Weather Index Based Microinsurance for Agriculture Industry

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Abstract. Agriculture is particularly susceptible to weather fluctuations. Climate change and agriculture productivity are inextricably linked. Thus, agriculture insurance should be introduced in Malaysia to manage losses and help small farmers to be aid from financial risk that is linked to the impact of the weather conditions on the crop yield. This study presents an investigation on the implementation of weather index based crop insurance contract for the states with the high correlation between the crop production and weather indices. The main aim of the study is to identify the appropriateness of the index insurance to selected crops in different regions in Malaysia. The Rainfall Anomaly Index and Standardized Precipitation Index are chosen in this study. Crop data is detrended to remove presence of time trend before determining the correlation between weather indices. The study continued with the computation of the trigger and exit thresholds for weather indices that corresponds to the crop loss using model-based clustering which will be used to calculate the expected annual loss and pure premium for each crop in different locations. The results showed that only several crops in certain locations are affected by weather. This research also includes farmers’ affordability to pay for premium.

Keywords: Rainfall Anomaly Index, Standardized Precipitation Index, Weather Index Based Microinsurance.

1. Introduction
Malaysia’s agriculture industry has remained an important sector to the economic growth as it has contributed to 7.1% (RM101.5 billion) to the Gross Domestic Product (GDP) in 2019 according to the Department of Statistics Malaysia (2020).

The agriculture landscape is dominated by smallholders and small farmers [1]. Smallholders are small operators that farm industrial crops such as rubber, palm oil and cocoa, whereas small farmers are small operators that farm food crops such as vegetables, fruits and paddy.

Most crops in agriculture are heavily influenced by weather to obtain the optimum production. However, future expectation of climate in Malaysia has shown a concerning trend where the temperature is predicted to signify an increasing pattern, whereas rainfall is expected to have an opposite direction over the years [2]. The projections of climate change showed mild climate related disasters are likely to become frequent in the long term. These disasters refer to the occurrence of floods, droughts and...
landsides due to excessive rainfall and strong winds. These weather conditions will affect the performance of crops which will consequently decrease the agriculture productivity and crop yield.

Nevertheless, weather index based insurance as a financial product has been introduced as an alternative to allow small farmers manage losses from weather risks. The weather index based insurance has in fact already been implemented in a few developing and rural countries [3]. Weather index based insurance poses potential in reducing the risk of impact of crop loss in the agriculture industry and should be taken into consideration for implementation.

The paper proposes the implementation of a suitable weather index based microinsurance model in Malaysia. The states are divided according to their regions: East Malaysia, East Coast, Northern, Central and Southern. Several objectives to be attained such as to determine the relationship between crop production and weather indices Standardized Precipitation Index (SPI) and Rainfall Anamoly Index (RAI). Next, determine index threshold trigger and exit levels for weather index that is significant to crop production. The last analysis focus is on calculating the premium of weather index based insurance for the selected crop.

2. Literature Review
There are various weather index based insurances for agriculture provided in other countries such as Africa, China, Mexico, Ethiopia, India, Ukraine, and the United States with different plans using different valuation methods. Some has shown a positive impact to both farmers and insurer. Some weather factors that are included are rainfall, precipitation, temperature, and air quality index. Insured will receive payouts when the real weather index has reached a certain level as according to the insurance plan.

The advantages of weather index based insurance are the reduction in moral hazard and adverse selection [4]. Weather index based insurance also has better transparency and lower transaction costs for the [5]. The payouts will be given based on the weather index instead of the actual loss, therefore this will help the insurance companies save the money on checking the actual loss. However, index insurance is exposed to basis risk which increases when the weather measuring station is further away from the insured place. Since the insured will have to pay premiums based on the expected loss, the expected loss are calculated based on data from weather measuring stations does not reflect the real weather condition at the insured’s area [6]. Apart from this problem, this insurance has been proven to be a functional tool that protects smallholder farmers from weather risks [7]. In addition, weather index based insurance can also be used for development goals where it could increase production [8].

2.1. Detrending Crop Data
Crop production data is detrended to counter the problems of realized huge changes in recent years due to improvements in techniques used [9]. Since one of the major impacts of increasing crop production is improvement in planting technique, the main factor to remove trend in the crop production is time trend [10]. The most common approach to detrend data with deterministic increasing trends is by using Least Square Error regression techniques [9]. Correlation between crop production and time is analysed to determine the presence of time trend, the increasing crop production over time [11]. A study conducted by [10] tests for correlation between rice yield and time trend to test for presence of time trend. Ordinary Least Square (OLS) regression is also used to detrend paddy yield data. Meanwhile, a study conducted by [11], used OLS regression, Huber robust regression and bisquare robust regression to detrend data. In the study of [12] and [13], the yield series were detrended to remove the effect of time on crop yields by applying first order deterministic model (linear regression) and normalizing the yield series thereafter.

