Evaluation of Economic Damages on Rice Production under Extreme Climate and Agricultural Insurance for Adaptation Measures in Northeast Thailand

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In northeast Thailand, the ratio of irrigated agricultural land was only 7.6% (in 2012) and others were rain-fed so that climate change makes agricultural production more unstable and also makes crucial damage to the societies and economics in rural area. To mitigate these issues, it is desirable to develop and disseminate enhanced adaptation systems. In this study, we focused on weather induced economic damages and effectiveness of index-based insurance system in northeast Thailand. Firstly, we evaluated how affect the seasonal rainfall amount and patterns on rice yield and production through correlation analysis by using the meteorological and agricultural statistic data. Wet-season rice had significant positive relationship with 3 months accumulated rainfall. 8 province had positive correlation R>0.3 with Jul-Sep accumulated rainfall which was employed for insurance index. And then, probability analysis was applied to monthly rainfall. As a result, setting amount and periods of index value was suitable. Secondly, household survey was conducted to grasp farmer's conditions of water use, cultivation, income balance. According to the 60 famers interview, average household income was 341,160 Baht /year, consisting of 122,433 Baht/year from agriculture and 218,727 Baht/year from non-agriculture. In recent year, some province had 600 million Baht economic loss. In 2000, total production value of wet-season rice in each province were ranged from 460 million Baht (Mukdahan) to 4,160 million Baht (Surin) so that 600 million Baht economic loss was enough large in provincial level. However, recent agricultural damage was not so large (less than 5%), because most part of farmers income relied on non-agricultural sector.

Keywords— agricultural damage, household survey, risk assessment, climate change adaptation

I. INTRODUCTION

Climate change has caused water shortage, floods and severe natural disasters. The consequential losses and damage in the agricultural sector will result in the decline of global agricultural production, causing food insecurity. For Thailand, climate change has a direct effect on the export of food and agricultural products, which is one of the main revenue sources of the country. For example, Thailand had severe flood in 2011: more than one million people were affected by severe flooding for several weeks caused of persistent rainfall. In 2013-2015, Thailand has been experiencing one of the worst droughts in decades, leading to critical low levels of water reservoirs countrywide. Even though future climate change scenarios are still being debated, it is likely that Thailand will be disproportionately affected by the consequences of climate change. Furthermore, agriculture is the main income basis of poor farmers. Thus, climate change has a tremendous impact on poor individual farmers and has aggravated the poverty issue (The Eleventh National Economic and Social Development Plan, 2012 [1]).

In previous study, the relation between crop production and weather condition was evaluated. Shiraiwa et. al.(2002) [2] evaluated the regression between rice production and accumulated monthly rainfall by using 20 years statistical data in whole Thailand. In case of wet season rice, rice production was strongly related with planted area rather than rice yield. Because rainfall amount in wet season significantly affect to planted area. On the other hand, rice yield in wet season was not so sensitive to rainfall amount, because most farmers had additional water source such as shallow ground water or small ponds in emergency case. Suzuki et. al.(2014) [3] evaluated the relation between maize and weather condition in North Thailand and mentioned that maize was more sensitive to climate than wet season rice. Yoshida et. al. (2018) [4] evaluated that agricultural economic loss of around 600 million Baht was often occurred in Northeast Thailand in case of wet-season rice.

Agricultural insurance protects against loss of or damage to crops. It has great potential to provide value to low-income farmers and their communities, both by protecting farmers when shocks occur and by encouraging greater investment in crops. However, in practice its effectiveness has often been constrained by the difficulty of designing good products. Agricultural insurance can indemnify policyholders for losses, though such indemnity products are relatively rare due to the high costs of administration and the risk of fraud. More commonly, agricultural microinsurance is index-based, providing farmers with payouts tied to the performance of an index (such as a rainfall gauge), rather than indemnifying them for crop losses actually experienced. While they avoid the need for costly (and often impossible) verification of damage, index products have a shortcoming in the form of basis risk, the difference between the performance of the index and the damage the policyholder actually suffered. In some cases, this basis risk can be quite large, but can be reduced through improvements in the index [5].

