Designing Rainfall Index Insurance for Rubber Plantation in Balikpapan

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Abstract. Rubber commodity is one of the essential agricultural sectors in the City of Balikpapan. Rubber plantation has become a leading product to boost the economic growth in Balikpapan from the agricultural sector. However, this commodity is vulnerable through the changes of rainfall index since less rainfall can decrease the amount of latex in a rubber tree. This unexpected event will make a financial loss to farmers because of delaying the cultivation time. Therefore, the crop insurance for rubber farmers should be discovered. This study applied the Burn Analysis method to determine some classes of rainfall index and calculating the crop insurance premiums based on Black Scholes methods. The lowest class of rainfall index is 1264.36 mm with the crop insurance premiums at this class is Rp. 521,482.73. Otherwise, the highest rainfall index is 1761.36 mm whereas the premium level is Rp. 568,592.93.

1. Introduction
Rubber tree (Hevea brasiliensis Muell. Arg) is one of leading commodities for the agricultural sector in Indonesia. Indonesia has the largest rubber plantation in the world, it reaches 3.6 million ha. These commodities have become one of source income in foreign exchange, employment, and it also has an important role to preserve the environment and biomass [1]. Moreover based on East Kalimantan Plantation Agency, Rubber plantation in the City of Balikpapan known as the largest crop commodities which has approximately 4510 Ha of plantation land and it was successfully cultivated around 2445 tons in 2019. Therefore, rubber has a significant role in the agricultural sector to improve the economic growth of Balikpapan.

Nowadays, the tendency of climate change brings a threat to the agricultural sector, for instance in rubber plantations. Climate change potentially decreases the bioclimatic barriers to the next expansion of rubber plantations within the area and increases challenge on remaining biodiversity both within and outside of protected areas [2]. Naturally, the rubber tree can grow well with a mean daily air temperature of 25-28°C, annual rainfall amounts exceeding 2,000 mm and a high number of rainy days ranging from 100-150 days. Since the fluctuation of weather conditions, rubber plantations may be affected by ongoing climate variability because the rainfall index will determine the amount of latex in a rubber tree [3].

This inconvenience situation can lead to financial loss for rubber farmers. Their income will depend on the amount of latex that can be cultivated from rubber trees. It means that the farmer’s income also depends on the climate index. For instance, if the rainfall occurred during the summer period it can cause the breakout of leaf disease, particularly with powdery mildew. Moreover, the heavy rain can decrease
in tapping days, and can bring to the reduction of rubber productivity. In contrast, when the rainfall drops, the latex production will plunge from the ideal level. Given this situation, it leads to the ideas for protecting the farmers from financial loss by designing agricultural insurance for rubber plantations.

Agricultural insurance encourages farmers by reimbursing farmers’ losses [4]. In insurance has been designed to overcome the failure condition caused by external factors such as weather and natural disaster. Moreover, the insurance can motivate farmers to enhance their agricultural operation and maximize profit [5]. There were several cities designing the agricultural insurance to protect their farmers. However, the city of Balikpapan, in particular, did not have this type of insurance. Since this insurance depends on the regional climate profile, by designing this insurance it will give significant information for farmers, the government, and their relevant stakeholder to provide an insurance for rubber plantation in Balikpapan.

Several previous studies conducted crop insurance design with several methods, one of the most popular is using burn analysis to perform appropriate insurance premiums based on climate index. One of them is the research conducted by Ariyanti [6] who uses the historical burn analysis to examine the crop failure in paddy plantation. Then, they also used Black Scholes model to determine the insurance premiums. The risk insurance is assumed to be a put option model, afterwards the premium value can be determined as well as the option value [7]. Taking this into account, using the similar approach this research will examine the relation of rainfall index to the crop insurance premium for sustainability rubber plantation in Balikpapan.

2. **Research Methodology**

This research consists of two major parts, namely rainfall index classification and premium simulation. Firstly, a burn analysis method was used to design rainfall index clustering to determine the trigger of the insurance. Moreover, the selected trigger would be used to calculate the insurance premium using Black Scholes’s option approximation.

2.1. **Burn Analysis Methods**

Based on the previous research conducted by Putri et.al [8], Burn Analysis has several advantages. Firstly, the analytical process involved a large scale of historical data which is reliable to measure all possible risks. The other advantages, the Burn Analysis method provide a useful information to analyze the impacts of the weather index on financial conditions. There are several steps to conduct the Burn Analysis approach [9]:

1. Measuring the average rainfall index in each ten days for a month. This step is designed to create the index window of the insurance.
2. Calculating the threshold value which represents the maximum amount of rainfall calculated in each ten day period. The threshold value used in this study is based on the daily potential evapotranspiration value in Indonesia. It has been explained that Indonesia has an average 5 mm/day, then the threshold in 10 days is 50 mm.
3. The adjusted rainfall index created by comparing the average rainfall index in each ten days with the threshold value. If the average is greater than the threshold, then the rainfall is deducted to the threshold. On the other hand, if the average is below than the threshold then it takes for the next calculation. After comparing, the adjusted rainfall in a year is created.
4. Defining the exit value as the minimum rainfall index in the insurance contract.
5. Creating the trigger classification using the percentile data of rainfall index. Then, the trigger is used to determine the insurance premiums.