2.2. Relationship between Crop Yields and Weather Factors
Various studies have been done to identify the correlation between commodities and weather factors such as temperature, rainfall, precipitation, Ultraviolet index and air quality. A study suggested applying two different weather variables specifically temperature and rainfall index using the thermal-hydraulic index [14]. This study used multivariate analysis of variance to explain the effect of few weather
variables on the crop yield. Moreover, a research done by [15] used partial least square regression to
distinguish weather factors that affect crop yield in different areas and seasons. The study was conducted
in 92 French districts.

Furthermore, a study by [16] built a weather index model that predicted forest fires risk in Lebanon
and Mediterranean. This study determined the most affecting weather variables on loss which in this
case is a fire ignition by using Spearman, Pearson and Kendall’s Tau correlation analysis. The degree
between two variables that are linearly related is measured using Pearson’s correlation coefficient.
Meanwhile, Spearman and Kendall measure the association degree and strength between two variables.
Spearman and Kendall’s Tau approaches are a good measurement of relationship between ordinal
variables. Pearson’s correlation coefficient has been used in many studies in determining the impact of
weather of agricultural production [12].

2.3. Index Calculation
Each weather indices have different input of weather variables such as temperature, rainfall and
precipitation. Each of these weather indices is a good indicator for different types of weather events.

World Meteorological Organization (WMO) recommended that Standardized Precipitation Index
(SPI) is the most appropriate weather index for drought and climate risk management. SPI is much
simpler to calculate than more complex drought indices like the Palmer Drought Severity Index (PDSI),
because the SPI only requires precipitation data, whereas the PDSI requires multiple variables one of
which is the soil water available capacity, which must be locally calibrated otherwise the results would
not be spatially comparable [17]. The SPI is consistent over time and space, and it is unaffected by
changes in geography or topography. It also avoids the drawbacks associated with the PDSI index, as it
just requires the precipitation variable, which is available with considerably finer spatial and temporal
coverage over the globe's land areas [17].

Reference [18] developed the PDSI, which is widely used in drought evaluation studies, to measure
the cumulative departure in atmospheric moisture supply and demand. PDSI computation begins with
determine the monthly departure of moisture from normal weather index by calculating the gaps between
actual precipitation and precipitation that is climatically appropriate for the current conditions. A study
from [19] that did research in China, they discovered that PDSI describe drought severity more precisely
than a percentage of precipitation anomaly. PDSI requires multiple variables that are not available with
adequate spatial and temporal coverages over the globe, making it difficult to be compared spatially and
temporally ([20]; [21]). The PDSI is also based on some empirical relations derived from specific
locations, limiting its universality and applicability [22] and having it computed at a fixed 44 timescales
makes it an unsuitable index for monitoring different types of drought [20].

Rainfall anomaly index (RAI) is used as a single hydro-climatic index for estimating climatic change
wetness and dryness conditions. RAI has regarded as a remarkable procedural simplicity index because
it only requires precipitation data [23]. According to [24], RAI offers a higher degree of transparency
and tractability and demands a lower degree of sophistication than the SPI, concerning the evaluation
criteria for drought indices proposed by [25]. It is also computationally less demanding than SPI but
with comparable performance as reported by the aforementioned studies. Based on [26], RAI have
performed relatively equally with Bhalme and Mooley drought index (BMDI) and the Palmer drought
index (PDI) in detecting meteorological drought periods. It is also mentioned that precipitation used in
RAI is the most important climatic element necessary as an input into meteorological drought study.
Finally, RAI have less intricate computational steps or high-level data requirements compared to other
weather indices.

2.4. Threshold Calculation
There are two threshold levels that will be calculated, known as trigger and exit levels. Trigger level is
where crop is expected to have loss where payout is given. Exit level is the weather index when it reaches
maximum indemnity payment. Clustering the observations to differentiate the observations into groups
with different characteristics. Data points are grouped into two distinct clusters; low weather index with
low crop yield, and high crop yield with high weather index ([27], [28]). A study conducted by [28],
compare the trigger threshold level obtained by cluster analysis and logistic regression models resulted in lower trigger threshold than the trigger level obtained from cluster analysis. This will be resulted in lower coverage and premium. Cluster analysis creates groups with maximized similarity between members of cluster. Threshold level that are using cluster analysis is a better estimation compared to the ways of averaging the weather index since the cluster is grouped based on low crop yield.