Northeast Thailand is major agricultural producing area where regional production was more than 50% of wet-season rice in whole Thailand. However, the ratio of irrigated agricultural land was only 7.6% (in 2012) and others were rain-fed so that climate change makes agricultural production more unstable and makes crucial damage to the societies and economics in rural area. Sompo Japan insurance company was selling Index-based agricultural insurance in this region, however current selling is around 1 % of farmers only. In this study, we focused on weather-index insurance for climate change adaptation measure. To evaluate the weather index of agricultural insurance, firstly, we evaluated how affect the rainfall amount and patterns on rice production by regression analysis, and probability analysis also applied to estimate the return period of rainfall index. Secondly, agricultural damage and it's impact on farmer's household income was evaluated.

II. MATERIAL AND METHODS

To evaluate the impact of weather-induced economic loss of wet-season rice production in Northeast Thailand, two kinds of analysis were conducted in this study. Firstly, we evaluated how affect the seasonal rainfall amount and patterns on wet-season rice production through correlation analysis by using the meteorological and agricultural statistic data. And return periods of rainfall index also estimated by probability analysis. Secondly, household survey was conducted to grasp farmer's conditions of water use, cultivation, income balance. And then, economic loss by weather induced agricultural damage was estimated and impact on farmer's household income was evaluated by using the agricultural statistic and crop price data.

A. Study area

In this study, we selected Northeast Thailand for analytical area. Fig.1 shows the location of study area and provincial administrative boundary and rainfall gauge location map in this region. Currently 20 provinces are located in Northeast Thailand, however 17 provincial area map before 1996 (Fig.1 (b)) was used in this analysis. Because only 17 provincial data were available in agricultural statistic before 1997. Northeast Thailand covers 160,000 km^2 and roughly coterminous with the Khorat Plateau. The plateau consists of two plains: the southern Khorat plain is drained by the Mun and Chi rivers, while the northern Sakon Nakhon plain is drained by the Loei and Songkhram rivers. The average temperature range is from 19.6 °C to 30.2 °C. Rainfall is unpredictable and concentrated in the rainy season from May to October. Annual rainfall fluctuation was 800-1400 mm/year, and this amount was smaller than another region in Thailand. Therefore, agricultural production has been strongly affected by climate. The ratio of irrigated agricultural land was only 7.6 % so that production was sensitive to drought and flood condition. Current production data such as yield, harvested area of wet-season rice were shown in Fig.2. Rice yield increased gradually caused by variety or farming practice improvement. And harvest area also gradually increased in this region.

For weather index insurance, Sompo Japan set three thresholds according to the timing and degree of drought. They are: early drought, drought and severe drought. The compensation is a fixed loan percentage of the loan principal

