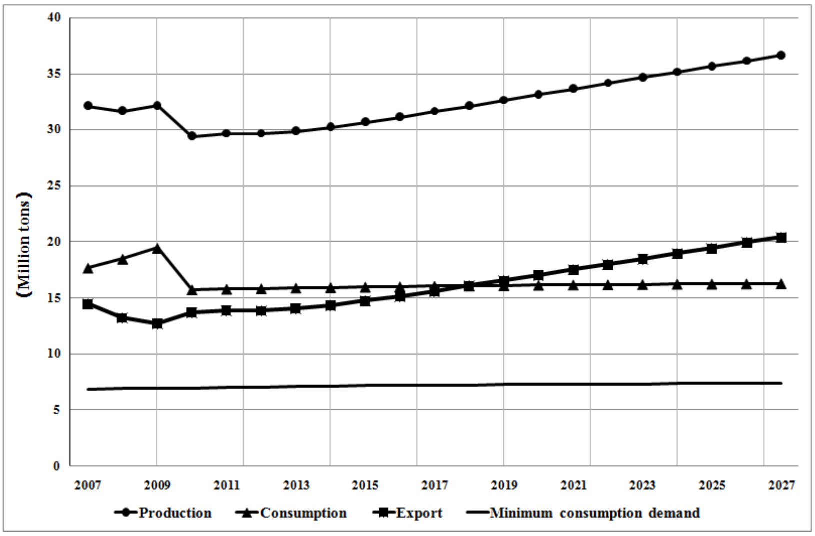

Figure 1. Comparison of economic impact under climate condition in 2007 (BY)

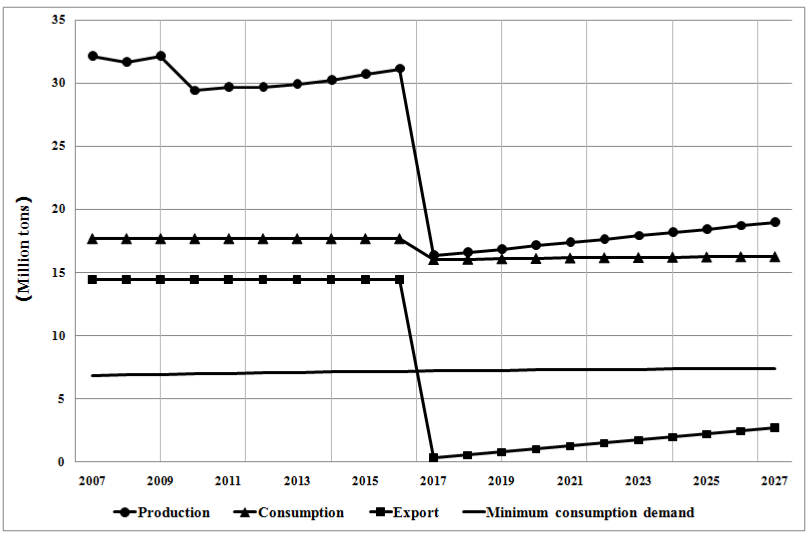

Figure 2. Comparison of economic impact under A2 scenario during 2017-2027

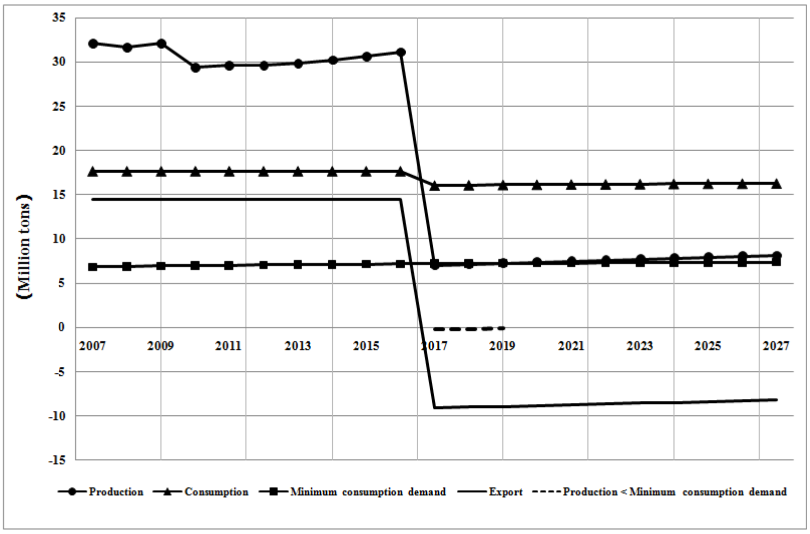

Figure 3. Comparison of economic impact under B2 scenario during 2017-2027

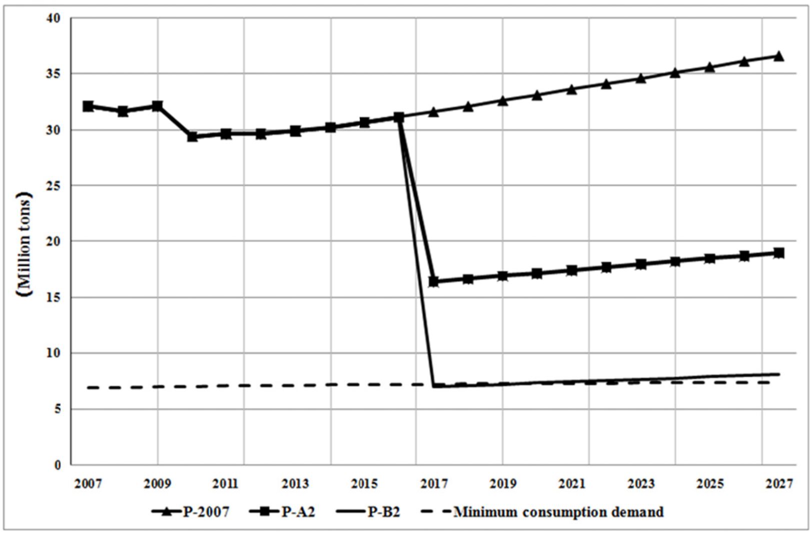

Figure 4. Comparison of the amounts of rice production under climate conditions in 2007, and A2 and B2 scenarios during 2017-2027

