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Application of weather index-based insurance for paddy yield: The case of Malaysia

Yvonne Wong Jing Wen *, Raja Rajeswari Ponnusamy, Ho Ming Kang

School of Mathematics, Actuarial and Quantitative Studies, Asia Pacific University, Kuala Lumpur, Malaysia

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ABSTRACT

Agriculture is primarily vulnerable to vagaries of the weather. The impact of climate change is always intertwined with agricultural production. Therefore, in order to manage these losses, agricultural insurance should be initiated in Malaysia to the farmers to handle the financial risks associated with the impact of weather conditions on the crop yield. This study presents the results of a pilot scale investigation on weather index-based paddy insurance in five selected states in Malaysia. The aim of this study is to determine the appropriateness of this insurance model for each selected paddy cropping zone in Malaysia. Suitable weather indexes were chosen based on the relationship of these indexes and the paddy yield in each zone by employing the method of Ordinary Least Square regression and robust regression. The weather index-based insurance contract is designed based on the natural phenomenon and the time trend had been removed in order to reduce the basis risk. By investigating the relationship, a paddy insurance contract was then designed. However, the results showed that three paddy cropping zones are not suitable to uptake this index insurance as the regression models reported that the vagaries of weather did not cause a significant impact on the paddy yield of these states. This study reveals diversified insurance product design of each zone based on different weather indexes, which suggests that more weather variables should have to be taken into account in order to design a more robust weather-index insurance.

1. Introduction

Agricultural insurance has been booming in other developing countries, such as U.S., Canada, Australia, Asia, Latin America and Africa. There are different kinds of insurance scheme being implemented such as multiple peril insurance, indemnity insurance, area-based index insurance and weather-based index insurance. However, currently there is no agricultural insurance scheme pertaining to production of paddy has been practiced in Malaysia. The aim of introducing agricultural insurance is to secure development of the agriculture industry and protect farmers from the loss of negative impacts of natural catastrophes. Traditional agricultural insurance implemented in other countries depends heavily on the direct measurement of the quantity of loss or damage experienced by the farmers. Therefore, weather index-based insurance is another alternative to the traditional insurance, in which the insurer will reimburse the loss to the farmers based on a stipulated weather condition that is highly related to the crop yield. The application of weather index-based crop insurance is especially important for the paddy farmers in Malaysia with the prospect of crop failure, driving by the adverse weather condition. With this insurance, farmers will receive adequate cash aid in the event of natural catastrophe such as drought and flood. The findings of this study can be used as one of the crucial guides to the government to deliberate with insurers for developing an appropriate agricultural insurance scheme in Malaysia.

The paper proposes an implementation of a suitable weather index-based paddy insurance model for the five selected states in Malaysia. An optimal strike level for signal of paddy loss is identified. The analysis focuses on the calculation of the pure premium paid by the farmers after considering the government subsidy rate on the premium.

* Corresponding Author.
Email Address: yvonnewjw1@hotmail.com (Y. W. J. Wen)
https://doi.org/10.21833/ijaas.2019.06.008
Corresponding author's ORCID profile:
https://orcid.org/0000-0002-7179-9994

2. Traditional agricultural insurance products

2.1. Challenges arise from traditional indemnity-based agricultural insurance products

Generally, traditional indemnity-based agricultural insurance products measure the crop loss and pay insurance compensation on-site according to the actual loss of the policyholders. In some studies, the outcomes show that traditional agricultural insurance products also plagued with several challenges, although the products are proven to bring benefits to the farmers. They find that there is hidden information about the risk exposures between the policyholders and insurance company. The presence of asymmetric information between the counterparties give rise to moral hazard and adverse selection. These problems have affected the continued sustainability and health of these insurance products (He et al., 2019). This in turn impede the development of agricultural insurance market.

2.1.1. Moral hazard

Moral hazard occurs when the good husbandry practices are reduced after purchasing an agriculture insurance contract or the production practices on the part of the client are totally altered, which leads to incur higher loss claims. For instance, they will have incentive to take additional risks such as seeding in infertile areas, utilising less fertiliser or planting out of season (Iturrioz, 2009). In turn, the loss will not commensurate with the premiums collected that used to cover the expected indemnities and administrative costs of the insurer, which will give rise to the probability of the uninsurable market. The fact of being insured tempts the farmers to act irresponsibly to reduce loss, compared to the uninsured farmers.

