Risk Assessment of Agricultural Affected by Climate Change: Central Region of Thailand

Pratueng Vongtong[1*], Suwut Tumthong[2], Wanna Sripetcharaporn[3], Praphat klubnual[4], Yuwadee Chomdang[5], Wannaporn Suthon[6]

[1*,2,3,4,5,6] Faculty of Science and Technology, Rajamangala University of Technology Suvarnabhumi, Ayutthaya, Thailand
e-mail: [1*]pratueng.w@rmutsb.ac.th,
[2]suwut@rmutsb.ac.th,
[3]wanna.s@rmutsb.ac.th,
[4]praphat.k@rmutsb.ac.th,
[5]yuwadee.c@rmutsb.ac.th,
[6]wannaporn.ka@rmutsb.ac.th

Abstract — The objective of this study are to create a risk model of agriculture with the Geo Information System (GIS) and calculate the Agricultural Vulnerability Index (AVI) in Chainat, Singburi, Ang Thong and Phra Nakhon Si Ayutthaya provinces by selecting factors from the Likelihood Vulnerability Index (LVI) that were relevant to agriculture and the climate. The data used in the study were during the year 1986-2016 and determined into three main components that each of which has a sub-component namely: (1)Exposure component consisting of the minimum and maximum temperature; (2) Risk-sensitive component (Sensitivity) consisting of total annual water runoff, annual soil water amount and number of nature hazard and (3) Adaptive capacity components consisting of distance from water source. The researchers then calculated the sub-district average agricultural fragility index (AVI) in the study areas.

The results showed that the average AVI was between 0.381424154-0.673695. The maximum value was found in Phai Wong sub-district, Ang Thong province, followed by Sao Rong Hai sub-district, Ang Thong province and Na Khu sud-district, Phra Nakhon Si Ayutthaya province which were at 0.673695, 0.656638 and 0.647445, respectively, while the minimum average AVI was found in Bang Phutsa sub-district, Sing Buri province was at 0.3814.

Keyword- GIS, Vulnerability, Agricultural, Climate Change, Risk Assessment

I. INTRODUCTION

At the present, the global climate today is changing and directly affecting the atmosphere. It also affects the agricultural sector, which is inevitably the human food source, especially in Thailand where the main occupation of the people in Thailand is agriculture which is in line with the report of the Land Use Report of 2010/2013 revealed that land use for agriculture has a total area of 174,306,042 rai [1], but due to the changing climate, the cultivation of Thai economic crops was considerably affected [2]

In addition, the economic impact of global climate change on rice production in Thailand was assessed [3] on the impact of climate change. The results of assessment indicated that climate change affected the economic dimension of rice production in Thailand. Both the quantity of production and income of farmers.

This study applied the concept of the Likelihood Vulnerability Index (LVI)[4] and Agricultural Vulnerability Index (AVI) [5] by selecting the components related to agriculture and climate as a study factor which covered the concept of climate change and processing with a Geographic Information System (GIS) to obtain a model of agricultural risks from climate change and the calculation of the agricultural vulnerability index (AVI), the results obtained from this research can be used as information for planning and determining guidelines to help farmers in the area.

II. LITERATURE REVIEWS

The study of climate change applied the models in various formats such as the Regional Climate Model :PRECIS which was studied in South Africa [6]. In Thailand, this study was conducted to study the impact of climate change on economic crops [2]. The results of climate change studies on rice, sugarcane, cassava and maize production in Thailand of found that that in the long term, the effects of global warming affected the cassava farming in Northeast critically. Similarly, maize farming problem was widely dispersed severely in many areas of the country. For rice farming, the lower yield was found due to the rain distribution and sugarcane was affected by soil moisture, which depended on rainfall [2]. In addition, the report on the economic impact assessment of global climate change on rice production in Thailand [3] indicated that climate change affected the economic dimension of Thailand's rice production. Both the quantity of production and income of farmers.