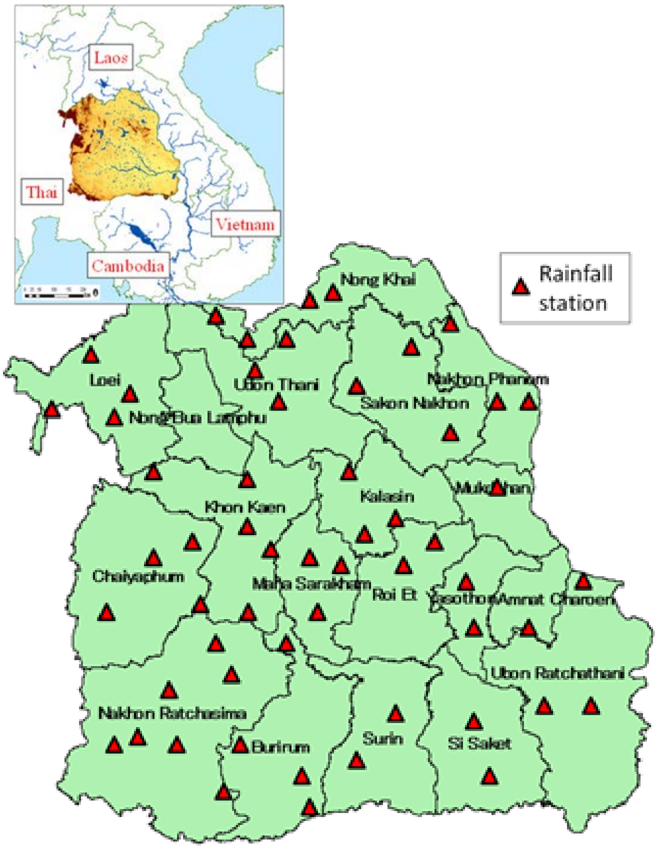

Fig.1 administrative boundary and rain gauge station map

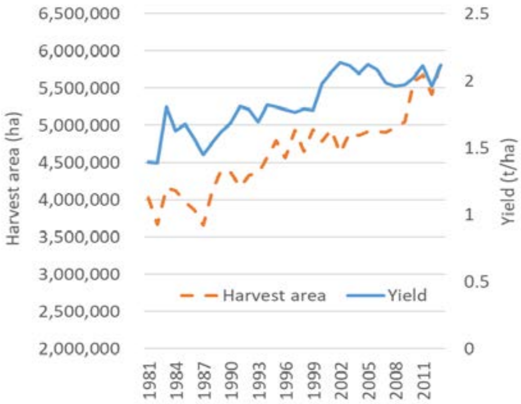

Fig.2 Historical change of rice yield and harvested area

between BAAC and each farmer, and the percentage is fixed for each threshold in advance. If the sum of rainfall in the month of July is below the threshold of an early drought, 10% of the insurance principle is paid as compensation. The policy contract is terminated afterwards. If the sum of the rainfall in July is above the threshold then the policy contract continues until the end of September. When the sum of rainfall during the months of August to September is below the threshold of drought or severe drought, 15% or 40% of the insured loan principal is paid respectively. In case of Khon Kaen province, the insurance premiums was defined based on the amount of loans. The farmers have to pay 10% of their loan for their insurance premium. And weather index was defined as "Early drought" means that the sum of rainfall in July is below 100 mm. "Drought" or "severe drought" means the sum of rainfall from August to September is below 320 mm or 220 mm respectively.

B. Correlation analysis

In Northeast Thailand, agricultural production had been affected by climate condition, especially extreme drought and flood. Therefore, it is important to evaluate the crop sensitivity to monthly rainfall. In this study, we analyzed the correlations between crop yield and monthly rainfall. The data of crop yield and harvested area from 1993 to 2013 were available in agricultural statistic published by OAE (Office of Agriculture and Economics in Thailand). And 41 stations data of monthly rainfall from 1993 to 2013 also collected from TMD (Thai Meteorological Department) and RID (Royal Irrigation Department). The location of rain gauge station was shown in Fig.1(b).

At first, both of them were standardized as following manner, and then correlation analysis was applied. Agricultural production can be calculated as following equation by multiplying 2 contributed components.

$$RP = RY \times PA \times RHA \qquad (1)$$

where, RP: rice production, RY: rice yield, PA: plantted area, RHA: ratio of harvested area (=harvest area/ planted area).

A time series of rice yield can be divided into three major sources of variation. These are identified as i) technological change, ii) meteorological variability and (iii) random "noise". The technological change in yields occurred due to the recent advancement in agricultural technology. In this study, pre-5 years average yield value was calculated and only the deviation from pre-5 years average were used for correlation analysis to off-set the trend of technological change [2]. The third component of the impact and contribution of random noise is very little.

Among meteorological parameters, rainfall is one of the most important elements which affect crop yield significantly. Because air temperature was enough high during all season in NE Thailand. In this study, The Standardized Precipitation Index (SPI) was calculated and used for correlation analysis. SPI is a normalized index representing the probability of occurrence of an observed rainfall amount when compared with the rainfall climatology at a certain geographical location over a long-term reference period. It quantifies observed precipitation as a standardized departure from a selected probability distribution function that models the raw precipitation data. The raw precipitation data are typically fitted to a gamma or a Pearson Type III distribution, and then transformed to a normal distribution [6].

