Available online at https://journal.rescollacomm.com/index.php/ijbesd/index

International Journal of Business, Economics and Social Development

e-ISSN 2722-1156
p-ISSN 27722-1164

Vol. 5, No. 1, pp. 94-103, 2024

Calculation of Rice Farming Insurance Premium Price in Magelang City Based on Rainfall Index with Black-Scholes Method

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Abstract

Indonesia is a country with two seasons, the rainy season and the dry season. Unstable rainfall can affect rice production and may cause crop failure. The amount of rice production in Indonesia, one of which is in Magelang City, is quite large, so the losses that may be experienced are quite significant. Therefore, a way to reduce the impact of losses experienced by farmers is needed, one of which is through the rice farming insurance program. The purpose of this study is to determine the premium price of rice farming insurance based on rainfall index based on the exit value and trigger value in each growing season. Insurance using the rainfall index can provide protection to farmers due to too little rainfall or too much rainfall. Too much rainfall can cause damage to rice plants resulting in crop failure. The premium calculation method uses the Black-Scholes principle, while the exit value and trigger value are determined by the Historical Burn Analysis method. The result of this study is to obtain various trigger values and exit values as well as premiums that must be paid by farmers in each normal, high, and low (dry) rainfall condition. This value determines the premium price obtained for normal rainfall which is IDR 735,739.66 to IDR 871,698.64, for high rainfall the premium price obtained is IDR 1,404,184.75 to IDR 1,643,307.75, and for low rainfall (dry season) it is IDR 5,541,806.10 to IDR 6,689,629.88.

Keywords: Rice farming insurance; Rainfall Index; Black Scholes; Historical Burn Analisis.

1. Introduction

Extreme rainfall, whether too high or too low, can be detrimental to the agricultural sector. Agricultural businesses, which are often full of risk and uncertainty, are vulnerable to weather fluctuations. Onyeneke et al. (2021) showed that weather changes, such as unpredictable increases or decreases in rainfall, can threaten rice production, creating uncertainty for farmers.

Unpredictable weather changes have a significant impact on crop yields, challenging the agricultural sector. One solution to reduce the risk of losses due to weather fluctuations is the implementation of agricultural insurance policies for farmers (Tang et al., 2021). Agricultural insurance is considered an effective alternative to protect farmers from risks related to production outcomes.

The selection of climate indices in agricultural insurance is considered an appropriate step because there is a high correlation between climate events and crop losses (Abdi et al., 2022). One of the methods used to calculate climate index insurance is Historical Burn Analysis (Dewi et al., 2017). In its application, the trigger value and exit value are calculated to obtain the index value that will be used in the premium calculation. In the context of agricultural insurance, farmers are required to pay a premium every harvest season, and the premium calculation can be done using the Black-Scholes method based on the climate index based on the trigger value and exit value.

There are relevant previous studies, such as those conducted by Qosim et al. (2018) on determining the price of agricultural insurance premiums based on the rainfall index where this method uses the Stochastic Weather Generator to determine the rainfall index and evaluate the premium value fairly. Another study, conducted by Filiapuspa et al. (2019), with the black-scholes model research has applications in the field of insurance and finance such as pricing crop insurance.

Based on the phenomena described, this research was conducted to integrate the Historical Burn Analysis method in determining the rainfall index based on the trigger value and exit value in each growing season, namely in normal, high, and low rainfall conditions in Magelang City from 2015 to 2022. Meanwhile, to calculate the premium price of agricultural insurance, this research developed the Black-Scholes Method. This approach not only considers economic aspects, but also provides improvements in predicting premium prices more accurately and fairly.

2. Literature Review

2.1. Rainfall Index Based Agricultural Insurance

Running a rice cultivation business as a farmer does not always produce the harvest as expected. The activity of growing rice is always accompanied by risks, which often result in loss of income for the farmers. Various threats arise, one of which is caused by rainfall instability. If rainfall cannot be predicted properly, crop yields are negatively affected and have a significant impact on production.