Data were applied and analyzed by applying relevant factors into the GIS to assess agricultural risks which used factors from the Agricultural Vulnerability Index (AVI) [5] and then processed by GIS to create a risk assessment model of the study area and presented it in the form of maps [7][8].

III. RESEARCH METHODOLOGY

This study define study area , Information source, and study method as follow:

1) Study Area

The scope of this study area defined the study areas in the lower central region of Thailand which were:

Chainat province has total area of 2,469.746 square kilometers with the administration divided into 8 districts and 51 sub-districts [9], Sing Buri province has total area of 822.478 square kilometers with the administration divided into 6 districts, and 43 sub-districts [10], Ang Thong province a total area of 968.372 square kilometers with the administration divided into 7 districts, 73 sub-districts [11] and Phra Nakhon Si Ayutthaya province has total area of 2,556.64 square kilometers with the administration divided into 16 districts and 209 sub-districts [12].

The modeling of agricultural risks from climate change deployed the climate data between 1986 and 2016 which was 30 years in total gained from the Meteorological Department.

2) Data Analysis

2.1) Deployed the minimum and maximum temperature information obtained from the daily minimum and maximum values measured for each month to find the average minimum and maximum temperature of each year

2.2) Calculated the annual runoff using the total annual rainfall data, slope data and the water coefficient [13] with the equation (1) as follows:

$$R=P*Rc*Area \quad (1)$$

when R is runoff (cubic meter)
P is rainfall (millimeter)
Area is grid size (square meter)
Rcis runoff coefficient, can be calculate form Equation (2)

$$Rc=(a*P)+b \quad (2)$$

when a and b are the coefficient of Rc
Where the values of a and b depend on the slope of the area as shown in Table I [13].

TABLE I. Runoff Coefficient

Terrain type	Slope	a	b
Flat area	0-5%	0.1293	-6.2370
Gentle slope area	> 5-15%	0.1293	-3.0540
Rolling area	>15-30%	0.1295	1.4890
Steep area	>30%	0.1295	5.7160

2.3) Calculated the annual soil water. The data used were rainfall, runoff, deep percolation, and evapotranspiration. All this information were provided for a total annual quantity and then calculated the water amount in the soil using the Raster Based Model, as shown in Equation (3) [14].

$$SW=P-(R+D+E) \quad (3)$$

when SW is annual soil water (cubic meter)
P is annual rain fall (cubic meter)
R is annual runoff (cubic meter)
D is annual deep percolation (cubic meter) calculated from equation (4).
E is annual evapotranspiration (cubic meter)

The annual deep percolation was calculated based on the soil hygroscopicity at a depth of 0.50 m by considering the coefficient of soil porosity with the equation (4) [14].

$$D=(P-(E+R))-(Spore*Area*0.5) \quad (4)$$

When spore is coefficient of soil porosity as shown in Table II [13].

TABLE II. The Coefficient of soil porosity

Soil type	Coefficient of soil porosity
Clay	0.60
Clay loam	0.60
Coarse	0.40
Loam	0.50
Loamy sand	0.40
sand	0.40
Sand clay loam	0.50
Sandy clay	0.40
Silt loam	0.50

2.4) Calculated the distance from the river by using the Euclidian distance method

2.5) Collected statistics on natural hazards such as flood, storms and drought from 2012-2016 for a total of 5 years from the Provincial Disaster Prevention and Mitigation Office of the study areas, classified the number of natural hazard occurring in various forms, arranged in the form of spatial data in the provincial information layer and calculated the average number of flooding, storms and drought during the year of study

2.6) Designed the agricultural risk model and calculation of AVI

Agricultural risk modeling and AVI calculation applied the [4] concept of Livelihood Vulnerability Index (LVI) by selecting components related to climate, water and natural hazards to be the main components and sub-component. The researchers then created an agriculture risk model with GIS, analyzed data in Vector Based Model to present agricultural risk models in the form of maps. The AVI value was then calculated by means of averaging by weighting each component and calculated the value of AVI at the sub-level with the following steps

(1) Defined the main components and sub-components to create a risk model for the agricultural sector as shown in Table 3.