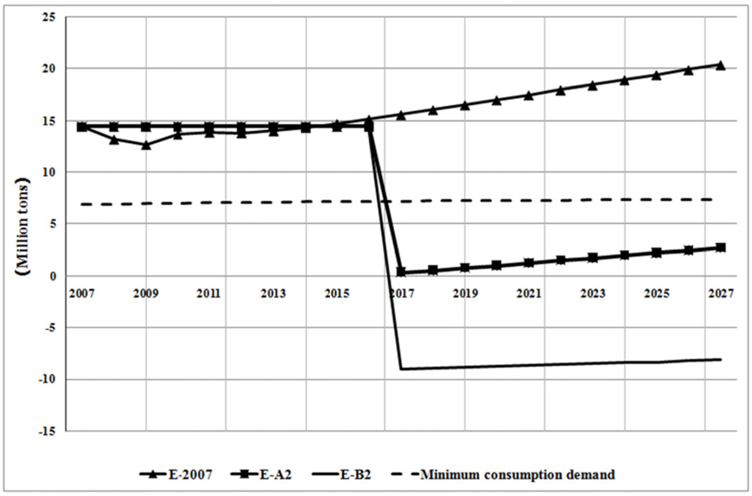

Figure 5. Comparison of the level of consumption demand under climate conditions in 2007, and A2 and B2 scenarios during 2017-2027

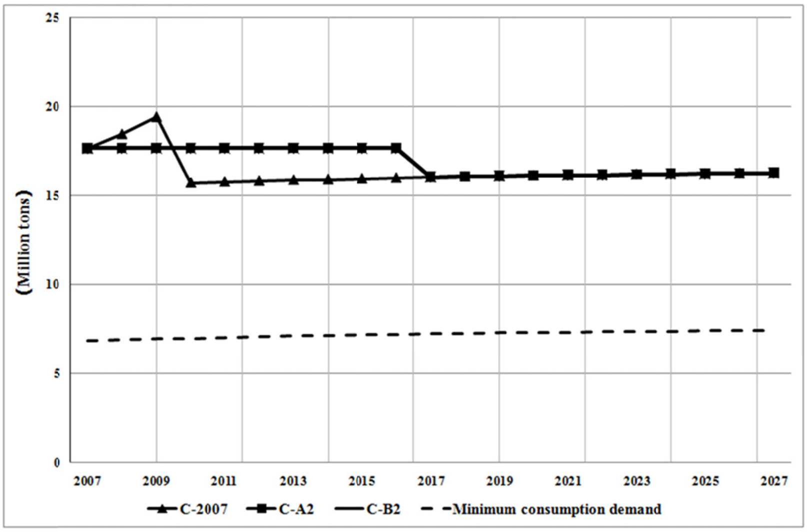

Figure 6. Comparison of the volume of exports under climate conditions in 2007, and A2 and B2 scenarios during 2017-2027

Based on the estimations of rice production from 2007 to 2027, Figure 1 illustrates that the amounts of rice production and export will constantly increase while the demand will not be changing significantly and will stay higher than the minimum demand level. Figure 2 illustrates that in A2 scenario the amounts of rice production and export will fall sharply until 2017 when the amounts will start increasing steadily again after farmers get used to the new weather. It is also found that after 2017 in A2 scenario the amount of rice export will be lower than the minimum level of consumption demand, and in B2 scenario (Figure 3), the amount of rice production will undergo a sharp fall after 2017, followed by a very small increase. The amount of rice production is likely to fail to meet the level of consumption in BY scenario as the production level will become equivalent to the minimum level of consumption demand, leaving no surplus rice for exports.

Figure 4 illustrates that in both A2 and B2 scenarios the amounts of rice production will be lower than those in the predicted BY scenario. The amount of rice production in A2 scenario will be higher than that in B2 scenario while the levels of consumption are equal in both scenarios as shown in Figure 5. With regard to exports, the volumes of rice exports in both A2 and B2 scenarios will be lower than the volume of exports in the BY scenario, given that the volume of exports in A2 scenario is higher than that in B2 scenario, the scenario in which the volume of exports is nearly zero as shown in Figure 6.