2.1.2. Adverse selection

Adverse selection happens when technical expertise deficiencies make the insurance providers find it hard and costly to distinguish between low-risk and high-risk policyholders and hence fail to determine premiums corresponding with each type of risk exposure (Romero and Molina, 2015). As a result, it will negatively affect the profitability of insurers as the payment of indemnities is much greater than premiums collected (He et al., 2019). Romero and Molina further asserted that the consequences of adverse selection will hamper the emergence of insurance market (Romero and Molina, 2015).

2.2. Innovations to traditional agricultural insurance products

Due to the aforementioned challenges, the development of traditional agriculture insurance product is obstructed throughout the world. To tackle these problems, indemnity-based insurance product has been shifted to area yield index-based insurance and again to weather index-based insurance (Binswanger-Mkhize, 2012).

2.2.1. Area yield index-based insurance

According to Smith and Watts (2009), area yield index-based insurance tenders indemnity when the realised average yield of insured crops in a prespecified area is less than the guaranteed yield, which is irrespective of the farm-level yield. It is independent of the characteristics of the policyholders, and thus the policyholders alone are unable to control the probability of insurance payoff. Besides, Mahul and Stutley (2010) also claimed that the guaranteed yield is usually set as 50 to 90 percent of the expected yield. The prespecified area is normally at a country or district level so that collusion by any individual farmers can be prevented. Hence, this insurance product can minimise the chances of moral hazard and adverse selection. On the contrary, due to the dependence of historical data, the insurer may have problems in looking for the accurate area yield history data. Besides, indemnities will only be paid three to six months after the official results of area yields are published, which allow the occurrence of bad effects of the yield loss before the policyholders can get the indemnity. These drawbacks consequently affect the development of area yield insurance scheme.

2.2.2. Weather index-based insurance

Weather index insurance has same advantages with area yield insurance, but it provides timely indemnities based on weather index such as rainfalls, humidity or extreme temperatures (Iturrioz, 2009). Weather index insurance provides compensation based on the attainments of a specified weather parameter measured during a stipulated period of time at a predetermined weather station. The farmers will be protected against index realisations that can be either so low or so high that they might encounter crop losses. Therefore, weather index insurance can prevent the problems of adverse selection and moral hazard found in traditional agriculture insurance product as the physical phenomena are observable and thus cannot be controlled by either party (Iturrioz, 2009). Bokusheva and Breustedt (2012) in their experiment in Kazakhstan aimed to determine the potential reduction risk by index insurance using ex post measure, on the contrary, did not prove that weather index insurance is a reliable risk management tool. However, the author interestingly stated that this approach may not provide accurate predictions for gauging the effectiveness of an index-based insurance as it overestimates the risk reduction of insurance tools.

Although these insurance products significantly eliminate adverse selection and moral hazard, both these products expose the policyholders to basis risk (Nguyen, 2013). For the case of area yield index, the degree of basis risk is controlled by how extent are the yield outcomes positively associated with area-yield index. Basis risk will consistently increase in accordance with the expansion of geographic area. As for weather index, basis risk occurs when there are discrepancies in the actual risk encountered by farmers and the risk gauged by the insurance product due to the change in rainfall between planting area and the reference weather station. The researcher further commented that the difference in cover period and crop period will pose basis risk to the weather index insurance product due to the potential inconsistency between the real loss incurred to the farmers and contract payouts. The payouts paid in index insurance will imperfectly correlate with the actual loss of farmer, which make the index insurance product less attractive (Smith and Watts, 2009). In line with other study such as Binswanger-Mkhize (2012) and Carter et al. (2007), these scholars agreed that weather index has higher basis risk than area yield index insurance because weather index insurance covers less perils than area yield insurance.

However, most of the literature focuses largely on weather index insurance due to the availability of data on area yield index insurance, especially when historical country yield data is very important for the effectiveness of area yield index insurance (Smith and Watts, 2009). Therefore, compared to traditional agriculture insurance and area index yield insurance, weather index insurance is much more attractive in terms of the information and resources availability, in which this insurance scheme requires only historical weather data that is easier to acquire from official department.

