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Article

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

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Abstract. In northeast Thailand, the irrigated agricultural land was only 7.6% (in 2012) of total and others were classified as rain-fed so that climate change makes agricultural production unstable and also makes negative impact to the societies and economics in rural area. To mitigate these issues, it is desirable to develop enhanced adaptation measures. 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 regression analysis by using the meteorological and agricultural statistic data. 8 province had positive correlation R>0.3 with Jul-Sep accumulated rainfall. And then, probability analysis was applied to monthly rainfall which was employed for insurance index value. As a result, setting amount and periods of insurance index was suitable. Secondly, household survey was conducted to investigate farmers' conditions of water use, cultivation, income balance. In recent year, agricultural damage on farmers' income was not so large (less than 3%), because 65% of farmers' income relied on non-agricultural sector. That might be the one reason of constraints of insurance sales.

Keywords: Agricultural damage, household survey, risk assessment, climate change adaptation.

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1. Introduction

Agricultural water use became more competitive by increased pressure from urbanization, industrialization, and climate change could affect to water supply and agriculture through changes in the seasonal timing and amount of rainfall, as well as severe floods and prolonged droughts. Approximately, 70% of the global water withdrawal and 85% of consumptive water use is directed toward irrigation. Therefore, information on the water use of agricultural sector is highly relevant in assessing the possible impact of changes in climate and socio-economic factors on regional water and food supply. Since it is necessary to provide large amounts of water to paddy fields compared with other upland crops, water harvesting and management in paddy fields is especially important for efficient water use and for regional water cycle in Thailand.

Recently, climate change has caused water shortage or severe natural disasters. The weather induced losses and damage in the agricultural sector will leads the decline of global agricultural production, causing insecurity of food. For Thailand, climate change has a direct effect on the export of food and agricultural products, which is one of the main income sources of the country. For example, Thailand had experienced severe flood in 2011: one of the worst floods in historical record. In 2015, Thailand had severe drought, leading to critical low levels of water allocation in whole country. Furthermore, agriculture provide the main income basis of farmers. Thus, climate change has a huge impact on individual farmers and has aggravated the problem of poverty (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] estimated the regression between rice production and accumulated monthly rainfall by using 20 years statistical data in Thailand. Rice production was strongly related with planted area rather than rice yield for wet season rice in Northeast Thailand. Because rainfall amount in the beginning of wet season significantly affect to planted area. On the other hand, rice yield 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 condition than rice. Yoshida et al. (2018) [4] evaluated that agricultural economic loss of sugarcane and cassava. Sugarcane yield had positive regression with rainfall in wet season, however cassava had negative regression because cassava was root vegetable. And mix farming was recommended to stabilize the farmers' income from their agricultural land.

Agricultural insurance protects economic loss or damage under extreme climate condition. It has great potential to provide value to low-income farmers and their communities, both by supporting farmers when severe income loss occurs and by encouraging greater investment in cropping system. However, in practice its effectiveness has often been constrained by the data availability. More commonly, agricultural microinsurance is index-based, providing farmers with guarantee depend on the performance of an index, rather than compensate them for economic losses actually occurred. While index -based system avoid the needs for cost verification of damage, it has a disadvantage in the form of "basis risk", the difference between the performance of the index and the damage which farmers actually suffered. In some cases, this "basis risk" is 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 sthat agricultural production was sensitive to climate, and climate change makes crucial impact to the societies and economics in rural area. Sompo Japan-Thailand 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 its impact on farmers' household income was evaluated.

2. 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 regression 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 farmers' conditions of water use, cultivation, income balance. And then, economic loss by weather induced agricultural damage was estimated and impact on farmers' household income was evaluated by using the agricultural statistic and crop price data.

2.1. Study Area

In this study, we selected the Northeast region in Thailand for study area. Figure 1 shows the provincial administrative boundary and the location of rainfall gauges in this region. Currently, 20 provinces are located in Northeast Thailand, however 17 provincial area map before 1996 was used in this analysis. Because only 17 provincial data were available in agricultural statistic before 1997. Northeast Thailand covers about 168×10^3 km² and coterminous with the Khorat Plateau. The Khorat plateau consists of two plains: one is the southern Khorat plain drained by the Mun and Chi rivers, and another is the northern Sakon Nakhon plain drained by the Loei and Songkhram rivers. The average temperature ranged from 19.6 °C to 30.2 °C. Rainfall amount is unstable and concentrated in the rainy season from May to October.