C. Probability analysis

The probability analysis of seasonal rainfall is important to predict the relative frequency of occurrence in different group interval of annual rainfall with reasonable accuracy. The monthly accumulated rainfall data are ranked in descending order and various probabilistic methods are applied to determine the return period. From the Probabilistic methods, Gumbel, Log-normal and Normal distribution methods were used. The rainfall data are arranged into a number of intervals with definite ranges[7].

D. Estimation of agricultural economic loss

Agricultural economic loss was evaluated from agricultural statistic and crop price data. One problem is how to definite the normal year condition. Crop yield of rice was gradually increased in Fig.2 This might be caused by variety improvement, increasing fertilizer or pesticide input, etc. Such technological aspect should be removed and only the climate aspect should be accounted. Therefore, in this study, pre-5 year average rice yield was employed as the normal condition, and deviation from pre-5 years average was extracted shown in Fig.3. Agricultural economic loss was calculated from this deviation part multiplying the harvested area and crop price.

Fig.3 Schematic image of economic loss estimation

E. Household surveying

To grasp the farmers behavior against to climate condition, oral interview to the farmers was conducted in 2016 and 2017. We selected three location in Khon Kaen province, such as i) mainly irrigated area, ii) mainly rainfed upland crop area, iii) mainly rainfed and salt affected soil area. Table1 shows the contents of questionnaire about household structure, water use, cultivation, livestock, non-agricultural job, etc. The total sample is 60 households (20 farmers in each location).

Table1 Contents of questionnaire to farmers

1. Household structure	Number of menbers
	(Age, Education, Job...)
2. Water Use	Domestic water(bottle water, tap water, ground water)
	Agricultural water(rainfed, surface/ground water irrigation)
	Small ponds (for irrigation, aquaculture, other use...)
3. Cultivation	Crop calender (seeding/transplant, fertilizer, pestiside, harvest)
	Planted area, yield, production
	Others(land ownership, machine use…)
4. Livestockes	Spieces of livestockes, head, price
	Purpose of use (agriculture, sell, eat, milk...)
5. Non-Agriculture	Job, permanent/temporaly, income
	Stability and satisfaction
6. Others	Knowledge of climate change inpact
	Knowledge of agricultural insurance

III. RESULT AND DISCUSSION

Before you begin to format your paper, first write and save the content as a separate text file. Keep your text and graphic files separate until after the text has been formatted and styled. Do not use hard tabs, and limit use of hard returns to only one return at the end of a paragraph. Do not add any kind of pagination anywhere in the paper. Do not number text heads-the template will do that for you.

Finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar:

A. Result of Correlation analysis

Correlation analysis was applied between standardized crop production and standardized monthly rainfall. In this study, from 1 to 6 month accumulated monthly rainfall was used. Wet season rice production had significant positive relationship with 3 month accumulated rainfall (Table2). 9 provinces had positive correlation R>0.3 with Jun-Aug accumulated rainfall. Rice transplanting normally start from June or July so that