Besides, all the studies in Malaysia suggested that adaptation and mitigation are the only strategies that can sustain the production of paddy in the long run in order to cope with the adverse climate change. None of these studies had attempted to postulate agricultural insurance in Malaysia as their solutions to remedy the problem. In this respect, it could say that the absence of implication of agricultural insurance in Malaysia hampers the development of paddy sector.

3. Research methodology

3.1. Sampling methodology

This study employs annual paddy yield data from five states in Malaysia, which are furnished by Paddy Statistics of Malaysia in 2014 that published annually by Department of Agriculture (DOA). These data contain the paddy yield of the following states in Malaysia from 2005 to 2014: Johor, Perlis, Selangor, Terengganu and Sabah. These five states are selected because they produce the highest quantity of paddy yield in their respective geographical regions in Malaysia. Johor, Perlis, Selangor and Terengganu represent the southern region, north-west region, central region and north-east region in Peninsular Malaysia respectively, while Sabah represents the region in East Malaysia.

The monthly weather data of each state is acquired from Malaysian Meteorological Department (MMD), which include cumulative rainfall and average daily temperature from 2005 to 2014. The origin of the weather data is from five weather stations situated in single study state (one in each state) which are Senai (Johor), Chuping (Perlis), Subang (Selangor), Kuala Terengganu (Terengganu), Kota Kinabalu (Sabah).

3.2. Methodology of modelling

The analytical methods primarily draw upon existing data and are mostly conducted using "R" software.

3.2.1. Removing trend in crop yield

Fitting a trend and examining the residuals are used in this study to remove the technology trend with the utilisation of historical crop yield data. This method is generally one of the yield detrend methods in the past studies such as Osborne and Wheeler (2013) and Lobell and Field (2007). Least squares regression techniques is generally applied for deterministic trends that move the yields up over time (Goodwin and Mahul, 2004). In this study, paddy yields are detrended by fitting linear regression. From these model, the most appropriate trend fitting to the data will be chosen. The residuals that derive from the model will generate a time series without any trend.

Eq. 1 shows how to detrend a temporal series of paddy yields:

$$Y = \hat{Y} + \varepsilon_t = X_t\beta + \varepsilon_t \quad (1)$$

where Y_t= Actual paddy yield of year t; $\hat{Y}_t$= Trend predicted-yield of year t; X_t= Some function of time; ε_t= Error term (deviations) of year t.

Assume that the paddy yields are normalised to 2014 level (the final year in yield data), the deviation of year t is added to the 2014 yield prediction, which can derive Eq. 2.

$$\hat{Y}_{t,2014} = \hat{Y}_{2014} + \varepsilon_t \quad (2)$$

where $\hat{Y}_{t,2014}$= Adjusted predicted paddy yield of year t based on 2014 yield level; $\hat{Y}_{2014}$= Trend-predicted yield of year 2014.

3.2.2. Determination of regression estimation techniques

Compared with studies by Chen (2011), which employed OLS regression only to detrend the paddy yield in Zhejiang, China as case study, three different approaches (OLS regression, Huber robust regression and bisquare robust regression) are subsequently performed in this study to isolate the technological impact from the crop yield data and estimate paddy yield. This can help to identify the most suitable trend model to conduct the following studies. Determination of accurate estimation techniques is important to avoid overestimation of the risk that a policyholder faces. Two forecasting errors such as Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE) are used to determine which models best in all of three linear regression.

3.2.3. Correlation analysis

Correlation analysis is used to check the relationship of different function. The first analysis is to determine the correlation between time trend and paddy yield in each of the selected zone. Secondly, it is conduced to check the correlation between paddy yield deviation and time in order to examine the adequacy of the regression model. The assumption of homoscedasticity of errors is not violated when the correlation of this result is shown to be zero. Thirdly, the detrended yield is regressed on the weather variables separately, which include rainfall and temperature to test the correlation between climate change and crop yield. Pearson coefficient R is an approach that has been widely employed to capture the effect of climate variables on agriculture yield (Poudel and Shaw, 2016; Lobell and Field, 2007). Therefore, this study also uses the same method to evaluate the relationship between the explanatory variables and response variables. Each of the weather index is tested using this method to determine the best fit index for paddy yield in the major paddy crop state in Malaysia. This step is critical in order to minimise product design basis risk as the chosen weather index should be able to explain a high variability in the yield of paddy in the selected states.