4. Discussion

A comprehensive evaluation of the impact of climate change on the rice sector in Thailand is important, both for making policy decisions and considering adaptation processes. In some areas, they are autonomous reactions driven by self-regulatory mechanisms, but in some other areas they respond to specific and planned policy interventions. Changes in rice yields can be measured by field experiments and using the estimate results of the crop growth model to forecast future. However, evaluating the impact on economic mechanisms such as price effects, shifts in domestic and international supply and demand requires the economic theory. This study examines possible effects of climatic change focusing on weather data of A2 and B2 scenarios and its impacts on rice production, consumption, and export by using world and Thai rice market model. This is consistent with the study of Parry et al., (1999; 2004; 2005) combined a supply and demand model of agricultural products such as basic linked system (BLS) and CERES-Wheat. Furthermore, Wu et al., (2007) combined EPIC model and IFPSIM model. Their results elucidate that climate change will generally reduce production potential and increase risk of hunger in poor countries. Also, many studies were able to find significant relationship between climate variables and rice yield using econometric models. Mendelsohn et al., (1994) mentioned that climate change's impacts can be measured by quantitative methods, the net production value, or changes in asset value such as land assets. Mendelsohn et al., (1994) employed Ricardian model to measure economic impacts on agricultural sector of the United States, and used multiple regression analysis to find the relationship between farmland value and climate factors such as temperature and amount of rain, as well as other physical factors such as soil type and slope. The analysis has led to a conclusion that climate factors such as temperature and amount of rain help raise the crop revenue in the United States. Similarly, Kabubo-Mariara and Karanja (2007) employed Ricardian model and multiple regression analysis to find the relationship among net income of farmers, climate and physical factors, and socio-economic data about farmers in Kenya. They found that climate change played a part in deducting net income of the farmers. Also, their model predicted that the climate change would cause a loss of approximately 97.01 to 236.63 US$ to the low-and-mid potential zones. In high potential zone, the loss would be approximately -0.11 to 63.34 US$. There was also a study conducted by Chang (2002) which investigated the economic impacts on the agricultural sector of Taiwan. Price-endogenous spatial equilibrium model was used to measure changes in and the distribution of welfare in the agricultural sector, with an assumption that the market has perfect competition in order to achieve the maximum total welfare – which is the sum of consumer surplus and producer surplus. In climate change scenarios, variables were temperature (from 0 to 2.5 ºC) and amount of rain (from -10% to 15%), and 1994 was set as base year. The findings indicated that despite changes in temperature and amount of rain that have impacts on the agricultural sector of a subtropical country like Taiwan, the total welfare has been constantly improving by 1.80 – 5.86% when compared with that of the base year. In terms of welfare distribution to producers and consumers, it is found that the producers receive more benefits than consumers. However, in scenarios where the amount of rain changes but temperature does not, it is found that the producer welfare will go down by 0.06 – 3.26% and will be good for consumers. Based on our scenarios, it is certainly possible that farmers' adaptation is still also important in the regional competitions. For instance, if their yields decline less than in other countries, and they can expand their rice farming, production and exports of the crop with reduced yields, they will gain in productivity and the profitability of growing higher due to the influence of international production, international markets and international trade might be changed. Similar arguments were also discussed in Juliá and Duchin (2007) and Nelson et al. (2009).

According to A2 and B2 scenarios of this study, we found that both scenarios the temperature will be increased and precipitation will be decreased, it will be very harmful for rice yields and farmers would lose their net revenue. This is consistent with the studies of Sanghi et al. (1997; 1998) employed Ricardian model of India and Brazil found significant negative effects with a moderate long-run climate change scenario under increasing 2 ºC of mean temperature and 7 % in precipitation by the end of the 21st century leading to losses on the order of 10% of agricultural profits. Especially, dry land rice farms, non-irrigated areas and hilly regions in semi-arid regions may undermine any positive effects by reducing the net revenue whereas increase revenue for the irrigated rice farms (Ajetomobi et al., 2010; Thapa & Joshi, 2010). For example the cereal production will be increased by 50% in irrigated areas and annual economic growth rate in Ethiopia might increase from1.9 to 2.1% by 2015 and this might increase the GDP by 3.6% per year (Diao & Pratt, 2007). Moreover, Krishna (2011) mentioned that with climate change rice production in developing countries will be declined by 11.9%, which will reduce revenue to smallholder farmers. On the other hand, with Business-as-Usual rice production might have increased by 434.9% in 2050. However, farmers' profits from rice depend on input costs (i.e. labor, land, seeds, fertilizers, and other chemicals), yields, and market sales values for the crop. This entire factor can be affecting not only rice production but also in turn affect food system in the future (Mngale, 2009). Whenever, food security diminishes, then people's livelihoods get impaired. This leads to poverty and hunger, with negative impacts to smallholder farmers and poor countries (FAO, 2008). Thus, adaptation and copping measures should be developed to combat the impact of climate change. Considering the climate change's impacts on agricultural productivity, the land use, and the agricultural policy, this study aims to examine farmers' behavioral adaptability, to encourage them to prepare for the upcoming impacts, and to suggest guidelines for their farm resizing. Thornton et al., (2009) suggested that adaptation can be constrained by institutional, economic, political and social environment in which smallholder farmers operate. In addition, Kurukulasuriya and Mendelsohn (2008) recommended that lack of knowledge, financial constraints, knowledge and information on the choice of adaptation options, labor constraints, shortage of land, and poor potential for irrigation are barriers to adaptation facing most of the farmers. For Thailand, if we consider problems of Thai farmers carefully we will see that such problems have remained unsolved for a long time, including land-related issues, farming systems development, water management, production costs, and marketing. Most of the farmers have gone to only primary school and not above, and the education system is a factor that pushes local people to seek jobs elsewhere as it is not related to local jobs at all. The teaching method does not encourage students to become entrepreneurs, and when the students finish their high school they cannot find suitable local jobs. Also, they do not want to be farmer as the profession is not highly valued. Only a small number of farmers are eager to keep improving their knowledge and expertise, and when some of them are selected to serve as their community leadership, they are bound with so many rules and regulations that they cannot truly contribute to the rest of the farmers. We can ensure that human resources in Thailand are good quality. The farmers will do it well if the state agencies at local and national levels can provide proper supports for their farming and help them find the best way to reduce production costs, prepare the best seeds, manage water resources, make natural fertilizers, stay hungry for new knowledge, technology, and information updates. In the study of Baldwin et al., (2013) showed that input cost of Thailand was 352 US$/ton (10,912 baht/ton) higher than other exporters such as Vietnam and India, with at 225 US$/ton (6,975 baht/ton) and 230 US$/ton (7,130 baht/ton), respectively. In term of rice consumption, Timmer et al., (2010) examined considerable evidence that rice consumption per person declines with increases. It means that rice consumption levels for food are inversely correlated with economic development, with the lowest income countries in the region (Cambodia, Burma, Laos, and Vietnam) consuming more rice per person than the wealthier countries (Malaysia and Thailand) as well as depend on rice demand and price. Thus, in the short run, farmers are suggested to find their optimal level of production. Major modifications of the farming system might not be finished shortly, but the crop choice can be improved immediately. For example, farmers may plant or harvest crops that grow well in warm weather earlier than before, allowing them to have more time to grow and yield more, and they may also have to come up with a new set of different crops after accepting the notion of optimal crop choice from Europe. According to Olesen and Bindi (2002), farmers may have to replace crops with high level of uncertainty in their yield rates such as barley with crops that have low yield rates but generate stable income such as pet grass, which also helps retain soil moisture.