2.5. Premium Calculation
One of the simplest approaches to price index insurance is the burn analysis method that uses historical data to model future trends. Previous study from [29] and [30] used burn analysis method to price insurance contract. This approach involves valuing the insurance policy based on past data and used the mean as the approximate payout value [31]. However, this approach has a few limitations such as the future events are only based on the historical data and probabilities of future event might be disrupted by few major events [4]. Based on [32], the assumption that history will replicate itself in the future is a major flaw in burn analysis method, which indicated that current temperature trends or extreme fluctuations that could take place in the future will not be able to be predicted by the model. In addition, the burn analysis method has a large number of errors due to events that were not modelled as potential future events due to its absence in the past [33].

Next, index modelling is also used in pricing of weather index based insurance. This approach fits the claim data into a distribution and the mean is considered as the expected value of claims [34]. Index modelling turns the weather index empirical distribution to a parametric distribution. Based on research conducted by [5], the results from index modelling are more accurate compared to the burn analysis approach. However, both burn analysis and index modelling underestimates the premiums [34]. In addition, the index modelling has been widely used to price index based insurance. For instance, [12] used index modelling in pricing rainfall index insurance in Nepal. Reference [35] adapted the model to price weather index insurance for wheat production in Tartu. [28], [27] applied the model to design the index insurance in Indonesia and Ghana, respectively.

3. Methodology

3.1. Sampling Methodology
This study uses yearly crop yield data of Pahang and Kelantan representing East Coast region, Perak and Kedah representing Northern region, Sabah and Sarawak representing East Malaysia, Johor representing Southern region and Selangor representing Central region from 2000 to 2020 provided by Department of Agriculture (DOA). The crop types that are included in this research are bananas, watermelons, pineapples, durians, sweet potatoes, cassava, sweet corn, brassica and tomatoes. The data chosen for the research are based on a state in Malaysia with the highest production of crop selected from East Malaysia, Central, East Coast, Northern and Southern region. The state selected represents the region with different geographical conditions in Malaysia. Simply, the districts involved are Sabak Bernam, Kinta, Cameron Highland, Tumpat, Kuala Langat, Johor Bahru, Kluang, Samarahan, Kuching, Tuaran, Kota Bharu, Sepang, Batu Pahat, and Bandar Baharu.

The daily weather data from each state are collected from Malaysia Meteorological Department or known as MET Malaysia, which include temperature, precipitation, rainfall evaporation and solar radiation from 1st January 1991 to 1st January 2021. The weather data is derived from 26 weather stations in each state based on the highly produce crop yield in those districts.

3.2. Method of Modelling
The analytical methods primarily draw upon existing data and are mostly conducted using “R” software.

3.2.1. Detrending Crop Data. There are many factors that affect the amount of crop production. Detrending crop yield serves the purpose of removing non-weather factors throughout the observation period on crop yield data [10], [36]. The factors include technological advancement, government policies and topography factor. Crop yield data will be detrended by fitting data into Ordinary Least
Square (OLS) regression, robust regression [11]. A study conducted in China [10] used OLS regression to detrend their crop yield data. This study used OLS regression and quadratic regression to remove time trend on crop yield data. Presence of time trend is detected in crop that has strong Pearson’s correlation coefficient between crop production and time. Determination of accurate estimation by observing the p-value is used to identify the most suitable trend model and avoid overestimation of the risk that a policyholder face [11].

Formula for Ordinary Least Square (OLS) or linear regression is as follows:

$$y_t = \hat{y}_t + \varepsilon_t$$  \hspace{1cm} (1)

$$y_t = \beta_0 + \beta_1 x_t + \varepsilon_t$$  \hspace{1cm} (2)

Formula for quadratic regression model is as follows:

$$y_t = \hat{y}_t + \varepsilon_t$$  \hspace{1cm} (3)

$$y_t = \beta_0 + \beta_1 x_t + \beta_2 x_t^2 + \varepsilon_t$$  \hspace{1cm} (4)

$y_t$ = Actual crop yield at time $t$

$\hat{y}_t$ = Trend-predicted crop yield at time $t$

$x_t$ = Year of crop production

$\beta_0$ = Trend-predicted crop yield at start of crop production

$\beta_1$ = Coefficient for variable year $x_t$

$\beta_2$ = Coefficient for variable year $x_t^2$

$\varepsilon_t$ = Difference between the actual and trend-predicted crop production

The detrended crop production value is obtained by this formula:

$$d_t = y_t - \hat{y}_t$$  \hspace{1cm} (5)

$y_t$ = Actual crop yield at time $t$

$\hat{y}_t$ = Trend-predicted crop yield at time $t$

$d_t$ = Detrended crop production

3.2.2. Weather Index Calculation. SPI is calculated by estimating the probability density of rainfall over a given time period, specifically 12 months period in this research. Meanwhile, the Rainfall Anomaly Index (RAI) categorizes the severity of rainfall anomalies based on all previous data available.