The government seeks to provide economic protection to farmers through the agricultural insurance program. This insurance is one alternative that helps farmers deal with the risks that arise in their agricultural businesses. The concept of index-based insurance is part of the parametric approach, where the insured party pays a premium when it suffers a loss due to a natural event. In this case, the loss was triggered by rainfall instability.

2.2. Lognormal Distribution

According to Türkkan et al. (2019), a variable can be considered a log-normal distribution if the variable can be interpreted as the product of a number of independent random variables, each of which is positive, provided that the natural logarithm of variable X, symbolized as $\ln X$ has a normal distribution.

In determining the premium price in the Black-Scholes model, it is important to test the log-normal distribution of the rainfall index data. The Kolmogorov-Smirnov test is used to statistically test the distribution of rainfall by comparing the values of D and D_{table}. Calculating the D value can use the equation (1).

$$D = maks\,|F(x) - S(x)| \tag{1}$$

Where, $F(x)$ is the cumulative frequency distribution, and $S(x)$ is the cumulative frequency distribution of observation scores.

2.3. Historycal Burn Analysis Method

According to Dewi et al. (2017), in the development of climate index insurance in various regions, the method often used is Historical Burn Analysis (HBA). HBA is recommended for areas with limited climate data, especially in terms of rainfall which is very relevant for agriculture. In processing the data to determine the rainfall index, the steps of the Historical Burn Analysis method developed by the International Research Institute (IRI) Columbia University are used as follows:

1. Determining the window index period
   The window index is the insured period. The selection of the window index can be adjusted to the rainy or dry season.
2. Calculation of dasarian rainfall
   Decadal rainfall is the amount of rainfall that occurs every 10 days for the insured period. In calculating dasarian rainfall, you can use the following equation.

$$Month_{decade\ 1} = \sum_{t=1}^{10} h_t \tag{2}$$

$$Month_{decade\ 11} = \sum_{t=1}^{20} h_t \tag{3}$$

$$Month_{decade\ 21} = \sum_{t=1}^{30} h_t \tag{4}$$

   With h_t is daily rainfall.

3. Calculation of the cap value
   The term cap signifies the upper limit for the calculated rainfall during a ten-day period. The establishment of the cap value is intricately tied to the daily evapotranspiration potential (ETP) value. The formula employed for computing the 10-day cap value is given as equation (5):

$$\text{Cap}_{\text{dasarian}} = \text{ETP value} \times 10 \text{ days} \tag{5}$$

4. Determine the amount of adjusted rainfall

In determining the adjusted rainfall, the result in the sum of the rainfall of each dasarian and the cap value of the dasarian is used.

- If the total rainfall of a dasary < cap, then the total rainfall of the dasary is used.
- If the dasarian rainfall total > cap, the cap value is used.

5. Collecting rainfall data

The adjusted rainfall values for each coverage period are averaged using equation (6).

$$\lambda_x = \frac{1}{n}\sum_{j=1}^{n} x_j \quad (6)$$

Where λ_x is average decadal rainfall for each year, n is number of data, and x_j is adjusted rainfall.

6. Determination of exit value and calculation of trigger value

The Exit value is the lowest rainfall data after compilation, where no payments are made, while Trigger is a percentile calculation of the average rainfall per year that has been sorted from the lowest rainfall to the highest rainfall. The percentile calculation on the Trigger value can use equation (7).

$$P_k = data\ sequence - \frac{k(n+1)}{100} \quad (7)$$

Where, n is the number of data and k is an integer less than 100 (1,2,3,...,99).

2.4. Coverage Value

The amount of coverage for farmers can be calculated by adding the initial capital and operational costs. This approach provides a comprehensive picture of the financial protection provided to farmers, covering both initial capital and operational costs during the farming process. Thus, the amount of coverage determined reflects the extent of financial protection provided to farmers to address risks and losses during agricultural activities.