TABLE III. Components and sub-component for calculating the AVI

Main components	Sub-components
1. Exposure	1.1 Average monthly of minimum temperature each year
	1.2 Average monthly of maximum temperature each year
2. Sensitive	2.1 Annual runoff
	2.2 Annual soil water
	2.3 Average number of nature hazard
3. Adaptive	3.1 Distance from water body

(2) Since the information taken as a sub-component in each component were different, it was necessary to arrange the data of every component in the same format by means of Standardize based on the Human Development Index [4] as equation (5).

$$\text{Index}_{st} = \frac{S_t\text{-}S_{\min}}{S_{\max}\text{-}S_{\min}} \quad (5)$$

When Index_{st} is the standardize of sub-component S for sub-district$_t$

S_t is the value of sub-components S for sub-district$_t$

S_{min} and S_{max} there are minimum and maximum values of sub-components S for all sub-districts, respectively

(3) Calculated the average value of the sub-elements contained in each of the main components that have been Standardized [5] as equation (6)

$$M_t = \frac{\sum_{i=1}^{n} \text{Index}_{sti}}{n} \quad (6)$$

when M_t is components index of sub-districtt

Index_{sti} is represents the sub-component S, indexed by i

n is number of sub-components in each major component

(4) Calculated the AVI value as equation (7) [14].

$$\text{AVI}_t = \frac{\sum_{i=1}^{3} W_{m_i} M_{t_i}}{\sum_{i=1}^{3} W_{m_i}} \quad (7)$$

when AVI_t is Agricultural Vulnerability Index for sub-district t,

W_{m_i} is determined by the number of sub-component that make up each major component

IV. RESULTS OF THE STUDY

1) The component analysis results for the study were as follows:

1.1) The minimum temperature in Chainat province was found in the area of Sapphaya district at 23.234 degrees Celsius, Singburi province had the minimum temperature in In Buri area at 23.370 degrees Celsius. Phra Nakhon Si Ayutthaya province had the minimum temperature in the Maha Rat district area which was same as Ang Thong province's minimum temperature in Chaiyo district area at 23.787 degrees Celsius as shown in Figure 1 (a)

1.2) The maximum temperature in Phra Nakhon Si Ayutthaya Province was found at ThaRuea district at 33.907 degrees Celsius, followed by Ang Thong province at Wiset Chai Chan district at 33.855 degrees Celsius, Chainat province's area of maximum temperature was at Sapphaya district at 33.844 degrees Celsius and in Singburi province, the maximum temperature is in In Buri district at 33.822 degrees Celsius as shown in Figure 1 (b).

1.3) The study of annual runoff was found that the maximum runoff was at 6.036 billion cubic meters whereas the minimum amount was 3.578 billion cubic meters as shown in Figure 1, when considering each province, it was found that: Chainat province: The maximum runoff was at 4.704 billion cubic meters in Noen Kham district whereas the minimum runoff was found in Sapphaya district at 4.339 billion cubic meters. Singburi province: The maximum runoff was at 4.694 billion cubic meters in Khai Bang Rachan district whereas the minimum was found in Phrom Buri district at 4.068 billion cubic meters. Phra Nakhon Si Ayutthaya province: The maximum runoff was at 5.826 billion cubic meters in Phak Hai district whereas the minimum was found in ThaRuea area at 3.578 billion cubic meters as shown in Figure 1 (c).