| RAI     | RAI Category        |
|---------|---------------------|
| ≥ 4.00  | Extremely rainy     |
| 3.00 – 3.99 | Highly rainy    |
| 2.00 – 2.99 | Moderately rainy  |
| 0.50 – 1.99 | Low rainfall      |
| −0.49 – 0.49 | Normal          |
| −1.99 – −0.50 | Slight reduction in rainfall |
| −2.99 – −2.00 | Moderate reduction in rainfall |
| −3.99 – −3.00 | Large reduction in rainfall |
| ≤ −4.00 | Extreme reduction in rainfall |

| SPI   | SPI Category          |
|-------|-----------------------|
| ≥ 2.00 | Extremely wet         |
| 1.50 – 1.99 | Severely wet |
| 1.00 – 1.49 | Moderately wet |
| 0 – 0.99 | Mildly wet            |
| −0.99 – 0 | Mildly drought        |
| −1.49 – −1.00 | Moderately drought |
| −1.99 – −1.50 | Severely drought |
| ≤ −2.00 | Extremely drought     |
3.2.3. **Relationship between Crop Yields and Weather Indices.** To evaluate the relationship between weather indices and crop yield, Pearson correlation is calculated for both weather indices, RAI and SPI. The calculation of the Pearson correlation coefficient is to detect the impact of weather on crop production has been used in many studies [12], [14]. Weather index with the significant relationship with crop yield will be selected for further process.

3.2.4. **Index Trigger and Exit Thresholds Determination.** To determine the trigger and exit thresholds, crop data and weather data are clustered into groups using model-based clustering. Model-based clustering considers data to come from a specified number of clusters as opposed to k-means clustering [37]. These groups have different characteristics such as low crop production in dry weather condition and low crop production in wet weather condition. For when the correlation is positive, the thresholds are determined from the cluster of low crop yield in dry weather condition. On the other hand, for negative correlation, the thresholds are determined from the cluster of low crop yield in wet weather condition.

The trigger threshold reflects the mean value of weather index in the specified cluster. Meanwhile, the exit threshold for positive and negative correlation is determined by the value of minimum and maximum weather index in specified cluster respectively.

3.2.5. **Premium Calculation.** The insurance contract is one year renewal. In this study, the policyholders are required to pay pure premium only, given that the administration costs and profits of the insurance company are not included. In order to calculate the premium, weather indices are fitted into a normal distribution and the parameters are estimated. Then, the expected loss is then calculated before premium will be calculated.

The payout formula for extremely dry condition is as follows:

\[
Payout = \begin{cases} 
IA & \text{if } R_A \leq R_E \\
IA \left( \frac{R_T - R_A}{R_T - R_E} \right) & \text{if } R_E < R_A \leq R_T \\
0 & \text{if } R_A \geq R_T 
\end{cases}
\]  
(6)

The payout formula for extremely wet condition is as follows:

\[
Payout = \begin{cases} 
0 & \text{if } R_A \leq R_T \\
IA \left( \frac{R_A - R_T}{R_E - R_T} \right) & \text{if } R_T < R_A \leq R_E \\
IA & \text{if } R_A > R_E 
\end{cases}
\]  
(7)

IA = Insured amount (RM1)
R_A = The actual weather index
R_T = Trigger threshold, a weather index threshold where payout starts
R_E = Exit threshold, where the maximum payout is the insured amount (IA)

The expected annual loss formula for dry condition is as follows:

\[
EAL = IA \int_{-\infty}^{R_E} f(R_A) \, dR_A + \int_{R_E}^{R_T} IA \left( \frac{R_E - R_A}{R_T - R_E} \right) f(R_A) \, dR_A
\]  
(8)

The expected annual loss formula for wet condition is as follows:

\[
EAL = \int_{R_T}^{R_E} IA \left( \frac{R_A - R_T}{R_E - R_T} \right) f(R_A) \, dR_A + IA \int_{R_E}^{\infty} f(R_E) \, dR_E
\]  
(9)

IA = Insured amount (RM1)
EAL = Expected annual loss of crop production
f(R_A) = Distribution function of weather index
\( R_A = \) The actual weather index  
\( R_T = \) Trigger threshold, a weather index threshold where payout starts  
\( R_E = \) Exit threshold where the maximum payout equal to insured amount (IA) is paid.

Computation of Premium is as follows:

\[
P_{\text{pure premium}} = e^{-r(t)} \mathbb{E}[\text{Annual Loss}] 
\]

(10)

\( r = \) The discounting factor which corresponds to the risk-free interest rate for \( t \) year contract (0.065)  
\( t = \) Number year of contract (1 year)

Farmers’ affordability to pay the premium calculated from (3.21) will then be tested. According to Household Income and Basic Amenities Survey 2019 report, the mean annual income for agriculture industry is RM22,380.00. Then, the annual expenses data for each district is then obtained from Household Expenditure Survey 2019 report.