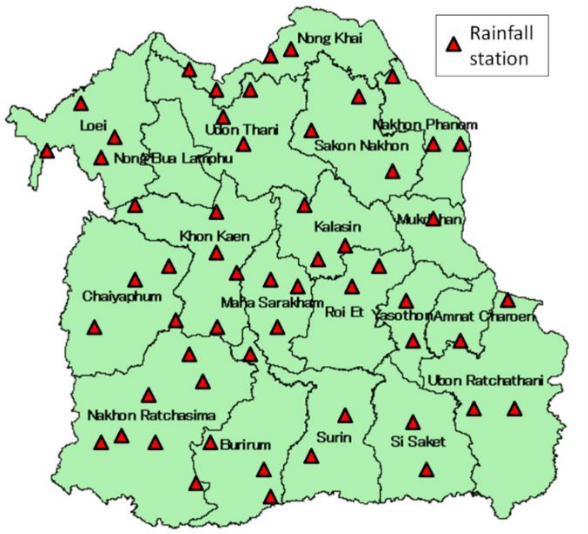

Fig. 1. Administrative boundary and rain gauge station map.

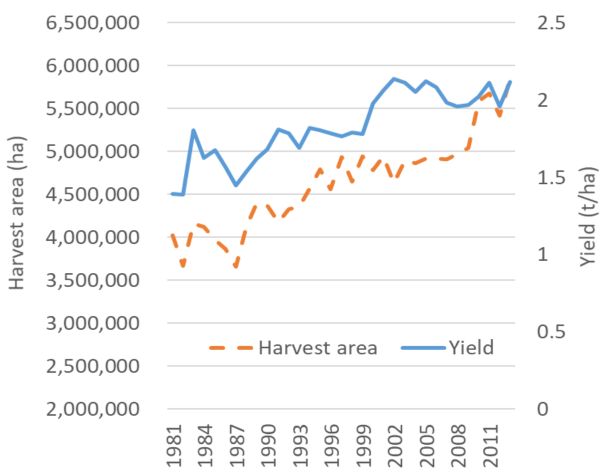

Fig. 2. Historical change of rice yield and harvested area in NE Thailand.

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 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-Thailand set three thresholds according to the timing and degree of drought, such as "early drought", "drought" and "severe drought". The compensation is a fixed percentage of the loan principal between BAAC (Bank for Agriculture and Agricultural Cooperatives) and each farmer, and the percentage is fixed for each threshold in advance. If the monthly rainfall in July is smaller than the threshold value of an "early drought", 10% of the insurance principle is paid to farmer, and then the contract is terminated afterwards. If monthly rainfall in July is larger than the threshold, then the contract continues until the end of September. When the accumulated rainfall during August to September is smaller than the threshold of "drought" or "severe drought", 15% or 40% of the insured loan principal is paid respectively. In case of Khon Kaen province, farmers pay 10% of their loan for 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.

2.2. Regression 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 regression between wet-season rice production and monthly rainfall. The data of rice production, yield and harvested area from 1981 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 1981 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.

Agricultural production can be calculated as following equation by multiplying three contributed components.

$$RP = RY \times PA \times RHA \tag{1}$$

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

At first, we checked which components was dominant factor to affecting rice production. the data of rice production, yield, planted area, and monthly rainfall were standardized as following manner, and then regression analysis was applied. In this study, pre-5 years average yield value was calculated and only the deviations from pre-5 years average were used for regression analysis to off-set the trend of technological change, such as variety improvement, or fertilizer and pesticide input [2].

Among meteorological parameters, rainfall is most important factor which affect rice production significantly. Because air temperature was enough high during all season in Northeast Thailand. In this study, The Standardized Precipitation Index (SPI) was calculated and used for regression analysis. SPI is a normalized index representing the probability of occurrence of an observed rainfall amount when compared with the rainfall at a certain monitoring station over a long-term reference period [6].

2.3. Probability Analysis

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

2.4. Estimation of Agricultural Economic Loss

Agricultural economic loss was estimated 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 and rice production also had same trend. 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 considered. Therefore, in this study, pre-5 year average rice production 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 crop price as following Eq. (2).

$$EL = (Pave- RP) \times Price \tag{2}$$

where, EL: economic loss, Pave: pre-5year average production, RP: rice production, Price: rice price. When the EL value became less than zero, EL was replaced by zero to extract only damage cost.