1.4) The study of total annual soil water was found that the maximum amount of was at 3.84 billion cubic meters whereas the minimum amount was at 1.500 billion cubic meters as shown in Figure 1 (d). When considering each province, it was found that: Chainat province: The maximum of annual soil water was at 3.84 billion cubic meters in Noen Kham district whereas the minimum was found in Mueang Chai Nat district at 1.691 billion cubic meters. Singburi province: The maximum amount of annual soil water was at 3.348 billion cubic meters, in Phrom Buri district whereas the minimum was found in Mueang Sing Buri district at 1.500 billion cubic meters. Ang Thong province: The maximum amount of annual soil water was at 3.110

billion cubic meters in Sawaeng Ha district whereas the minimum was found in Mueang Ang Thong district at 2.255 billion cubic meters.and Phra Nakhon Si Ayutthaya province: The maximum of annual soil water was at 3.006 million cubic meters in Wang Noi district whereas the minimum water was found in Phak Hai district at 2.562 billion cubic meters

1.5) Distance from water body When considering each province, it was found that: Chinat province: The minimum distance from the water body in Sapphaya district was at 414.26 meters whereas the maximum distance from the water body was in Sankhaburi district at 2,893.92 meters. Singburi province: the minimum distance from the water body was in Muang Sing Buri district at 144.14 meters whereas the maximum distance from the water source was in Bang Rachan district at 1,615.26 meters. Ang Thong province: the minimum distance from the water body was in Pa Mok district at 180.55 meters whereas the maximum distance from the water body was in Wiset Chai Chan district at 1,503.02 meters. Phra Nakhon Si Ayutthaya province: the minimum distance from the water body was in Phak Hai district at 165.52 meters whereas the maximum distance from the water body was in ThaRuea district at 2,686.72 meters as shown in Figure 1 (e).

1.6) Natural hazards: This study compiled natural hazard statistics in the provinces of Chainat, Singburi, Ang Thong and Phra Nakhon Si Ayutthaya such as floods, storms and drought, which is considered as naturel hazards that affects the agricultural sector from the Provincial Disaster Prevention and Mitigation Office And Department of Disaster Prevention and Mitigation during the year 2012-2016 in a total of 5 years. Due to limitations on record keeping, some years had no statistical data on natural disasters. The researchers then classified the type of nature hazard each year and defined the average number of natural hazard of each type per year. The study found that: Flood: Phra Nakhon Si Ayutthaya Province was found to have the most floods. The average of the flood incidents in the past 5 years was 1 time per year. Storm: Phra Nakhon Si Ayutthaya Province was found to have the most storm, that there were 50 times of storm in 2014. The average number of storm in 5 years was 12 times per year. Drought: The study area had no record in drought.