The excess of income over expenses is then calculated for each crop and district as follows:

\[
\text{Excess of income over expenses} = RM \ 22380 \ - \ \text{Mean annual expenses} \quad \text{(11)}
\]

The premium that farmers can pay will be calculated as:

\[
P_{\text{premium payment}} = 1\% \times \text{Excess of Income over Expenses} \quad \text{(12)}
\]

The maximum insured amount can be covered is then calculated as follows:

\[
\text{Maximum insured amount} = \frac{P_{\text{premium payment}}}{P_{\text{pure premium}}} \times RM1 \quad \text{(13)}
\]

4. Results and Analysis

4.1. Detrending Data

The normality of crop data is tested using Shapiro-Wilk test. Shapiro-Wilk test indicator values as shown in Table 3 are greater than 0.05 which shows that the data are well-distributed.

Table 3. Shapiro-Wilk Test on Crop Data.

| Crop Type | District | Region   | W       | p-value  |
|-----------|----------|----------|---------|----------|
| Banana    | Sabak Bernam | Central | 0.91352 | 0.1533   |
| Brassica  | Kinta    | Northern | 0.86539 | 0.1097   |
| Brassica  | Cameron Highland | East Coast | 0.87331 | 0.1334   |
| Cassava   | Tumpat   | East Coast | 0.97373 | 0.8797   |
| Cassava   | Kuala Langat | Northern | 0.85435 | 0.1706   |
| Cassava   | Johor Bahru | Southern | 0.93347 | 0.1801   |
| Pineapple | Kluang   | Southern | 0.91606 | 0.0957   |
| Pineapple | Samarahan | East Malaysia | 0.96133 | 0.7499   |
| Sweet Corn | Kinta | Northern | 0.89480 | 0.1596   |
| Sweet Corn | Kota Bharu | East Coast | 0.91961 | 0.0974   |
| Sweet Corn | Tuaran | East Malaysia | 0.87694 | 0.1203   |
| Sweet Potato | Kinta | Northern | 0.87647 | 0.1188   |
| Sweet Potato | Sepang | Central | 0.91682 | 0.0989   |
| Tomato    | Cameron Highland | East Coast | 0.96370 | 0.8362   |
| Tomato    | Batu Pahat | Southern | 0.94250 | 0.6358   |
| Watermelon | Bandar Baharu | Northern | 0.92320 | 0.3844   |
| Watermelon | Kluang | Southern | 0.93833 | 0.2460   |
| Watermelon | Kuching | East Malaysia | 0.94263 | 0.5827   |
Crop with increasing crop production trend shows presence of time trend which is detected by having strong correlation value with time as shown in Table 4.

**Table 4.** Correlation between Crop Production and Time Trend.

| Crop type   | District       | Correlation between Crop Production and Time |
|-------------|----------------|---------------------------------------------|
| Brassica    | Kinta          | 0.8741149                                   |
| Pineapple   | Kluang         | 0.6764216                                   |
| Sweet Corn  | Tuaran         | 0.9507105                                   |
|              | Kinta          | 0.9440577                                   |
|              | Kota Bharu    | 0.6695797                                   |
| Sweet Potato| Kinta          | 0.9298185                                   |
|              | Sepang         | 0.5236215                                   |
| Watermelon  | Bandar Baharu  | 0.6394950                                   |

The crop data that are detrended are as follows:

**Figure 1.** The actual and detrended brassica production in Kinta, Perak.

**Figure 2.** The actual and detrended sweet potato production in Sepang, Selangor.

**Figure 3.** The actual and detrended sweet corn production in Kinta, Perak.

**Figure 4.** The actual and detrended sweet corn production in Kota Bharu, Kelantan.

**Figure 5.** The actual and detrended sweet potato production in Kinta, Perak.

**Figure 6.** The actual pineapple production and detrended pineapple production in Kluang, Johor.
After computation of the correlation coefficient to determine the relationship between crop yield and weather indices, there are some crop types that have weak correlations with the weather indices and otherwise. In this study, absolute correlation coefficient between two weather indices that ranges from 0.25 and above are significant and chosen. Therefore, relationship between weather index and crop production that are significant is indicated when the absolute correlation coefficient value is more than 0.25 and non-significant relationship is when the absolute correlation value is lower than 0.25.

The positive sign for correlation coefficient specifies that the lower the value of weather index, the lower the crop production. On the other hand, the negative sign for correlation coefficient describes the relationship as the crop production decreases when the weather index value increases. The weather index with higher absolute correlation coefficient value will be proceeded for further calculation due to a stronger relationship between the weather index with the crop production. The observation revealed that the relationship between the crop production and weather index does not solely depends on crop type but also depends on the location and the geographical background of the region.