5. Conclusion

Studies about the climate change's impacts on agriculture mostly focus on physical and biological impacts, and little has been done to investigate the socio-economic impacts. Only few studies have pointed out to the fact that an increase in temperature will result in lower agricultural productivity, and that farmers will have to make some adaptations to minimize the impacts – by optimizing crop rotation and land use, and resizing their farmlands, for example. This study is among the first in Thailand to develop an integrated body of knowledge within this field, and further investigations are also required to make a complete body of knowledge. Generally, rice grown in irrigated areas has higher yield rate than that grown in non-irrigated areas where the yield rate depends largely on the amount of rain during the growing season in Thailand. Models and analyses based on the IPCC SRES – A2 and B2 scenarios in 2017 – have led to the following findings.

In the central region, the average amounts of major rice season production in 2007, A2 and B2 scenarios are 3.67, 2.54 and 0.84 ton/ha, respectively, whereas the average amounts of second rice season production are 4.68, 1.06 and0.39 ton/ha. In both A2 and B2 scenarios, rice production is clearly affected by factors such as an increasing amount of carbon dioxide and rising temperatures. In the short run, weather change is the most influential factor, resulting in smaller amounts of rain in most of the regions in Thailand. The northeastern region is the most affected area by the weather change while such regions as the eastern and southern are least affected. In fact, these two regions turn out to enjoy larger amounts of rain due to the monsoon that carries heavy rain to the region.

From comparative analyses, it is found that both rice production and export in the BY scenario are likely to expand until 2027, and there will be a sufficient amount of rice surplus for export, which is nearly the same level as that of domestic consumption in A2 scenario. In 2017, the amount of rice production will be only slightly higher than the domestic demand, leaving a small rice surplus of up to two million tons for export, compared to 14 million tons in 2016, will be created a loss in value approximately 5,280 dollar. However, in B2 scenario, the rice production capacity will be much lower than the domestic demand, meeting only half of it in 2017. From 2017 to 2019, the rice production capacity will undergo a constant fall and no longer meet the market demand as a result; it is estimated that there will be a shortage of approximately 0.038 to 0.218 ton of rice. It is therefore important to note that if B2 scenario became reality in 2017, the rice production capacity of Thailand would nearly fail to meet the minimum level of domestic demand. Our results point out that both A2 and B2 scenarios the amounts of rice production will be lower than those in the predicted BY scenario. The amounts of rice production in A2 scenario are higher than those in B2 scenario in every region. Rice exports in both A2 and B2 scenarios will be lower than the volume of exports in the BY scenario while A2 scenario is higher than that in B2 scenario.

As rice is a large and essential part of the agricultural sector in Thailand, both positive and negative changes that might result from the selection of rice varieties all have great impact on the economy. Consequently, it is very important that the involved agencies thoroughly investigate the climate change's impacts in different dimensions and develop a body of knowledge around this issue. However, economic analyses carried out in this study have several limitations. Some parameters used in the models are not up-to-date as the EPIC model has never been used in estimating rice production in Thailand before. These parameters need to be more specific in order to improve the accuracy of the models, particularly the shape of farmland and rice choices. For example, each study area is an 11x11 (km) grid and parameters are assumed to be the same throughout the grid despite the fact that there are some small differences across grids.

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Appendix A

Table A1. The data used for the world rice market model

Year	*QW*	*P*	*WP*	*PO*	*PP*	*I*
1966	245,122,007	55.25	3,392,364	11.89	297.03	0.1514
1967	250,408,972	58.00	3,463,446	11.56	264.80	0.1557
1968	257,808,654	58.50	3,537,051	11.09	302.90	0.1623
1969	264,171,283	48.50	3,612,027	10.53	288.94	0.1709
1970	285,877,621	31.40	3,687,496	9.94	269.02	0.1811
1971	292,303,528	40.00	3,763,291	11.85	221.64	0.1890
1972	294,913,104	65.55	3,839,485	12.72	341.44	0.1950