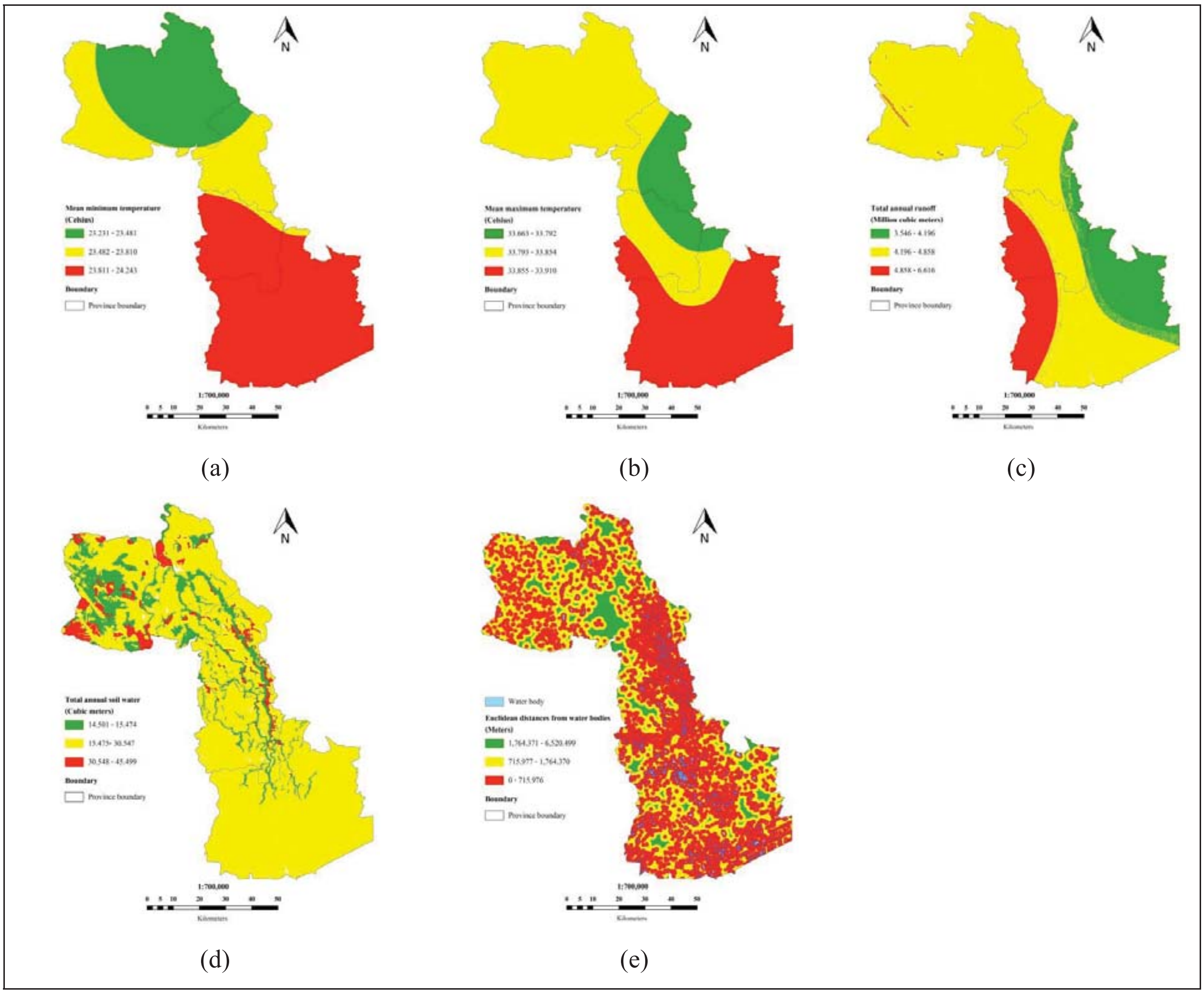

Figure 1. Shows the sub-component for creating an agricultural risk model.

2) Agricultural risk model

In this study, three main components were determined that each of which consisted of 6 sub-component, namely the minimum temperature, maximum temperature, annual runoff, annual soil water, number of nature hazard and distance from the water body by preparing the factors used in research, importing and processing data with geographic information systems. A model was then created and presented it in the form of a map. For the calculation of the fragility index of agriculture in this research, Vector Based Model analysis was used by importing all 6 sub-components which were standardized in the form of attribute data of the layer of district administrative boundary information in the form of the GIS database. The fragility index was then calculated by calculating the weighted average of each main component. The results of the modeling of the agricultural sector with GIS were shown in Figure 2.

3) Agricultural Vulnerability index

In this study found that: Chainat Province: the agriculture fragility index was between 0.3967771-0.5441169, the sub-district with the maximum average AVI was Suk Duean Ha sub-district, Noen Kham district at 0.5441169 whereas the sub-district with the minimum average AVI was Nai Mueang sub-district,. Mueang Chai Nat district at 0.3967771.

Secondly, Singburi province: the agriculture fragility index was between 0.381424-0.498606, the sub-districts with the maximum average AVI was Nong Krathum sub-district in Khai Bang Rachan district at 0.498606 whereas the lowest average AVI was Ton Pho sub-district, Mueang Sing Buri district at 0.381424.