Oddly, there are certain crops that has two different relationships with SPI and RAI where one is negative and another is positive, vice versa. This may be due to different calculation and formula used.
in RAI and SPI. In particular, RAI incorporates a ranking procedure to assign magnitudes to positive and negative precipitation anomalies utilizing a normalization procedure [25] whereas SPI computation includes fitting an optimal probability distribution function (PDF) to the precipitation time series aggregated at different timescales and the resulted cumulative probability distribution (CDF) is followed with normalization [17]. The weather index with higher absolute correlation coefficient value will be proceeded for further calculation due to a stronger relationship between the weather index with the crop production.

4.3. Trigger and Exit Thresholds of Weather Indices

The trigger weather index is an index where the payout for crop can be claimed. The exit weather index indicated the weather index where maximum payout is paid, any weather index above the exit weather will still only receive the maximum payout. The computation of trigger and exit weather index are using model-based clustering. The cluster that is chosen is based on low production of crop with low value of weather index

The trigger RAI and exit RAI for sweet corn in Kinta are -1.721 and -1.831, respectively. Payout are issued when the weather index reaches the trigger level and maximum payout are received when the weather index is equal or above the exit RAI. Based on Table 6 the trigger RAI and exit RAI indicated there would be slight reduction in rainfall for the weather. In other words, the sweet corn is sensitive to rainfall that may lead to decrease in the sweet corn productivity. In fact, humidity causes sweet corn to have stalk rot infection. Thus, the loss can be funded by the payout received by the insured.

Payout for pineapple in Samarahan is triggered when the weather index reaches -3.082 which is the large reduction in rainfall category and maximum payout can be received when the weather index is in the extreme reduction in rainfall category for RAI. The pineapple production in Kluang may be disrupted when there is a large reduction in rainfall since the trigger weather index is -3.361 whereas the exit threshold weather index is -3.737. Naturally, pineapple is drought tolerant and are affected with prolonged cold weather since it causes the pineapple to be more acidic and retards the growth. Therefore, the trigger and exit weather index based on Table 6 did not reflect the trait of nature of the pineapple.

The tomato in Batu Pahat has both trigger and exit weather index to be in the same category which is mild drought according to Table I. Dry weather causes insufficient amount of water received by the tomato plant which in the long run reduces the tomato production. The insured are eligible to request for claim when the weather index reaches the threshold level to accommodate to the losses they may face. The maximum payout for tomato in Batu Pahat can also be received when the weather index reaches the exit weather index which is -0.555.

### Table 6. Trigger and Exit Thresholds for Positive Correlation Coefficient.

| Crop Type | District | Region   | Weather Index Type | Weather Index Trigger | Weather Index Exit |
|-----------|----------|----------|--------------------|-----------------------|--------------------|
| Sweet corn| Kinta    | Northern | RAI                | -1.721                | -1.831             |
| Pineapple | Samarahan| East Malaysia | RAI            | -3.082                | -5.503             |
| Pineapple | Kluang   | Southern | RAI                | -3.361                | -3.737             |
| Tomato    | Batu Pahat| Southern | SPI                | -0.368                | -0.555             |

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### Table 7. Trigger and Exit Thresholds for Negative Correlation Coefficient.

| Crop Type | District       | Region   | Weather Index Type | Weather Index Trigger | Weather Index Exit |
|-----------|----------------|----------|--------------------|-----------------------|--------------------|
| Banana    | Sabak Bernam   | Central  | SPI                | 0.325                 | 1.255              |
| Cassava   | Kuala Langat   | Central  | RAI                | 4.267                 | 6.038              |
| Sweet corn| Kota Bharu     | East Coast| RAI                | 1.079                 | 3.865              |
| Sweet corn| Tuaran         | East Malaysia | SPI            | 0.687                 | 1.067              |
| Watermelon| Kluang         | Southern | RAI                | 1.655                 | 5.174              |
Strong negative relationship between weather index indicated that the payout can be received once the weather index reaches or is more than the trigger weather index. The maximum payout is paid when the weather index reaches or is more than the exit weather index. The cluster that is chosen is based on low production of crop with high value of weather index.

From Table 7, the trigger for sweet corn in Kota Bharu is 1.079 which is in the low rainfall category. This means that the sweet corn is sensitive to rainfall that it may cause loss to the sweet corn production. On the other hand, the cassava in Kuala Langat can withstand rainfall to a high extent since the trigger value of RAI is 4.267 where the category of the weather index is extreme rainfall. Watermelon production in Kluang is easier to be affected by rainfall since the trigger value is low which is 1.655 where it is categorized as the low rainfall for RAI. Kluang’s climate is warm to hot all year round meaning that there is lesser rain. Watermelon is more adapted to the high temperature. Thus, any variation and fluctuation of rainfall may affect the watermelon production.