3.2.4. Insurance product design

The design of an effective weather index agriculture insurance depends mainly on the characterisation of the relationship between paddy yield and the proxies for the indemnity schedule. The subsequent step is to outline a well-planned paddy insurance contract for the selected states in Malaysia.

Regarding the paddy price, it is uniformly set at RM1200 per tonne across Peninsular Malaysia since 2016. This is based on the public announcement from Ministry of Agriculture and Agro-based Industry Malaysia in 2014. Therefore, in order to uniformalise the paddy price in all states, the paddy price in this study follows the latest official price set by the government.

Eq. 3 describes the calculation of pure premium and net premium. Pure premium is the expected value of the claim amounts to be paid by the insurer. It can be derived by the multiplication of the sum of the annual indemnity of the weather index-predicted paddy yield and its occurrence probability in the data sample period without including the risk premium.

$$\text{Pure premium} = \frac{1}{n}\sum_{i=1}^{n}\hat{I}_i \tag{3}$$

where n= number of years of paddy yield data sample; $\frac{1}{n}$= Probability of the occurrence of indemnification in the data history; $\hat{I}_i$= Indemnity amount of the weather index-predicted paddy yield from year i to n.

Eq. 4 shows the computation of net premium, which is the total amount of pure premium and the risk premium.

$$P(X) = E(X) + \lambda \cdot \sigma(X) \tag{4}$$

where $E(X)$ = Mean or expected value of claims amount, which refers to pure premium; $\lambda \cdot \sigma(X)$= Risk loading factor of the insurer, which refers to risk premium.

It is assumed to have no risk loading when the weather index data perfectly fit the paddy yield data in this study. In this case, the policyholders are required to pay pure premium only, given that the administration costs and profits of the insurance company are not included. However, in reality, risk premium should be considered because there might be misspecification of the weather index process and the uncertainty of parameter in the study. The risk of misspecification of weather index process can be determined by examining the weather index design, location of weather station and insurable paddy field and risk exposure period. Whereas the uncertainty of parameters can be adjusted through the standard deviation of the weather index variable. In this study, assume that the weather index processes are perfectly defined, the uncertainty of weather index variable is the only consideration of the calculation of risk premium.

As for the indemnity payment, it is only triggered when the weather index data falls below or above the strike level whichever correlates to the yield loss. Besides, the slope coefficient of the weather index variable is used as the tick size in the model in order to calculate the incremental change of indemnity for a change of weather index. The indemnity payment to the policyholder is given as Eq. 5:

$$I(X) = \gamma \cdot \max(K - X, 0) \tag{5}$$

where $I(X)$= Claim amount that will be paid to the policyholder within the contract year; γ= tick size, which monetises the weather index observations and quantifies the indemnity; K= Strike level of the selected weather index; X= Actual weather index value in the contract year.

3.2.5. Government premium subsidy for weather index based insurance

The governmental premium subsidy can be determined by multiplying the premium payment with the subsidy rate. Due to the absence of agriculture insurance scheme in Malaysia, the U.S. government subsidy rate will be followed by complying with the U.S. crop program as a benchmark which can be seen in Fig. 1.

Insurance Plan	---------------- Coverage Level (%) ------------------								
	CAT	50	55	60	65	70	75	80	85
Basic and Optional Units	100	67	64	64	59	59	55	48	38
Enterprise Units	n/a	80	80	80	80	80	77	68	53
Area Yield Plans	n/a	n/a	n/a	n/a	n/a	59	59	55	55
Area Revenue Plans	n/a	n/a	n/a	n/a	n/a	59	55	55	49
Whole Farm Units	n/a	80	80	80	80	80	80	71	56

Fig. 1: U.S. public subsidy rate (%) for crop insurance premiums, selected insurance plan, 2015

There are different levels of insurance coverage that can be chosen by the policyholder, which followed by certain government premium subsidy rate. The government premium subsidy gained by the insured can be indicated as Eq. 6:

$$\text{Government Premium Subsidy} = \text{Pure Premium} \times \text{Subsidy Rate} \quad (6)$$

4. Data analysis

4.1. Paddy yield and time trend

To address the assumption of the structural changes of paddy yields over time, the correlation between the paddy yield in each of the five selected states and time trend is presented in Table 1.