2.2. **Black Scholes Method**

The calculation of agricultural insurance premiums using option contracts is related to the term put cash or nothing. The state of the option contract assumes a constant risk-free interest rate (r) and all option investors are risk-neutral (risk-neutral Q) so that the value of the European type put option at time t is:
\[ P(S,t) = Ke^{-r(t)}N(-d_2) - (S_0 - qe^{-r(t)})N(-d_1) \]  

Which,

\[ d_1 = \frac{\ln\left(\frac{S_0 - PV(q)}{K} + (r + 0.5\sigma^2)(t)\right)}{\sigma\sqrt{t}} \]

\[ d_2 = d_1 - \sigma\sqrt{t} \]  

\( P(S,t) \) = Value of insurance premium or put option price,

\( N(-d_2) \) = Cumulative distributive function \(-d_2\),

\( N(-d_1) \) = Cumulative distributive function \(-d_1\),

\( S_0 \) = Current total annual rainfall (mm) (mm),

\( K \) = Trigger value or amount of rainfall insured (mm),

\( r \) = Risk free interest rate

\( \sigma \) = Standard deviation,

\( q \) = Constant dividend rate,

\( t \) = Period of payment.

An important part of climate index insurance is the contract of insurance based on objective parameters (e.g., on the index of rainfall or temperature) at a specified weather station over a specified agreed period of time. The policyholders receive payment if the rainfall index value is below the amount of the trigger for historical rainfall data. The insurer will receive an amount of \( P(S,t) \) when the contract matures at \( S_t < K \), or receive zero payment when \( S_t > K \). Therefore the premium value is determined when it has the maximum of \( S_t \) and it assumes that there is a constant dividend value of 0. Suppose \( P \) represents a lump sum payment from the insurance contract, then the agricultural insurance premium value based on the rainfall index can be calculated by the following equation:

\[ \text{Premiums} = P \cdot e^{-r(t)}N(-d_2) \]  

2.3. Data and Materials

This research is focused on sample problems in the city of Balikpapan, therefore the rainfall historical data was obtained from the Meteorology and Climatology Bureau of Balikpapan. This research used the yearly average of rainfall index through 11 years from 2008 to 2018. From the descriptive analysis, it can be obtained that the mean of the data is 8.325093714 mm while the variance is 9.858516538 mm. The rainfall dataset is given in Figure 1.

![The Average of Yearly Rainfall Index in Balikpapan (mm)](image)

**Figure 1.** Average of Balikpapan’s Yearly Rainfall Index
The normality test of daily rainfall dataset is given in the table below.

\( H_0 \): Log of daily rainfall dataset has normal distribution
\( H_1 \): Log of daily rainfall dataset has not normal distribution

Using the Kolmogorov-Smirnov test to eleven years dataset (2008-2018) is calculated \( D_{\text{max}} = 0.278 \) while the critical value is 0.391 (at 5% of significant level). Because of \( D_{\text{max}} \) is below the critical value then the null hypothesis is accepted. So, the dataset has followed the normal distribution. The normality test is important to fulfill the requirements of black scholes methods [10].

In the preliminary study, After the normality test, the correlation test was conducted to examine the relation between rainfall index and annual rubber production in Balikpapan. This test can identify the impact of rainfall index on rubber production. The rubber cultivation historical data was examined from 2008 and 2018 and it is illustrated at Figure 2. Then, the coefficient correlation between these two variables is calculated at 0.6784528. This coefficient indicated that there was a moderately high relationship between rainfall index and annual rubber cultivation.

![Figure 2. Average of Annual Rubber Cultivations](image)

3. Results and Discussion
The research was started with analyzing the rainfall index to create the index window for the insurance programme. The daily rainfall index was adjusted to a ten days index. Therefore, each month was divided into three parts; day 1-10, 11-20, and 21-30. The next step was obtaining the threshold index of the rainfall in order to determine the adjusted rainfall total. If the rainfall index was calculated over the threshold, the rainfall index will be adjusted to the threshold. Otherwise, it will use the ordinary measure of the rainfall index. From the dataset, it was calculated that the threshold is 50 mm per year. Furthermore, the adjusted rainfall index is given in the table 1 below.