Table2 Correlation value of 3 month accumulated rainfall

(Province) (Month)	May-Jul	Jun-Aug	Jul-Sep	Aug-Oct	Sep-Nov	Oct-Dec
Buriram	0.30	0.32	0.30	0.13	-0.11	-0.13
Chaiyaphum	0.28	0.26	0.13	0.04	-0.14	-0.11
Kalasin	0.42	0.49	0.37	0.13	-0.05	-0.05
Khon Kaen	0.38	0.53	0.53	0.54	0.45	0.35
Loei	0.39	0.45	-0.30	0.08	-0.04	0.48
Maha Sarakham	0.15	0.45	0.54	0.42	0.32	0.25
Mook Zehnder Hahn	0.05	0.33	0.34	0.22	0.06	-0.25
Nakhon Phanom	0.00	-0.12	-0.19	-0.13	-0.07	0.04
Nakhon Ratchasima	0.27	0.35	0.33	0.05	-0.15	-0.32
Nong Khai	0.02	-0.12	-0.11	-0.24	0.02	-0.15
Roi Et	0.36	0.49	0.31	0.09	-0.18	0.07
Sakon Nakhon	-0.01	0.02	0.17	0.44	0.35	0.17
Sisaket	0.05	0.13	0.02	-0.04	-0.29	-0.32
Surin	0.38	0.47	0.34	-0.01	-0.49	-0.48
Ubonratchathani	0.27	0.24	0.14	0.08	0.12	0.21
Udon Thani	-0.12	0.26	0.48	0.26	0.17	-0.20
Yasothon	0.26	0.06	-0.12	-0.18	-0.21	0.07

rainfall in this season is quite important factor to control the rice planted area. Future rainfall change in this season might affect rice production significantly. On the other hand, wet-season rice production had negative relation to Oct-Dec rainfall in Nakhon Ratchasima, Si Saket and Surin. These provinces are located in Mun river basin having no large-scale dam so that flood may cause the reduction of rice production in these provinces. Chaiyaphum, Nakon Phanom, Nong Kai, Ubon Ratchthani and Yasothon province didn't have significant correlation in any season. These provinces has much rainfall compare with other provinces. Therefore, small change of accumulated rainfall may not affect rice production.

For weather index, July-Sep rainfall was employed. From table2, July-Sep accumulated rainfall also had positive correlation with rice production in 8 provinces, therefore employed index period looked like suitable. According to the Sompo Japan report [8], Jun-Aug rainfall was used for their first trial in Khon Kaen province. However, through the discussion with the farmers, index was changed to July-Sep. Because current year farming practice was changed from transplanting to direct seeding due to lack of labor power, rainfall amount of beginning stage became not so important for rice cultivation.

B. Result of Probability analysis

From the Rainfall Probability analysis on the monthly rainfall for Khon Kaen province, it was evident that Normal distribution was insufficient and Gumbel distribution was ascertained as the best fit distribution (Fig.4). Table3 showed estimated monthly rainfall in each return period in Khon Kaen province. In Khon Kaen, "Early drought" means that the sum of rainfall in July is below 100 mm and estimated return period is 4 years. "Drought" or "Severe drought" means the sum of rainfall from August to September is below 320 mm or 220 mm, and those return periods was estimated as 5 years and 30 years, respectively. In this case, expected payment per year from insurance was around 5.75% of farmers loan amount.

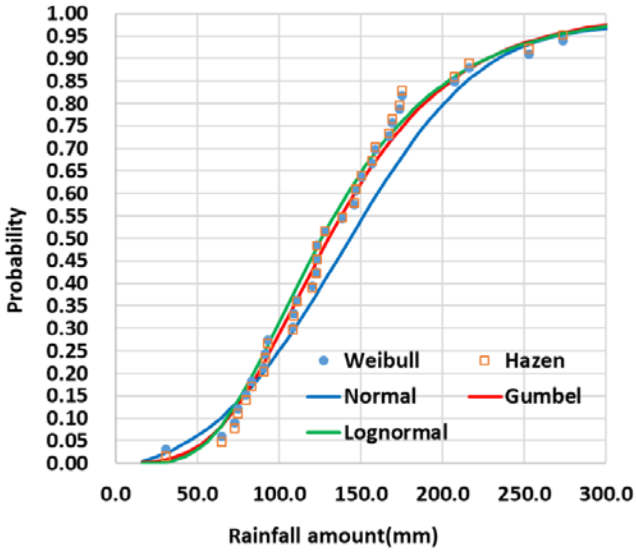

Fig.4 Fitting of probability distribution (July, Khon Kaen)