Year	*QW*	*P*	*WP*	*PO*	*PP*	*I*
1973	301,464,991	96.75	3,915,749	15.89	521.88	0.2070
1974	307,767,233	105.20	3,991,767	50.41	384.89	0.2297
1975	319,705,231	97.45	4,067,338	45.98	393.82	0.2508
1976	324,459,501	92.45	4,142,238	48.25	298.34	0.2653
1977	341,233,664	115.10	4,216,604	49.24	276.83	0.2827
1978	346,986,961	109.20	4,291,046	46.13	245.21	0.3039
1979	355,031,912	130.25	4,366,459	93.41	224.11	0.3384
1980	365,585,801	154.10	4,443,492	95.89	375.94	0.3841
1981	374,508,765	130.11	4,522,203	84.80	282.02	0.4237
1982	397,856,522	118.39	4,602,460	73.30	218.12	0.4498
1983	411,536,427	123.35	4,684,373	63.65	276.35	0.4643
1984	420,004,259	120.27	4,768,042	59.43	259.01	0.4843
1985	428,293,137	98.79	4,853,449	54.95	172.32	0.5015
1986	432,072,647	86.77	4,940,684	28.25	217.09	0.5108
1987	444,777,057	106.97	5,029,533	34.82	182.33	0.5296
1988	455,444,129	160.12	5,119,111	27.06	240.70	0.5514
1989	468,264,692	157.03	5,208,291	31.53	280.63	0.5782
1990	471,420,842	149.73	5,296,249	38.94	219.95	0.6094
1991	462,387,874	160.00	5,382,632	31.51	171.73	0.6347
1992	472,026,320	151.00	5,478,014	29.54	186.54	0.6540
1993	488,543,901	127.00	5,561,745	25.20	201.96	0.6734
1994	496,944,096	153.00	5,644,416	22.90	178.05	0.6908
1995	517,240,958	166.00	5,726,236	23.95	209.68	0.7106
1996	521,447,815	205.00	5,807,205	28.26	147.66	0.7314
1997	529,998,080	212.00	5,887,258	25.52	165.78	0.7480
1998	547,666,622	139.00	5,966,463	16.74	161.86	0.7599
1999	556,918,124	128.00	6,044,931	23.14	163.53	0.7766
2000	557,234,517	109.00	6,122,769	35.50	139.51	0.8028
2001	566,574,210	109.00	6,200,004	29.61	186.58	0.8254
2002	571,615,527	118.00	6,276,717	29.84	175.31	0.8385
2003	572,689,030	134.00	6,353,190	33.62	151.60	0.8575
2004	581,092,058	166.00	6,429,754	43.46	141.95	0.8806
2005	587,932,491	172.00	6,506,645	59.89	170.27	0.9103
2006	598,188,640	181.00	6,583,961	69.32	171.33	0.9397
2007	608,803,782	327.00	6,661,634	74.90	171.75	0.9665
2008	NA	291.00	6,739,605	96.91	185.33	1.0036
2009	NA	291.00	6,817,737	61.67	176.00	1.0000

I = Level prices at the base year (2009)

Appendix B

Table B1. Estimating the equilibrium quantity and rice price in the *world market*

Year	*QW*	*P*	*WP*	*PO*	*PP*
2008	707,303,805	312.375	6,739,605	96.91	185.33
2009	691,906,930	277.452	6,817,737	61.67	176.00
2010	653,555,086	282.249	6,895,888	63.67	176.00
2011	658,965,303	282.415	6,974,041	65.74	176.00
2012	659,152,315	287.299	7,052,133	67.87	176.00
2013	664,610,318	294.823	7,130,012	70.07	176.00
2014	672,926,215	303.897	7,207,456	72.35	176.00
2015	682,810,190	313.928	7,284,293	74.69	176.00
2016	693,559,467	324.586	7,360,429	77.12	176.00
2017	704,787,763	335.688	7,435,808	79.62	176.00
2018	716,281,336	347.126	7,510,344	82.20	176.00
2019	727,918,329	358.834	7,583,939	84.87	176.00
2020	739,626,130	370.771	7,656,527	87.62	176.00
2021	751,360,657	382.909	7,728,043	90.46	176.00
2022	763,093,374	395.229	7,798,445	93.40	176.00
2023	774,805,461	407.717	7,867,736	96.43	176.00
2024	786,485,926	420.364	7,935,915	99.56	176.00
2025	798,127,829	433.164	8,002,977	102.79	176.00
2026	809,726,210	446.109	8,068,917	106.12	176.00
2027	821,277,188	459.194	8,133,722	109.57	176.00