| Year | Rainfall index (mm) |
|------|---------------------|
| 2015 | 1224.2              |
| 2014 | 1274.4              |
| 2016 | 1284.4              |
| 2012 | 1309.4              |
| 2013 | 1414.5              |
| 2010 | 1515.3              |
| 2011 | 1560.9              |
| 2017 | 1606.6              |
| 2009 | 1674.3              |
| 2018 | 1717.6              |
Then the exit value is calculated using the average of the lowest rainfall index, that is the average of 2015 and 2014. The exit value is 1254.3 mm per year. The last step is obtaining the trigger value for the insurance. The trigger value was arranged from the percentile of rainfall index which the results is shown in the table 2.

| Class | Trigger (k) (mm) |
|-------|------------------|
| 1     | 1264.36          |
| 2     | 1299.4           |
| 3     | 1454.82          |
| 4     | 1570.04          |
| 5     | 1674.3           |
| 6     | 1761.36          |

The crop insurance is designed using the trigger class, therefore the trigger value will determine the insurance premium. The illustration of the insurance scheme is given in figure 3.

It is clear from figure 1, that the insurance will give full coverage if the rainfall index less than the exit number. Meanwhile, if the rainfall index falls between trigger and the exit value, the police holder will get partial coverage. Moreover, there will be no payment if the rainfall is higher than the trigger.

To determine the insurance premium, \( S_0 \) was assumed to be the rainfall index in the latest dataset, that is rainfall in 2018, and let’s take the first trigger class (1264.36 mm) as the rainfall index, then with the rate of 20% per annual, it can be calculated:

\[
 d_1 = \frac{\ln\left(\frac{1717.6}{1264.36}\right) + (0.20 - 3.13982747 + 0.5\left(9.858516538^2\right)) \cdot 1}{3.13982747\sqrt{T}} = 1,724,660,374
\]

\[
 d_2 = 1,724,660,374 - \sigma\sqrt{t} = -1,400,617,578
\]

Then the cumulative density function of \( N(-d_2) \) is 0.01344040.

To determine the insurance premiums, an interview with the rubber farmer in Balikpapan was conducted to observe the total cost in the rubber plantation processes. This interview has been done to small scales of rubber farmers in the North of Balikpapan. Based on the interview, the rubber plantation takes five years until it can be cultivated and the farmers have been approximately spending around Rp47,390,000 for the first year. However, the total expenditure in the following years will decline around Rp19,995,000 at the second to the fifth year.
For the first year of rubber plantation the crop insurance premium is approximated at

\[ \text{Premium} = Rp47,390,000. \ e^{-r(t)N(-d_2)}, \]
\[ = Rp47,390,000. \ e^{-0.20(t) \times 0.01344} \]
\[ = Rp521,482.73. \]

Furthermore, the premium for the second to fifth year is estimated around

\[ \text{Premium} = Rp19,995,000. \ e^{-r(t)N(-d_2)}, \]
\[ = Rp19,995,000. \ e^{-0.20(t) \times 0.01344} \]
\[ = Rp220,026.32. \]

The following shows the results of the calculation of the insurance premium value based on the rainfall index on rubber plantations with several different trigger values for the insurance premium value in the first year.

**Table 3. The Premium for First Year in Different Trigger**

| Trigger (mm) | Premiums (Rp) |
|--------------|---------------|
| 1264.36      | 521.482,73    |
| 1299.4       | 525.235,61    |
| 1454.82      | 540.994,22    |
| 1570.04      | 551.854,20    |
| 1674.3       | 561.160,58    |
| 1761.36      | 568.592,93    |

Moreover, the premiums for the next years is illustrated below,

**Table 4. Premium for the Second to Fifth Year**

| Trigger (mm) | Premiums (Rp) |
|--------------|---------------|
| 1264.36      | 220.026,32    |
| 1299.4       | 221.609,75    |
| 1454.82      | 228.258,69    |
| 1570.04      | 232.840,78    |
| 1674.3       | 236.767,37    |
| 1761.36      | 239.903,26    |

Based on the insurance premiums in table 3 and table 4, the different triggers had a slight impact through the insurance premium. The premium is designed to be paid at the first of each year in an insurance contract. The annual premium will cover the failure condition based on the trigger in that year. The insurance benefit will be paid if the condition in figure 1 is matched.

This results depends on the rainfall condition in Balikpapan which is known that the rainfall index in Balikpapan remains steady around the nearest years. As a result, the trigger value is defined with a slight difference in each class. Despite these conditions, in general it is known that as the trigger goes higher, the insurance premiums will increase moderately.

**4. Conclusions**

Based on the simulation, it is clear that the different trigger makes slightly similar premiums. This results depends on the rainfall condition in Balikpapan which is known that the rainfall index in Balikpapan remains steady around the nearest years. As a result, the trigger value is defined with a slight difference in each class. Despite these conditions, in general it is known that as the trigger goes higher, the
insurance premiums will increase moderately. The lowest class of rainfall index is 1264.36 mm with the crop insurance premiums at this class is Rp. 521,482.73. Otherwise, the highest rainfall index is 1761.36 mm whereas the premium level is Rp.568,592.93.

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