Sweet corn in Tuaran is more sensitive to the wet weather as it has lower trigger and exit thresholds. The resistance of sweet corn in Tuaran may be due to the climate of Tuaran itself. Lastly, the trigger for the banana production in Sabak Bernam is in the mildly wet weather category. The climate in Sabak Bernam is hot, oppressive, and overcast. However, if there is an increase in humidity, banana production may be disrupted.

4.4. Premium Calculation

Premium rate for each crop is calculated.

| Region      | Crop Type | District  | Expected Annual Loss | Premium (RM) |
|-------------|-----------|-----------|----------------------|--------------|
| Central     | Banana    | Sabak Bernam | 0.2208               | 0.2069       |
| Central     | Cassava   | Kuala Langat | 0.0002               | 0.0002       |
| East Coast  | Sweet Corn| Kota Bharu | 0.0208               | 0.0195       |
| Northern    | Sweet Corn| Kinta     | 0.1376               | 0.1289       |
| East Malaysia| Sweet Corn| Tuaran  | 0.0061               | 0.0057       |
| East Malaysia| Pineapple| Samarahan | 0.1237               | 0.1159       |
| Southern    | Pineapple | Kluang     | 0.2188               | 0.2050       |
| Southern    | Watermelon| Kluang      | 0.0101               | 0.0094       |
| Southern    | Tomato    | Batu Pahat   | 0.3269               | 0.3063       |

Based on Table 8, for Central region, the banana crop in Sabak Bernam has the highest premium for the weather index SPI. It showed that for the past year banana in Sabak Bernam is highly affected by the weather since the calculated premium is higher than cassava in Kuala Langat. Low temperature can give negative impacts to the growth of the stem and leaves and slow down the tree maturity. Meanwhile cassava in Kuala Langat has the lowest expected annual loss and premium due to the high value of trigger threshold shown in Table 7. Thus, the probability of exceeding trigger threshold is low resulting in low expected annual loss and premium. Cassava is a type of crop that are easy to plant as they can survive in optimum temperature 25 to 35°C with high rainfall.

In the East Coast region, the crops are sweet corn in Kota Bharu. As shown in Table 8, sweet corn in Kota Bharu portrays lower calculated premium than sweet corn in Kinta. The policyholder will pay RM0.0195 and RM0.1289 for each RM1 insured amount for sweet corn in Kota Bharu and Kinta respectively. The difference in the premium calculated albeit for the same crop type is due to different location has different weather condition. In addition, the crops in different location have different resistance towards weather.

In Northern region, the crops that are affected by weather is sweet corn in Kinta. The calculated premium for sweet corn is high which is RM0.1289. This is because the trigger and exit thresholds for sweet corn is high. Given that sweet corn has strong positive relationship with RAI, the weather index
in Kinta has low probability of reaching the trigger and exit levels. This results in high expected annual loss for sweet corn in Kinta.

East Malaysia region which includes Sabah and Sarawak has shown that the crops that are affected by weather are pineapple in Samarahan, and sweet corn in Tuaran. The probability of reaching trigger threshold for pineapple is higher than sweet corn which resulted in higher premium for pineapple than sweet corn as shown in Table 8.

Lastly, in Southern region, watermelon and pineapple in Kluang, and tomato in Batu Pahat are the crops that found to be affected by weather indices. The highest premium is for tomato as the trigger threshold is near to normal condition. This characteristic is observed from the clustering analysis which shows that tomato is very vulnerable towards dry weather condition. This leads to the high premium charge for tomato in Batu Pahat. Meanwhile, in Kluang, both watermelon and pineapple show a significantly stronger relationship with RAI compared to SPI. Premium calculated for pineapple is higher than watermelon.

Table 9. Annual Expenses, Premium Payment and Maximum Insured Amount.

| District   | Crop    | Annual expenses (RM) | Excess of Income over Expenses (RM) | Premium payment (RM) | Maximum Insured Amount (RM) |
|------------|---------|-----------------------|-------------------------------------|-----------------------|-----------------------------|
| Sabak Bernam | Banana | 21648                 | 732                                 | 7.32                  | 35.37                       |
| Kuala Langat  | Cassava | 22056                 | 324                                 | 3.24                  | 18685.12                    |
| Kota Bharu   | Sweet corn | 16992                | 5388                                | 53.88                 | 2765.10                     |
| Kinta        | Sweet corn | 15000                | 7380                                | 73.80                 | 572.36                      |
| Samarahan    | Pineapple | 16824                | 5556                                | 55.56                 | 9794.45                     |
| Tuaran       | Sweet corn | 15768                | 6612                                | 66.12                 | 322.53                      |
| Kluang       | Pineapple | 20556                | 1824                                | 18.24                 | 157.35                      |
| Kluang       | Watermelon | 20556               | 1824                                | 18.24                 | 1935.44                     |
| Batu Pahat   | Tomato  | 20844                 | 1536                                | 15.36                 | 50.14                       |

According to Household Income and Basic Amenities Survey 2019 Report, in year 2019, 58% of households in Malaysia under agriculture sector has monthly income below RM4,000 and median disposable monthly income of RM3,285. Farmers’ affordability in paying the premium is assessed for annual income of RM22,380, which is the mean annual income in Malaysia for agriculture sector based on the Household Income and Basic Amenities Survey 2019 Report.