Thirdly, Ang Thong province: the agricultural fragility index was between 0.436061-0.673695, the sub-district with the maximum average AVI was Phai Wong sub-district, Wiset Chai Chan District at 0.673695 whereas the sub-district with the minimum average AVI was Chaiyo district at 0.436061.

Finally, Phra Nakhon Si Ayutthaya province: the fragility index of agriculture value was between 0.436329- 0.647445. The sub-districts with the maximum average AVI was in Phak Hai district at Na Khu sub-district with the average AVI was 0.647445 whereas the sub-districts with the minimum average AVI was in Sam Phaniang sub-district, Ban Phraek District with the average AVI at 0.436329.

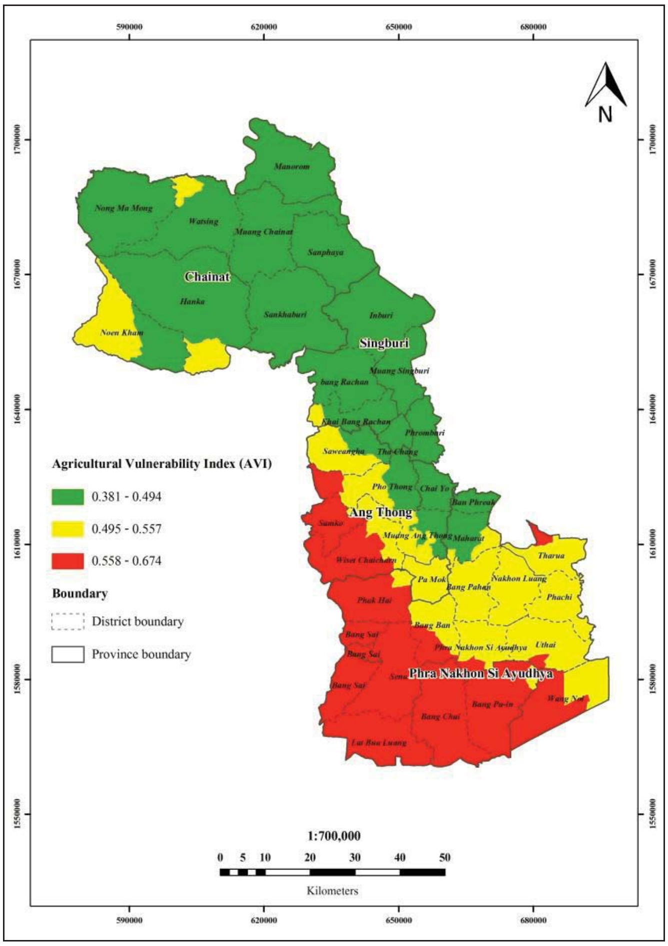

Figure 2. Agricultural risk model

V. CONCLUSIONS AND DISCUSSIONS

For agricultural risk model and the calculation of the AVI index which was between 0.381424-0.673695, it was found that the maximum values were found in Phai Wong sub-district and Sao Rong Hai sub-district, Wiset Chai Chan District, Ang Thong province at 0.673695 and 0.656638 respectively. The minimum AVI values were found in Nai Mueang sub-district, Mueang Chai Nat district, Chai Nat Province at 0.3967771. The calculated AVI index was similar to that of [14] study found that average of AVI values in the area of the eastern part of Thailand. From the results of the AVI index study in Wiset Chai Chan district, Ang Thong province, the AVI value was highest when considered the analyzed key components to create an agricultural risk model. For this area, the average risk components (Exposure) was 0.929987841. and the sensitivity (Sensitive) was equal to 0.662285098, which was higher than other areas. As a result, this area had higher AVI value than the other areas.

Suggestion, to study applied climate data, namely minimum-maximum temperature, annual total rainfall to assess with IDW method. Therefore, in order to be in accordance with the local conditions of each region of the country, an alternative climate estimation method should be selected in order to suit the terrain and be more reliable. There also should be a study of Scenarios to view the prediction results of the agricultural risk index that will occur in the future.

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