Table 1: Correlation between paddy yield and time trend

State	Correlation Coefficient
Perlis	0.86
Johor	0.86
Selangor	0.96
Terengganu	0.94
Sabah	-0.66

The results above show that the correlations between the paddy yield and the time trend are relatively good for each selected state. The correlation result of Sabah is not as high as other states, which might be due to the mountainous area in Sabah that limits the adoption of advanced production techniques. However, the moderately high correlation result indicates that the technological impacts should not be ignored in this region. This proves that the paddy yields in all the selected states have improved significantly in the past ten years (2005-2014) as the production techniques have gradually enhanced over time, especially in this developing and transition country. Therefore, the impact of technological developments on the paddy yield from time to time should be removed in order to capture the true trend of paddy yields. Fig. 2 reveals the time series plot of paddy yield in the selected states in Malaysia.

As presented in Fig. 2, there are some obvious outliers in each state, such that the paddy yield of Perlis and Johor in 2006; the paddy yield of Selangor in 2005 and 2008; and the paddy yield of Terengganu in 2013. The results show that there are sudden drops in the yield production in the corresponding years. However, these abrupt tumbles in the paddy yield can be explained. According to the reporters from various sources of news (Cheong et al., 2013), it is reported that each of these cases had experienced severe floods in above-mentioned years, which significantly caused large damages to the paddy fields and subsequently incurred great loss to the farmers. Since the reason of having these dramatic drops are clear, there is no reason to exclude these outliers from the models.

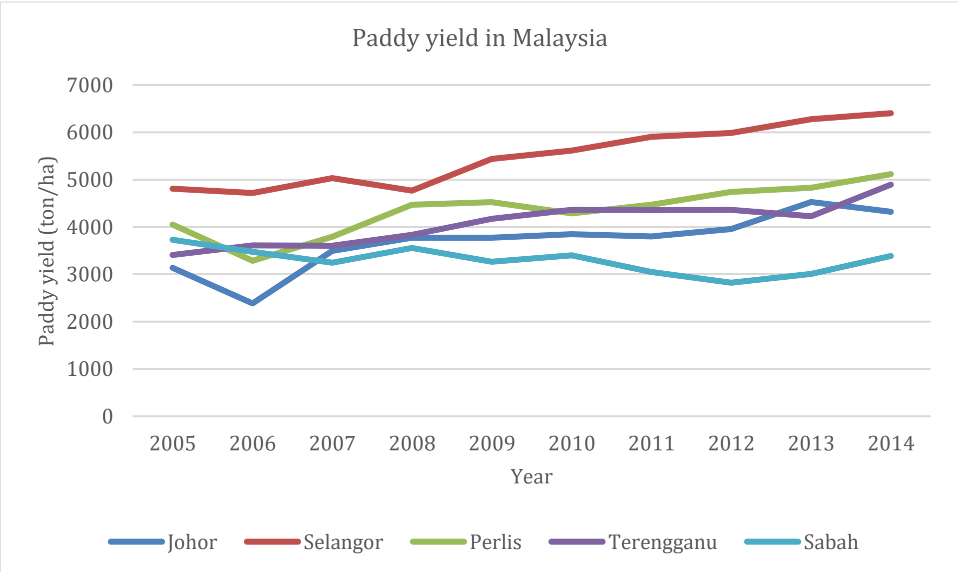

Fig. 2: Paddy yield in Malaysia from 2005 to 2014

4.2. Time series regression

Before conducting OLS regression and robust regressions, the first step is to check the assumptions of time series regression in order to provide an accurate and effective results. In doing so, there are four assumptions to be made on the model as described in Section 3.3.3. The next step is to compute linear regression by using OLS and robust estimations. The selection of the most suitable regression is based on the results of forecasting errors – Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE).