For each district, the annual expenses for household under agriculture category are as shown in Table 9. Excess income is calculated by the difference of mean annual income of RM22,380 and annual expenses according to districts. Affordable premium is defined as 1% of remaining available income as shown under column premium payment in Table 9. Given the premium rate in Table 8 and affordable premium in Table 9, the maximum insured amount is calculated by dividing the affordable premium by premium rate.

Maximum insured amount in Table 9 also reflects the affordable insured amount coverage for the farmers. Banana farmers in Sabak Bernam could only afford maximum of RM35.73 coverage if weather index reaches the exit threshold. In addition, tomato farmers in Batu Pahat could only afford maximum insured amount of RM50.14 if index reaches exit threshold. In other words, the farmers who opted to be covered more than the maximum insured amount may not be capable to afford the insurance. The small insured amount reflects low affordability of farmers to pay premium to cover for larger insured amount.

On the other hand, cassava farmers in Kuala Langat could cover for maximum insured amount of RM18,685.12 with premium charge of only RM3.24. This reflects that the premium rate is very affordable compared to the rest.
In summary, the premium calculated for the insurance ranges from 0.01 cent to 30.63 cents for each RM1 insured amount. The factors that could affect these values are the accuracy of original crop and weather data. The highest pure premium of 30.63 cents for RM1 insured amount is for tomato in Batu Pahat. Cassava in Kuala Langat has the highest maximum insured amount which is RM18,685.12 with a premium payment of RM3.24. This is due to the fact that the expected annual loss is at the minimum because of the low probability of occurrence of loss to the cassava in Kuala Langat. The sweet corn in Kota Bharu and Kinta has different maximum insured amount of RM2,765.10 with a premium payment of RM53.88 and RM572.36 with a premium payment of 73.80 respectively.

5. Conclusion
In this study, an index based microinsurance is designed and the pure premium for the insurance is calculated. Calculation of pure premium required the study to find the relationship between the weather index with the crop and calculate the exit and trigger threshold weather index that accommodates to the crop loss.

A weather index based insurance contract is completed for each region – Central, East Coast, Northern, East Malaysia and Southern. After detrending the crop yield data, the most correlated weather index with the crop yield was determined using a correlation test. The correlation between crop production and RAI are generally more significant than SPI for pineapple, cassava and tomato. Contrarily, banana and sweet corn in Kota Bharu, cassava and tomato show more significant relationship between crop yield and SPI than RAI. Meanwhile, watermelon does not show any consistent correlation strength difference between RAI and SPI correlation values. Therefore, based on the relationship of the selected crop and region we can conclude the most suitable region are in Central region, sweet potato is the most suitable located in Sepang. Next, in Northern region, Kinta is suitable for brassica, sweet corn and sweet potato while Bandar Baharu is suitable for watermelon. Crops in East Coast region that have face no growth difficulties are brassica and tomato in Cameron Highlands. Besides, Tumpat is suitable for the growth of cassava. In Southern region, cassava and pineapple are fit at Johor Bharu and Kluang respectively. Lastly, represent East Malaysia is Kuching where the most suitable crop to plant is watermelon.

Next, the second objective of computing the trigger and exit thresholds for each district specified weather indices. Crops that are affected by wet condition are banana in Sabak Bernam, cassava in Kuala Langat, sweet corn in Tuaran, and watermelon in Kluang.

The premium rates calculated in this research depends heavily on our data. A better estimation can be calculated with higher data quality. It can be concluded that the amount of premium payment made does not reflect a higher value for maximum insured amount and depends on the expected value loss for the crop which relates with the probability of crop loss. Cassava in Kuala Langat, sweet corn in Kota Bharu, Pineapple in Samarahan and Watermelon in Kluang shows high affordability as it covers for large maximum sum insured relative to premium payment. Therefore, weather index based are suitable to be implemented for these crops. On the other hand, Banana in Sabak Bernam, Sweet corn in Kinta and Tuaran, Pineapple in Kluang and Tomato in Batu Pahat shows low maximum sum insured relative to premium payment hence, it is not suitable to implement weather index based insurance to these crops.

Small farmers who wishes to reduce the weather risk faced which may contribute to disruption of crop production can be granted by the implementation of the weather index based insurance following the affordable premium payment. The insured amount not only will help the farmers in coping with the loss of crop production, but also increase their crop productivity.

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