Table3 estimated monthly rainfall in each return periods

Year	July (mm)	Aug+Sep(mm)
50	41	208
30	48	224
20	55	239
16	59	248
12	65	260
10	67	269
8	74	281
5	87	311
4	95	328
3	107	354
2	130	407

C. *Estimation of agricultural economic loss*

Agricultural economic loss during 1981-2013 due to drought or flood was estimated. Fig.5 shows estimated economic loss of wet-season rice in each province of northeast Thailand. Maximum economic loss was estimated around 2,000 million Baht in Udon Thani province in 1988, and in recent year also some province had 600 million Baht economic loss. In 2000, total production value of wet-season rice in each province were ranged from 460 million Baht (Mukdahan) to 4,160 million Baht (Surin) so that 600 million Baht economic loss was enough large in provincial level.

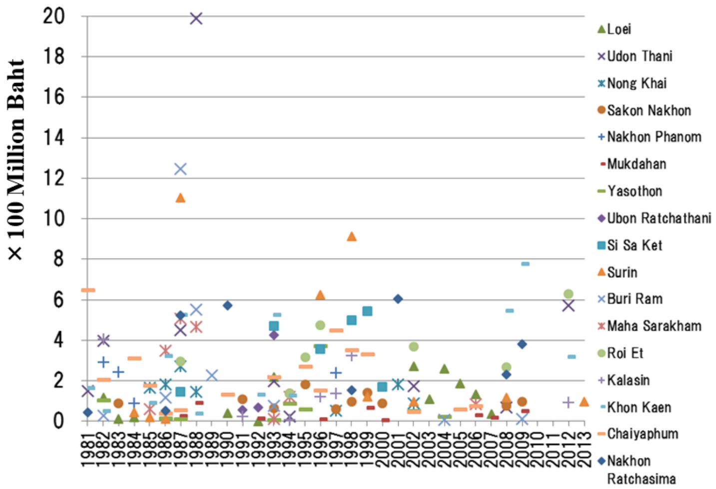

Fig5 Estimated economic loss of wet-season rice (1981-2013)

D. *Impact assessment on farmers household income*

According to the 60 famers interview, average household composition number of people was 4.54 and average age of workers was 44.0 years old. Average agricultural land area was 2.59 ha and all of households had paddy field to produce rice for self-consumption. Average household income was 341,160 Baht /year, consisting of 122,433 Baht/year from agriculture and 218,727 Baht/year from non-agriculture. For upland crop, cassava cultivation was favorable in this region, because of low labor input and strengthen to water stress. Famers could share their time to non-agricultural job rather than agriculture. Fig.6 shows historical change of farmers agricultural and non-agricultural income. Fig.6 contain not only questionnaire data but also contain the data from OAE (in 1983, 1988, 1992, 1996,1999). The ratio of agri- and non-agri income was not so changed and around 65% came from non-agriculture.

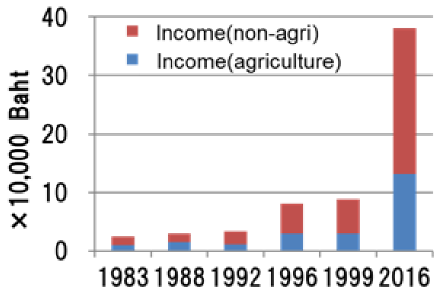

Fig.6 Historical change of farmers agricultural and non-agricultural income

For domestic water, 91% of households was used tap water, 85% of households was used bottle water, 13% of households was used ground water, 16% of households was used rain water. Most of farmers were using both tap water and bottle water and answered that those were safety and stable. For agricultural water use, small pond (36%), ground water (4%), canal water (15%) were used. Most of agricultural land was classified as rainfed in this area, however 79% of farmers answered that rice or upland crop production were stable. Only 39% farmers answered that agricultural income was stable, on the other hand 72% of farmers answered non-agricultural income was stable. 80% of farmers had livestock and they can sell it under the emergency cases. Also 80 % of farmers had agricultural machines (mainly tractor) and others can rent agricultural machines when they start cultivation.