4.3. Ordinary least square regression

Since all the assumptions of OLS regression are hold, the regression model can be conducted in this section. OLS approach is first employed to detrend the paddy yield data. The linear regression model involving time trend and paddy yield variables can be derived as Eq. 7.

$$Y_t = \beta_0 + \beta_1 X_t \quad (7)$$

where Y_t= Paddy yield variable of year t; β_0= Regression constant; β_1= Regression coefficient; X_t= Time Trend.

4.4. Robust regression

In this section, the linear regression model is repeatedly conducted again by using robust estimation techniques. The assumptions of using this model are almost the same, but it is less sensitive to the presence of outlying cases. The regressions for this section are performed using the two well-known M-estimators (Huber M-estimator and bisquare estimator). The t-test is applied to test the significance of explanatory variable on the response variable. Therefore, the time trend variable can be tested through hypothesis tests using t-statistic.

The two estimators are compared based on the results of forecasting errors against the respective predicted values to determine the most appropriate model to detrend the paddy yield time series. Two forecasting errors – Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE) are used to compare the performance of OLS and robust regressions. The model which yields the lowest errors is chosen for detrending the paddy yield data.

4.5. Adjusted paddy yield

Using the predicted paddy yield of 2014 – the last year in the yield data range, the adjusted paddy yields from 2005 to 2014 for each research area are derived. The reason of using the yield of 2014 as basis is because of that the paddy yield level in this year is considered to be the closest to the subsequent year's yield. In accordance with the assumption of time trend, the paddy yield is expected to increase over time. Therefore, the paddy yield is adjusted by using the Eq. 2, as depicted in Section 3.2.1. However, in real case, it is suggested to collect the data until the current year so that the paddy yield can be adjusted to the present year.

Firstly, the predicted yield and residuals of each year are derived based on the selected linear regression model in Eq. 1. Subsequently, the paddy yields of each year are normalized to the year of 2014 by adding the residuals of each year in Eq. 2.

4.6. Selection of weather index design

The adjusted paddy yields that have been detrended by time trend are regressed on the weather indexes to examine the correlation of paddy production behavior with the weather factors.

The most significance weather indexes are chosen. It shows that the adjusted paddy yield in Perlis is most correlated with rainfall, which indicates that the lower the rainfall amount, the higher is the paddy yield production. In Johor, the adjusted paddy yield is most likely to be affected by temperature. This implies that a warmer weather can help to increase paddy yield in that area. On the other hand, in Terengganu, the adjusted paddy yield appears to have negative correlation with the temperature. It shows that a lower temperature is more suitable for the growth of paddy. Besides, it is observed that the amount of rainfall mostly attributes to the paddy yield production in Selangor. This high negative correlation with rainfall index may due to the frequent of heavy storms that results in disastrous floods across the state. In Sabah, the rainfall amount has the strongest positive association with the paddy yield. It indicates that a high frequency of rainfall is good for the production of paddy. According to these results, the weather index selected for each state is shown in Table 2.

Table 2: List of weather index selected for each state

State	Weather Index
Perlis	Rainfall
Johor	Temperature
Selangor	Rainfall
Terengganu	Temperature
Sabah	Rainfall

Based on the chosen weather index for each state, a relationship between the weather index and paddy yield is performed in this section in order to draft a weather-based index insurance contract. OLS regression and robust regression are again conducted subsequently to determine the most suitable prediction equation based on the computation of Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE).

The relationship between the chosen weather index and the paddy yield in each state is tested by performing OLS regression and robust regressions (Huber-M estimator and bisquare estimator). The linear regression model of the adjusted paddy yield in each state with its respective selected weather index is similar as in Eq. 7 where X_t is the weather index variable of year t. The hypothesis testing is written as below:

H_0: $\beta_j = 0$
H_a: $\beta_j \neq 0$ (j=1, 2, 3, 4, 5)

4.7. Design of weather index-based insurance contract

Section here presents the designing of insurance product based on the linear model under different approaches determined in section above.

4.7.1. Calculation of indemnity

The strike level (K) calculation, it is presumed at the average level of rainfall amount in this study. Based on the linear regression equations, the calculations for tick size and strike level in Selangor and Sabah are shown as below. Table 3 and Table 4 summarise the strike levels and indemnity schedules.