Table B2. Estimating the equilibrium quantity and Thai Rice Market Model

Year	*ST*	*DT*	*E*	*P*	*TP*	*FX*
1966	13,500,000	10,462,278	2,280,146	55.25	32,772	20.00
1967	11,198,000	9,702,173	2,253,403	58.00	33,774	20.00
1968	12,410,000	10,328,915	1,626,539	58.50	34,799	20.00
1969	13,410,000	10,642,301	1,555,578	48.50	35,847	20.00
1970	13,850,000	11,022,599	1,615,280	31.40	36,915	20.00
1971	13,744,000	11,343,685	2,400,315	40.00	38,004	20.00
1972	12,413,000	11,488,959	3,196,769	65.55	39,110	20.00
1973	14,899,000	12,091,357	1,292,492	96.75	40,219	20.00
1974	13,386,000	12,083,787	1,605,243	105.20	41,319	20.00
1975	15,300,000	12,618,047	1,469,853	97.45	42,399	20.00
1976	15,068,000	12,359,447	3,011,621	92.45	43,453	20.00
1977	13,921,000	12,164,190	4,484,165	115.10	44,484	20.00
1978	17,470,000	13,767,302	2,490,644	109.20	45,494	20.00
1979	15,758,000	12,676,953	4,293,240	130.25	46,492	20.00
1980	17,368,100	12,621,562	4,292,133	154.10	47,483	20.00
1981	17,774,320	12,662,844	4,657,084	130.11	48,460	21.82
1982	16,878,510	11,979,721	5,808,156	118.39	49,423	23.00
1983	19,548,940	13,153,827	5,334,739	123.35	50,380	23.00
1984	19,904,820	12,725,139	7,028,617	120.27	51,346	23.64
1985	20,263,870	12,232,877	6,213,442	98.79	52,329	27.16
1986	18,868,160	12,554,712	6,919,963	86.77	53,340	26.30
1987	18,428,270	12,514,158	6,807,573	106.97	54,369	25.74
1988	21,262,900	12,563,666	8,094,757	160.12	55,371	25.29
1989	20,601,010	11,978,575	9,675,468	157.03	56,285	25.70
1990	17,193,220	12,053,275	6,208,630	149.73	57,072	25.59
1991	20,400,000	12,786,360	6,721,129	160.00	57,712	25.52
1992	19,917,000	12,395,570	7,977,366	151.00	58,226	25.40
1993	19,530,000	12,113,378	7,721,810	127.00	58,671	25.32
1994	21,111,000	12,834,829	7,520,355	153.00	59,127	25.15
1995	22,015,500	12,817,632	9,501,730	166.00	59,650	24.92
1996	22,331,600	13,950,198	8,381,759	205.00	60,258	25.34
1997	23,580,000	14,136,383	8,535,147	212.00	60,934	31.37
1998	23,450,000	14,365,686	9,994,674	139.00	61,660	41.37
1999	24,172,000	14,323,182	10,459,736	128.00	62,409	37.84
2000	25,843,880	15,648,250	9,425,493	109.00	63,155	40.16
2001	28,033,750	15,522,895	11,749,120	109.00	63,899	44.48
2002	27,991,820	15,688,053	11,243,113	118.00	64,643	43.00
2003	29,473,520	16,177,096	12,843,984	134.00	65,370	41.53
2004	28,538,230	16,304,391	15,319,286	166.00	66,060	40.27
2005	30,291,870	17,324,426	11,465,131	172.00	66,698	40.27
2006	29,641,870	17,417,414	11,485,401	181.00	67,276	37.93
2007	32,099,400	17,663,557	14,016,227	327.00	67,796	34.56
2008	31,650,630	18,461,189	15,586,909	291.00	68,268	33.36
2009	32,116,060	19,437,698	13,202,909	291.00	68,706	34.34

FX = Exchange rate (Baht per US dollar)

Table B3. Estimating the amounts of rice production, consumption and export

Year	*ST*	*DT*	*E*	*P*	*TP*
2008	31,650,630	18,461,189	15,586,909	312.375	68,268
2009	32,116,060	19,437,698	13,202,909	277.452	68,706
2010	29,394,006	15,709,007	13,684,999	282.249	69,122
2011	29,628,700	15,765,415	13,863,284	282.415	69,519
2012	29,636,811	15,817,138	13,819,673	287.299	69,892
2013	29,873,506	15,866,089	14,007,418	294.823	70,243
2014	30,234,007	15,912,240	14,321,766	303.897	70,571
2015	30,662,279	15,954,582	14,707,698	313.928	70,876
2016	31,127,798	15,994,070	15,133,727	324.586	71,158
2017	31,613,787	16,029,693	15,584,093	335.688	71,419

2018	32,110,976	16,063,410	16,047,566	347.126	71,661
2019	32,614,083	16,094,214	16,519,869	358.834	71,885
2020	33,119,963	16,123,084	16,996,879	370.771	72,091
2021	33,626,715	16,149,012	17,477,703	382.909	72,280
2022	34,133,108	16,172,982	17,960,126	395.229	72,454
2023	34,638,337	16,194,985	18,443,352	407.717	72,612
2024	35,141,933	16,215,015	18,926,918	420.364	72,755
2025	35,643,603	16,232,059	19,411,544	433.164	72,884
2026	36,143,141	16,248,117	19,895,024	446.109	73,000
2027	36,640,386	16,262,181	20,378,205	459.194	73,102

Table B4. Estimating the amounts of rice production and areas during 2007-2027 in each region of Thailand