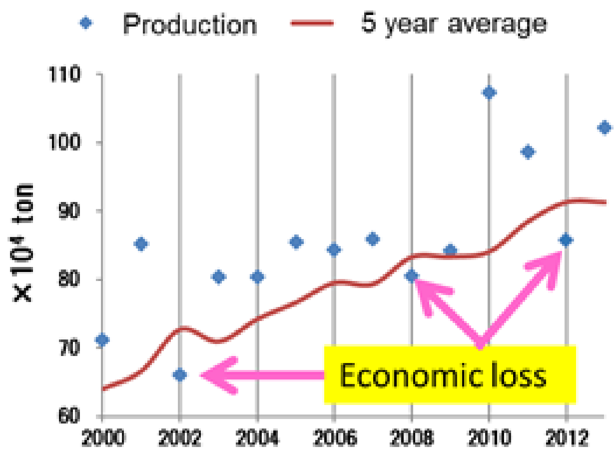

Fig. 3. Schematic image of economic loss estimation.

2.5. Household Surveying

To grasp the farmers' behavior under different climate condition, oral interview to the farmers was conducted in 2016 and 2017. We selected three locations in Khon Kaen province, such as i) irrigated area, ii) rainfed upland crop area, iii) 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).

Table 1. Contents of questionnaire to farmers.

1. Number of members	Relation, age, education, job
2. Water use	Domestic use (bottle water, tap water, ground water, rain water)
	Agricultural use (rainfed, surface irrigation, ground water irrigation)
	Small pond (for irrigation, aquaculture, other use)
3. Agriculture	Crop species, planted area, yield, production
	Crop calendar (seeding/transplanting, fertilizer, pesticide, harvest)
	Others (land ownership, machine use)
4. Livestock	Livestock species, quantity, price
	Purpose of use (agriculture, selling, eat, milk)
5. Non-agriculture	Kinds of job, permanent/temporally, income
	Stability and satisfaction
6. Others	Knowledge of climate change
	Knowledge or willing to buy agricultural insurance

3. Result and Discussion

3.1. Result of Regression Analysis

Regression analysis was applied to Eq. (1) to check which components was dominant factor to affecting rice production. Table 2 showed the partial regression coefficient between rice production and 3 contributing components such as rice yield, planted area, ratio of harvested area (=harvest area/ planted area). For wet season rice, planted area was dominant in 13 provinces and rice yield was only in 4 provinces. Farmers might be controlling their planted area depend on the rainfall amount to compensate the yield of rice in wet season. From this result, rice yield was not suitable to applied correlation analysis with monthly rainfall data. Therefore, rice production itself was employed for checking parameter in following correlation analysis.

Table 2. Partial regression coefficient of each components.

Wet season rice	Yield	Planted Area	RHA
Loei	0.66	0.70	0.56
Udon Thani	0.98	0.30	0.20
Nong Khai	0.43	0.73	0.43
Sakon Nakhon	0.74	0.81	0.31
Nakhon Phanom	0.49	0.76	0.31
Mukdahan	0.79	0.75	0.21
Yasothon	0.51	0.69	0.15
Ubon Ratchathani	0.45	0.87	0.25
Si Sa Ket	0.53	0.81	0.34
Surin	0.69	0.99	0.37
Buri Ram	0.60	0.56	0.20
Maha Sarakham	0.33	0.73	0.18
Roi Et	0.49	0.82	0.41
Kalasin	0.57	0.97	0.10
Khon Kaen	0.39	0.67	0.24
Chaiyaphum	0.52	0.74	0.22
Nakhon Ratchasima	0.72	0.55	0.32

And then, correlation analysis was applied between standardized rice production and standardized monthly rainfall. In this study, from 1 to 6 month accumulated rainfall was used for analysis. Wet-season rice production had significant positive relationship with three months accumulated rainfall (Table 3). 9 provinces had positive correlation R>0.3 with Jun-Aug accumulated rainfall. Rice transplanting normally start from June or July so that rainfall in this season is quite important factor to control the rice planted area. On the other hand, correlation of Oct-Dec rainfall showed negative value 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 Table 3, July-Sep accumulated rainfall also had positive correlation with rice production in 8 provinces, therefore employed weather index period for insurance looked like suitable. According to the Sompo Japan-Thailand, 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. Recently, farming practice was changed from transplanting to direct seeding due to lack of labor power in Khon Kaen, after that rainfall amount of beginning stage (in June) became not so important for rice cultivation.

Table 3. Correlation value between rice production and 3 month accumulated rainfall.

	May-Jul	Jun-Aug	Jul-Sep	Aug-Oct	Sep-Nov	Oct-Dec
Buri Rum	0.30	0.32	0.29	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	0.45	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

3.2. Result of Probability Analysis

From the 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). Table 4 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 less than 100 mm and estimated return period is 4 years. "drought" or "severe drought" means the sum of rainfall from August to September is less than 320 mm or 220 mm, and therefore 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, while farmers' payment for insurance is 10% of loan amount.