Table 3 reveals the strike levels (K) for insurance contracts in Selangor and Sabah. For the case in Selangor, the indemnity payment is triggered when the observed rainfall amount is more than 2906.89mm, which indicates that the paddy yield loss has occurred, as compared to the average yield of 6416.41ton/ha. In Sabah, the policyholder will be paid when the observed rainfall amount is less than 3124.38mm, as the paddy yield loss has occurred when compared to the average yield of 2964.21ton/ha. The indemnity amount functions are shown in Table 4. However, the strike level can be fixed at different values depend on the coverage demands of farmers. Assuming that the policyholders are risk takers, they will buy the insurance product that provides indemnity only when there is severe yield loss.

Table 3: Strike level (K)

State	Strike Level (K)	Average Paddy yield (ton/ha)
Selangor	Rainfall > 2906.89mm	6416.41
Sabah	Rainfall < 3124.38mm	2964.21

Table 4: Indemnity amount

State	Indemnity (RM/ha)
Selangor	Indemnity = 420 * max (X – 2906.89, 0)
Sabah	Indemnity = 372 * max (3124.38 – X, 0)

In such scheme, the premium will certainly be lower, but the policyholders need to bear the greater risks of having yield loss, as compared to the average yield level as set in this study. Therefore, the underwriters need to consider the risk demand of their policyholders before setting the strike level.

4.7.2. Pure premium

The selected prediction models in Selangor and Sabah are used to compute the predicted paddy yield using rainfall index variable. An example of pure premium calculation is shown by using case in Selangor in Table 5.

Table 5: Selangor annual paddy yield loss calculation results

Year	Rainfall (mm)	Adjusted Paddy Yield (ton/ha)	Predicted Paddy Yield (ton/ha)	Annual Yield Loss (ton/ha)
2005	2292.40	6643.95	6631.92	0.00
2006	3455.00	6348.18	6224.17	192.23
2007	2871.80	6460.41	6428.71	0.00
2008	3278.60	5989.63	6286.04	130.36
2009	2857.40	6457.86	6433.76	0.00
2010	3105.00	6427.09	6346.92	69.48
2011	2668.40	6519.32	6500.05	0.00
2012	3100.50	6396.55	6348.5	67.90
2013	2872.00	6483.77	6428.64	0.00
2014	2567.80	6437.29	6535.33	0.00
Average	2906.89	6416.41	6416.40	46.00

Table 6 shows the average annual paddy yield loss and pure premium of Selangor and Sabah. Yield loss does not arise when the observed weather index is less than the presumed strike level (2906.89mm). However, yield loss incurs when the observed rainfall index exceeds the strike level. As an exemplification of the yield loss calculation in 2005, the rainfall index is lower than the strike level, thus it does not trigger indemnity payment to the policyholder. However, in 2006, the yield loss occurs because the rainfall index is beyond the strike level. In this case, the yield loss is derived by subtracting the predicted paddy yield in 2016 from the average predicted paddy yield. The pure premium can be derived now by multiplying the expected annual paddy yield loss as shown in Table 5 with the presumed paddy price (RM1200).

Table 6: Pure premium for Selangor and Sabah

	Selangor	Sabah
Expected Annual Paddy Yield Loss (ton/ha)	46.00	47.46
Pure Premium (RM/ha)	55200.00	56952.00

Assuming that risk loading of the insurance company is not considered, the weather index-based insurance contracts of Selangor and Sabah are detailed in Table 7.

4.7.3. Risk premium

The average annual paddy yield loss is derived at the predetermined strike level shown above, when the regressor parameter varies within ±σ. The results of the variation are shown in Table 8.

Table 7: Design of weather index-based insurance contract for Selangor and Sabah

	Selangor	Sabah
Weather Index	Rainfall	Rainfall
Strike Level (K)	2906.89mm	3124.38mm
Tick Size (γ)	420.84RM/Index Point	369.60RM/Index Point
Contract Time	1 Year	1 Year
Indemnity	420 * max (X – 2906.89, 0)	372 * max (3124.38 – X, 0)
Pure Premium (RM/ha)	RM 55200.00	RM 56952.00

The results show that the average annual paddy yield loss in Selangor and Sabah have a variation of around ± 34% and ± 26% respectively when the rainfall parameter differs within ± σ. These percentage change in the loss of paddy yield implies the change in the expected annual paddy yield loss. A high change in the yield loss will result in a higher pure premium amount. For both state, the variation of expected yield loss is considerably acceptable, therefore the change of pure premium might not be so high. However, the risk loading of loss from these uncertainties should be carefully studied by the insurance companies. They must decide whether to share with the insured or bear the risk by themselves.