Year		*Major rice (Million ha, Million tons)*						*Second rice (Million ha, Million tons)*						*Sum*
		C	*E*	*N*	*NE*	*S*	*W*	*C*	*E*	*N*	*NE*	*S*	*W*	
2007	Area	1.44	0.13	2.41	6.81	0.16	0.08	0.80	0.07	0.55	0.09	0.02	0.07	12.63
	Production	5.27	0.47	6.92	11.37	0.87	0.25	3.75	0.34	2.25	0.32	0.11	0.17	32.10
2008	Area	1.42	0.13	2.38	6.71	0.15	0.08	0.79	0.07	0.54	0.09	0.02	0.07	12.45
	Production	5.20	0.47	6.83	11.21	0.86	0.24	3.70	0.33	2.22	0.32	0.11	0.17	31.65
2009	Area	1.44	0.13	2.41	6.81	0.16	0.08	0.80	0.07	0.55	0.09	0.02	0.07	12.64
	Production	5.28	0.48	6.93	11.38	0.87	0.25	3.75	0.34	2.25	0.32	0.11	0.17	32.12
2010	Area	1.32	0.12	2.21	6.24	0.14	0.07	0.73	0.07	0.50	0.09	0.02	0.06	11.57
	Production	4.83	0.43	6.34	10.41	0.79	0.22	3.43	0.31	2.06	0.30	0.10	0.16	29.39
2011	Area	1.33	0.12	2.23	6.29	0.14	0.07	0.74	0.07	0.50	0.09	0.02	0.06	11.66
	Production	4.87	0.44	6.39	10.50	0.80	0.23	3.46	0.31	2.08	0.30	0.10	0.16	29.63
2012	Area	1.33	0.12	2.23	6.29	0.14	0.07	0.74	0.07	0.50	0.09	0.02	0.06	11.66
	Production	4.87	0.44	6.39	10.50	0.80	0.23	3.46	0.31	2.08	0.30	0.10	0.16	29.64
2013	Area	1.34	0.12	2.24	6.34	0.14	0.07	0.75	0.07	0.51	0.09	0.02	0.07	11.75
	Production	4.91	0.44	6.44	10.58	0.81	0.23	3.49	0.31	2.10	0.30	0.10	0.16	29.87
2014	Area	1.35	0.12	2.27	6.41	0.15	0.07	0.75	0.07	0.51	0.09	0.02	0.07	11.90
	Production	4.97	0.45	6.52	10.71	0.82	0.23	3.53	0.32	2.12	0.30	0.10	0.16	30.23
2015	Area	1.37	0.13	2.30	6.50	0.15	0.07	0.77	0.07	0.52	0.09	0.02	0.07	12.06
	Production	5.04	0.45	6.61	10.86	0.83	0.23	3.58	0.32	2.15	0.31	0.10	0.17	30.66
2016	Area	1.39	0.13	2.34	6.60	0.15	0.08	0.78	0.07	0.53	0.09	0.02	0.07	12.25
	Production	5.11	0.46	6.71	11.03	0.84	0.24	3.64	0.33	2.18	0.31	0.11	0.17	31.13
2017	Area	1.41	0.13	2.38	6.71	0.15	0.08	0.79	0.07	0.54	0.09	0.02	0.07	12.44
	Production	5.19	0.47	6.82	11.20	0.85	0.24	3.69	0.33	2.22	0.32	0.11	0.17	31.61
A2	Production	3.59	0.49	2.47	5.63	2.15	0.48	0.84	0.13	0.14	0.04	0.25	0.15	16.36
B2	Production	1.19	0.24	1.05	2.82	0.92	0.17	0.31	0.07	0.09	0.02	0.07	0.06	7.00
2018	Area	1.44	0.13	2.41	6.81	0.16	0.08	0.80	0.07	0.55	0.09	0.02	0.07	12.63
	Production	5.27	0.48	6.92	11.38	0.87	0.25	3.75	0.34	2.25	0.32	0.11	0.17	32.11
A2	Production	3.65	0.50	2.51	5.72	2.18	0.49	0.85	0.13	0.14	0.04	0.26	0.15	16.61
B2	Production	1.21	0.24	1.06	2.86	0.94	0.17	0.31	0.08	0.09	0.02	0.07	0.06	7.11
2019	Area	1.46	0.13	2.45	6.92	0.16	0.08	0.81	0.07	0.56	0.10	0.02	0.07	12.83
	Production	5.36	0.48	7.03	11.55	0.88	0.25	3.81	0.34	2.29	0.33	0.11	0.18	32.61
A2	Production	3.71	0.50	2.55	5.81	2.21	0.49	0.86	0.13	0.14	0.04	0.26	0.15	16.87
B2	Production	1.23	0.25	1.08	2.91	0.95	0.17	0.32	0.08	0.09	0.02	0.08	0.06	7.22
2020	Area	1.48	0.14	2.49	7.03	0.16	0.08	0.83	0.08	0.56	0.10	0.02	0.07	13.03
	Production	5.44	0.49	7.14	11.73	0.90	0.25	3.87	0.35	2.32	0.33	0.11	0.18	33.12
A2	Production	3.77	0.51	2.59	5.90	2.25	0.50	0.88	0.14	0.15	0.04	0.26	0.15	17.14
B2	Production	1.25	0.25	1.09	2.95	0.97	0.18	0.32	0.08	0.09	0.02	0.08	0.06	7.33
2021	Area	1.50	0.14	2.53	7.13	0.16	0.08	0.84	0.08	0.57	0.10	0.02	0.07	13.23
	Production	5.52	0.50	7.25	11.91	0.91	0.26	3.93	0.35	2.36	0.34	0.11	0.18	33.63
A2	Production	3.82	0.52	2.63	5.99	2.28	0.51	0.89	0.14	0.15	0.04	0.27	0.16	17.40
B2	Production	1.26	0.26	1.11	3.00	0.98	0.18	0.33	0.08	0.09	0.02	0.08	0.07	7.45
2022	Area	1.53	0.14	2.56	7.24	0.17	0.08	0.85	0.08	0.58	0.10	0.02	0.07	13.43
	Production	5.61	0.50	7.36	12.09	0.92	0.26	3.99	0.36	2.39	0.34	0.12	0.19	34.13
A2	Production	3.88	0.53	2.67	6.08	2.32	0.52	0.90	0.14	0.15	0.05	0.27	0.16	17.66
B2	Production	1.28	0.26	1.13	3.04	1.00	0.18	0.33	0.08	0.09	0.02	0.08	0.07	7.56
2023	Area	1.55	0.14	2.60	7.35	0.17	0.08	0.86	0.08	0.59	0.10	0.02	0.08	13.63
	Production	5.69	0.51	7.47	12.27	0.94	0.27	4.05	0.36	2.43	0.35	0.12	0.19	34.64
A2	Production	3.94	0.54	2.71	6.17	2.35	0.52	0.92	0.14	0.15	0.05	0.28	0.16	17.92
B2	Production	1.30	0.26	1.15	3.09	1.01	0.18	0.34	0.08	0.09	0.02	0.08	0.07	7.67
2024	Area	1.57	0.15	2.64	7.45	0.17	0.09	0.88	0.08	0.60	0.10	0.02	0.08	13.83
	Production	5.77	0.52	7.58	12.45	0.95	0.27	4.11	0.37	2.46	0.35	0.12	0.19	35.14