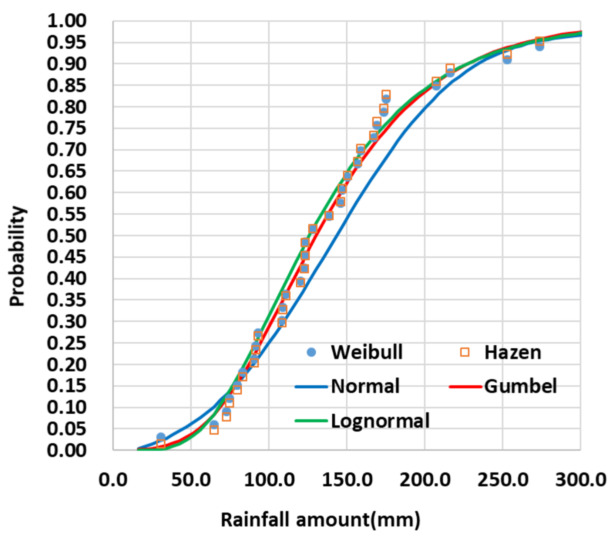

Fig. 4. Fitting of probability distribution (July, Khon Kaen).

Table 4. 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

3.3. Result of Agricultural Economic Loss

Agricultural economic loss during 1981-2013 due to drought or flood was estimated. Figure 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.

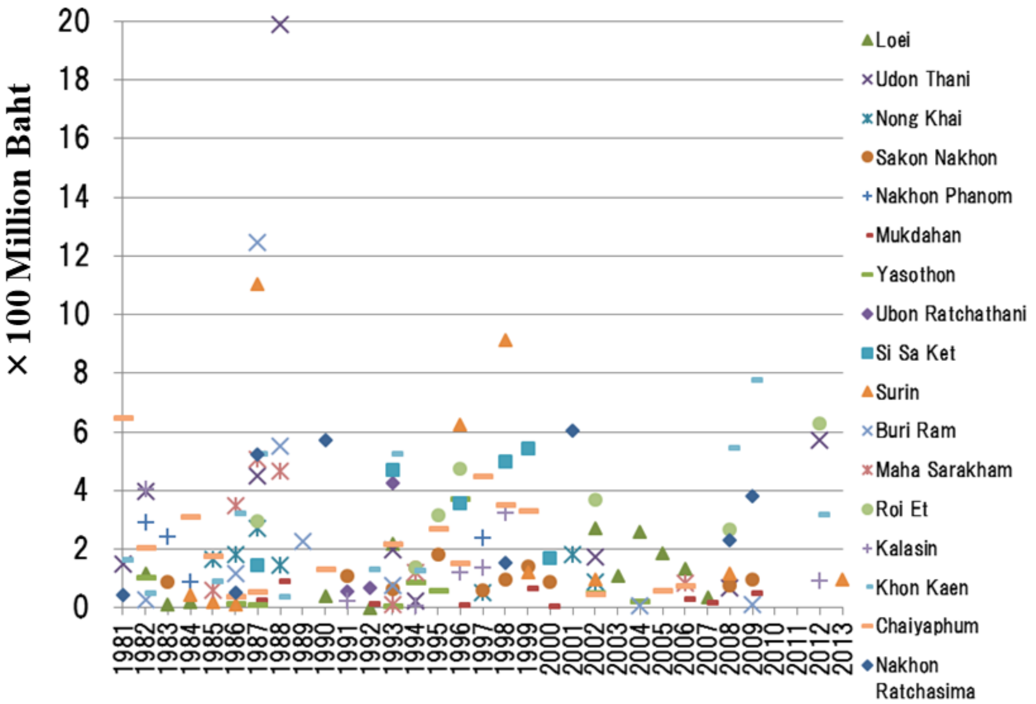

Fig. 5. Estimated economic loss of wet-season rice (1981-2013).

3.4. Economic Damage on Farmers Household Income

From the 60 farmers' interview results, average agricultural land area was 2.59 ha and all farmers had paddy field to produce rice for household. Average household income was about 34×10^4 Baht /year, consisting of 12×10^4 Baht/year from agriculture and 22×10^4 Baht/year from non-agriculture. Figure 6 shows farmers agricultural and non-agricultural income change. Figure 6 contains not only questionnaire data but also contain the oral interview data by OAE (in 1983, 1988, 1992, 1996, 1999). Around 35% of total income from agriculture and 65% came from non-agriculture, and the balance of agricultural and non-agricultural income was not change so much. Most of agricultural land was classified as rainfed in this area, so 61% of farmers answered that agricultural income from rice or upland crop cultivation were unstable.