4.7.4. Government premium subsidy

By using the U.S. crop insurance program as a baseline, this study assumes that five levels of insurance coverage are provided for the policyholders to select, which are 65%, 70%, 75%, 80% and 85%.

Table 8: Variation of annual paddy yield loss (Risk-added and Risk-reduced)

State	Variation of Yield Loss	Normal	Risk-added (+σ)	Risk-reduced (+σ)
Selangor	Average Annual Yield Loss (ton/ha)	46.00	30.17	61.64
	% Change in Average Annual Yield Loss		-34.42%	34.01%
Sabah	Average Annual Yield Loss (ton/ha)	47.46	60.10	35.44
	% Change in Average Annual Yield Loss		26.62%	-25.33%

As presented in Table 9 and Table 10, the pure premium that the policyholders actually pay is reduced by large amount after incorporating the government premium subsidy rate. The lower the level of insurance coverage chosen by the insured, the lower is the premium amount needed to be paid to the insurance company. The potential policyholders can choose to pay lower premiums according to the selection of insurance coverage level, but they also receive a lower indemnity amount. Therefore, it mostly depends on the risk appetite of the policyholders.

Table 9: Government premium subsidy and premium paid by policyholders for Selangor

		Selangor (Pure Premium = RM55200	
Level of Insurance Coverage	Government Premium Subsidy Rate	Government Premium Subsidy (RM)	Pure Premium paid by the Policyholders (RM)
65%	59%	32568.00	22632.00
70%	59%	32568.00	22632.00
75%	55%	30360.00	24840.00
80%	48%	26496.00	28704.00
85%	38%	20976.00	34224.00

Table 10: Government premium subsidy and premium paid by policyholders for Sabah

		Sabah (Pure Premium = RM55200	
Level of Insurance Coverage	Government Premium Subsidy Rate	Government Premium Subsidy (RM)	Pure Premium paid by the Policyholders (RM)
65%	59%	33601.68	23350.32
70%	59%	33601.68	23350.32
75%	55%	31323.60	25628.40
80%	48%	27336.96	29615.04
85%	38%	21641.76	35310.24

5. Conclusion

A simple weather index-based paddy insurance contract is completed for each state – Perlis, Johor, Selangor, Terengganu and Sabah. After detrending the paddy yield data, the most correlated weather index was determined through the correlation test with the paddy yield. OLS regression and robust regression (Huber-M and bisquare estimators) were conducted to test the relationship between the paddy yield and the chosen weather index. The final step was to design the insurance contract by determining the strike level, tick size and pure premium. From here, the indemnity calculation was derived.

From the study conducted, it is shown that there is no suitable fitting model in Perlis, Johor and Terengganu. The non-significant parameters indicate this insurance contract is not suitable to be implemented in these three areas as no weather index is appropriate to design the policy. In fact, this problem should be investigated in further by including a larger sample size and other index-based insurance, such as area-index and yield-index insurance contract.

In Selangor, the rainfall index is chosen as the most correlated weather index with the paddy yield. Presuming that all the potential insured are risk averse, they will receive an indemnity amount of RM 420 * Max (Observed rainfall amount – 2906.89mm, 0)/ha when the rainfall amount exceeds 2906.89mm. In order to get this indemnification, the policyholders are required to pay the pure premium of RM 55200.

As for insurance contract in Sabah, amount of rainfall is also selected as the weather index. The strike level is determined to be 3124.38mm, with the similar assumptions that the policyholders are risk averse. They will receive an indemnity of RM 372 * Max (3124.38mm – X, 0)/ha when the rainfall amount is less than the strike level. Both insurance model in Selangor and Sabah is only applicable in year 2015 as the final year in the data range of this study is 2014.

Compliance with ethical standards

Conflict of interest

The authors declare that they have no conflict of interest.

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