Year		Major rice (Million ha, Million tons)						Second rice (Million ha, Million tons)						Sum
		C	E	N	NE	S	W	C	E	N	NE	S	W	
A2	Production	3.99	0.54	2.75	6.26	2.39	0.53	0.93	0.14	0.16	0.05	0.28	0.16	18.18
B2	Production	1.32	0.27	1.16	3.13	1.02	0.19	0.34	0.08	0.10	0.02	0.08	0.07	7.78
2025	Area	1.60	0.15	2.68	7.56	0.17	0.09	0.89	0.08	0.61	0.11	0.02	0.08	14.02
	Production	5.85	0.53	7.69	12.63	0.96	0.27	4.16	0.37	2.50	0.36	0.12	0.19	35.64
A2	Production	4.05	0.55	2.79	6.35	2.42	0.54	0.94	0.15	0.16	0.05	0.28	0.17	18.44
B2	Production	1.34	0.27	1.18	3.18	1.04	0.19	0.35	0.08	0.10	0.02	0.08	0.07	7.89
2026	Area	1.62	0.15	2.72	7.67	0.18	0.09	0.90	0.08	0.62	0.11	0.02	0.08	14.22
	Production	5.94	0.53	7.79	12.80	0.98	0.28	4.22	0.38	2.53	0.36	0.12	0.20	36.14
A2	Production	4.11	0.56	2.82	6.44	2.45	0.55	0.96	0.15	0.16	0.05	0.29	0.17	18.70
B2	Production	1.36	0.27	1.19	3.22	1.05	0.19	0.35	0.08	0.10	0.02	0.08	0.07	8.00
2027	Area	1.64	0.15	2.75	7.77	0.18	0.09	0.91	0.08	0.62	0.11	0.02	0.08	14.42
	Production	6.02	0.54	7.90	12.98	0.99	0.28	4.28	0.39	2.57	0.37	0.12	0.20	36.64
A2	Production	4.17	0.57	2.86	6.53	2.49	0.55	0.97	0.15	0.16	0.05	0.29	0.17	18.96
B2	Production	1.38	0.28	1.21	3.26	1.07	0.19	0.36	0.09	0.10	0.02	0.09	0.07	8.11

Table B5. Estimating the economic impact under climate conditions in 2007, A2 and B2 scenarios

Year	2007 (Million tons)				A2 (Million tons)				B2 (Million tons)				
	P	C	Min.	E	P	C	Min.	E	P	C	Min.	E	P < Min.
2007	32.10	17.66	6.85	14.44	32.10	17.66	6.85	14.44	32.10	17.66	6.85	14.44	
2008	31.65	18.46	6.90	13.19	31.65	17.66	6.90	14.44	31.65	17.66	6.90	14.44	
2009	32.12	19.44	6.94	12.68	32.12	17.66	6.94	14.44	32.12	17.66	6.94	14.44	
2010	29.39	15.71	6.98	13.68	29.39	17.66	6.98	14.44	29.39	17.66	6.98	14.44	
2011	29.63	15.77	7.02	13.86	29.63	17.66	7.02	14.44	29.63	17.66	7.02	14.44	
2012	29.64	15.82	7.06	13.82	29.64	17.66	7.06	14.44	29.64	17.66	7.06	14.44	
2013	29.87	15.87	7.09	14.01	29.87	17.66	7.09	14.44	29.87	17.66	7.09	14.44	
2014	30.23	15.91	7.13	14.32	30.23	17.66	7.13	14.44	30.23	17.66	7.13	14.44	
2015	30.66	15.95	7.16	14.71	30.66	17.66	7.16	14.44	30.66	17.66	7.16	14.44	
2016	31.13	15.99	7.19	15.13	31.13	17.66	7.19	14.44	31.13	17.66	7.19	14.44	
2017	31.61	16.03	7.21	15.58	16.36	16.03	7.21	0.33	7.00	16.03	7.21	-9.03	-0.213
2018	32.11	16.06	7.24	16.05	16.61	16.06	7.24	0.55	7.11	16.06	7.24	-8.95	-0.127
2019	32.61	16.09	7.26	16.52	16.87	16.09	7.26	0.78	7.22	16.09	7.26	-8.87	-0.038
2020	33.12	16.12	7.28	17.00	17.14	16.12	7.28	1.01	7.33	16.12	7.28	-8.79	
2021	33.63	16.15	7.30	17.48	17.40	16.15	7.30	1.25	7.45	16.15	7.30	-8.70	
2022	34.13	16.17	7.32	17.96	17.66	16.17	7.32	1.49	7.56	16.17	7.32	-8.61	
2023	34.64	16.19	7.33	18.44	17.92	16.19	7.33	1.73	7.67	16.19	7.33	-8.52	
2024	35.14	16.22	7.35	18.93	18.18	16.22	7.35	1.97	7.78	16.22	7.35	-8.43	
2025	35.64	16.23	7.36	19.41	18.44	16.23	7.36	2.21	7.89	16.23	7.36	-8.34	
2026	36.14	16.25	7.37	19.90	18.70	16.25	7.37	2.45	8.00	16.25	7.37	-8.24	
2027	36.64	16.26	7.38	20.38	18.96	16.26	7.38	2.70	8.11	16.26	7.38	-8.15	

P = Production: C = Consumption: Min. = Minimum level of consumption demand: E = Export