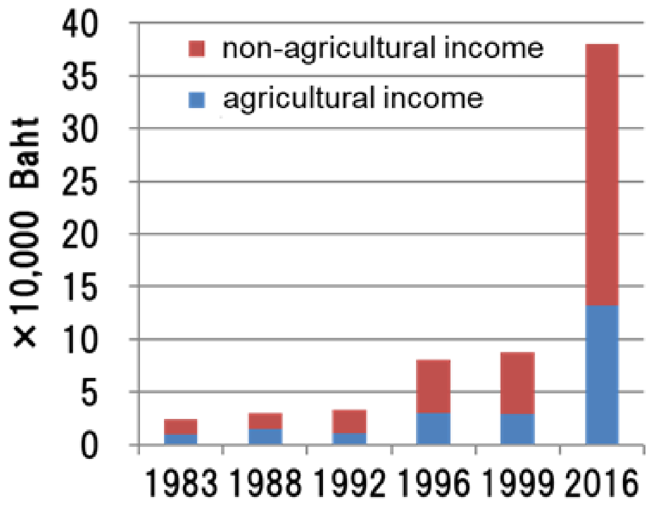

Fig. 6. Variation of farmers' agricultural and non-agricultural income.

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 1988-2013; 3) total household income can be interpolated by liner increase from data of Fig. 6; 4) agricultural economic loss per ha can be used from the data of Fig. 5.

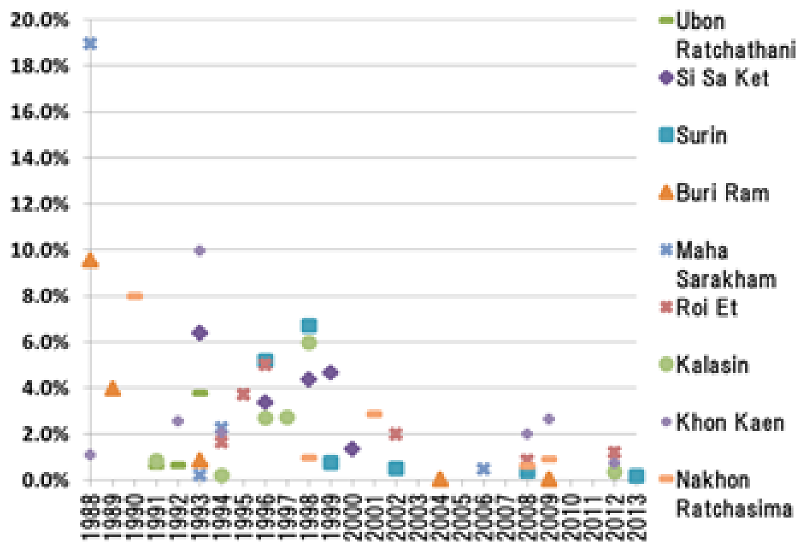

Fig. 7. Impact of agricultural damage on farmers' income.

Figure 7 shows impact of agricultural economic loss on farmers' household income in insurance selling province assuming wet-season rice cultivation. 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, more than 6 % economic loss was estimated every 3 years in some provinces, 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 make large impact on farmers' livelihood in this case. On the other hand, full-time farmers had relatively larger impact than part-time farmers. Therefore, full-time farmers are still potential buyer of insurance.

4. Conclusion

In this study, we focused on agricultural economic damages and effectiveness of index-based insurance system in northeast Thailand. Firstly, we evaluated the regression between the seasonal rainfall amount and rice production by using the agricultural statistic from OAE and meteorological data from TMD and RID. Wet-season rice had significant positive relationship with 3 months accumulated rainfall. 8 provinces 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 monthly rainfall in July is less than 100 mm and estimated return period is 4 years. "drought" or "severe drought" means the accumulated rainfall from August to September is less than 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, while farmer pay 10% of their loan. As a result, setting amount and periods of insurance index was suitable.

Secondly, household survey was conducted to grasp farmers' conditions of water use, cultivation, income balance. From the 60 famers interview results, average household income was about 34×10^4 Baht /year, consisting of 12×10^4 Baht/year from agriculture and 22×10^4 Baht/year from non-agriculture. Even in recent year, about 600 million Baht economic loss was estimated in some province. Total production value of wet-season rice in each province were ranged from 460 million Baht (Mukdahan) to 4,160 million Baht (Surin) in 2000 so that 600 million Baht economic loss was enough large in provincial level. However, recent agricultural damage was not so large for part-time farmers, because most part of farmers' income relied on non-agricultural sector. That might be the one reason of constraints of insurance sales.

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