By using the interview results, impact of agricultural economic loss on farmers household income was estimated. In this calculation, we employed as following assumptions, 1) agricultural land area was 2.59 ha/household, 2) the ratio of agri- (35%) and non-agri (65%) income was not change during 1998-2013, 3) total household income can be interpolated by liner increase from data of Fig.6, 4) agricultural economic loss in provincial level can be used from the data of Fig.5.

Fig.7 shows percentage of agricultural economic loss on farmers household income in insurance selling province assuming wet-season rice cultivation.

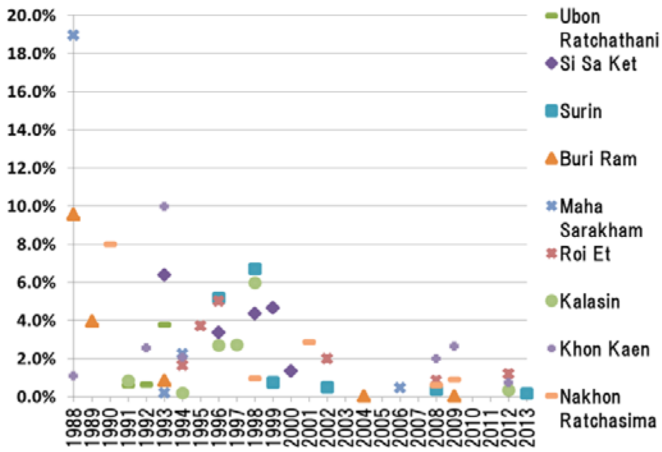

Fig.7 Impact of agricultural damage on farmers income

Average farmers income from paddy rice cultivation increased from 3,947 Baht/year/ha (1981) to 21.564 Baht/year/ha (2013) due to productivity improvement and crop price increase. Before 2000, in some province more than 6 % economic loss was estimated, however it declined less than 3% in recent year. During 1981-2013, consumer price index became 2.5 times, and farmers income became 13 times. Therefore, recent agricultural damage will not makes large impact on farmers livelihood in this case. On the other hand, full-time farmers had relatively large impact rather than part time farmers. They are still potential buyer of insurance.

IV. CONCLUSION

In this study, we focused on weather induced economic damages and effectiveness of index-based insurance system in northeast Thailand. Firstly, we evaluated how affect the seasonal rainfall amount and patterns on rice yield and production through correlation analysis by using the meteorological and agricultural statistic data. Wet-season rice had significant positive relationship with 3 months accumulated rainfall. 9 provinces had positive correlation R>0.3 with Jun-Aug accumulated rainfall. And 8 province had positive correlation R>0.3 with Jul-Sep accumulated rainfall which was employed for insurance index. And then, probability analysis was applied to monthly rainfall. In Khon Kaen, “Early drought” means that the sum of rainfall in July is below 100 mm and estimated return period is 4 years. “Drought” or “Severe drought” means the sum of rainfall from August to September is below 320 mm or 220 mm, and those return periods was estimated as 5 years and 30 years, respectively. In this case, expected payment per year from insurance was around 5.75％ of farmers loan amount. As a result, setting amount and periods of index value was suitable.

Secondly, household survey was conducted to grasp farmer’s conditions of water use, cultivation, income balance. According to the 60 famers interview, average household composition number of people was 4.54 and average age of workers was 44.0 years old. Average agricultural land area was 2.59 ha and all of households had paddy field to produce rice for self-consumption. Average household income was 341,160 Baht /year, consisting of 122,433 Baht/year from agriculture and 218,727 Baht/year from non-agriculture. Most of agricultural land was classified as rainfed in this area, however 79% of farmers answered that rice or upland crop production were stable. In recent year, some province had 600 million Baht economic loss. In 2000, total production value of wet-season rice in each province were ranged from 460 million Baht (Mukdahan) to 4,160 million Baht (Surin) so that 600 million Baht economic loss was enough large in provincial level. However, recent agricultural damage was not so large because most part of farmers income relied on non-agricultural sector.

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