Thus, the formula for calculating the amount of coverage is as follows.

$$Amount\ of\ coverage = Total\ Capital + Total\ Operating\ Costs \quad (8)$$

1.5. Black-Scholes Method

The Black-Scholes method is a technique used to estimate option prices. The Black-Scholes method was first developed in 1973 by Ficher Black and Myron Scholes. Ariyanti et al. (2020), wrote that the European type put option price determined by the Black-Scholes formula is as follows:

$$P = K\,e^{-rT}N(-d_2) - S_0 N(-d_1) \quad (9)$$

Where

$$d_1 = \frac{\ln\left(\frac{S_0}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \quad (10)$$

$$d_2 = \frac{\ln\left(\frac{S_0}{K}\right) + \left(r - \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T} \quad (11)$$

With P is the option price, e^{-rT} is the discount, S_0 represents the initial stock price, K denotes the strike price, r is the risk-free interest rate, σ_T signifies the standard deviation of the stock price, T corresponds to the time remaining maturity, $N(-d_1)$ is the normal distribution probability of d_1, and $N(-d_2)$ is the normal distribution probability of d_2 for the trigger limit.

Option pricing is similar to index insurance. Therefore, index insurance can be formulated in the same way as option prices, which in determining the price of index insurance uses the Black-Scholes method by considering the following:

1) The reference value (trigger) for index insurance is denoted as H.
2) The payment arrangement for index insurance takes the form of a lump sum.
3) The index adheres a lognormal distribution.

Entering into equation (11) the premium for index-based agricultural insurance can be computed by initially determining the cumulative distribution value d_2 through the subsequent equation:

$$d_2 = \frac{\ln\left(\frac{R_0}{H}\right) + \left(r - \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \tag{12}$$

Where R_0 is the latest rainfall value, H is the trigger value (the rainfall chosen as the index), r is the risk free interest rate, σ the standard deviation of the rainfall index, and T the harvest time of each year.

Furthermore, to calculate the rainfall index-based agricultural insurance premium, it can be calculated with the following equation (12).

$$Premi = Pe^{-rT}N(-d_2) \tag{13}$$

Where P is the insurance coverage price, $N(-d_2)$ indicates the probability of rainfall falling below the trigger value, with r representing the interest rate, and T denoting the harvest time per year.

3. Materials and Methods

a) Materials

The object used in this research is agricultural insurance premium based on rainfall index in Magelang City. The data used in this study used secondary data, namely rainfall data for 8 years starting from 2015 - 2022 in Magelang City obtained from the Central Bureau of Statistics and BMKG (Badan Meteorologi, Klimatologi, dan Geofisika, 2023 (dataonline.bmkg.go.id). Meanwhile, production costs and operational costs were obtained online from the website of the Department of Agriculture and Food Needs in Magelang City.

b) Methods

1) Collecting rainfall data in Magelang City from 2015 to 2022.
2) Determine the rainfall index using Historical Burn Analysis. The steps used are as follows:
   a. Determine the period to be insured.
   b. Determine the basic daily rainfall in equations (2) to (4).
   c. Determining the cap value in equation (5).
   d. Determining the amount of adjusted rainfall based on rainfall categories by taking into account the amount and average daily base rainfall which has been adjusted in each year in equation (6).
   e. Determine the Exit value based on the smallest rainfall value and determine the Trigger value based on the percentile value of the average annual rainfall, from each rainfall category.
3) Conduct a log-normal distribution test on the rainfall index which has been selected as a condition in fulfilling the Black-Scholes method.
4) Determine the price of agricultural insurance coverage as a reference in determining insurance premiums.

4. Results and Discussion

4.1 Determining the Rainfall Index

1) Determine the period to be insured.
   The periods used in this study are the normal rainy season, the season of heavy rain and wind, and the dry season (little rainfall).
2) Calculation of daily base rainfall.
   The daily base rainfall calculated is the sum of rainfall for every 10 days in the insured period. Rainfall summation for months with a day span between 28 or 29 and 31 will be done from day 21 to the last day of the month.
3) Calculation of the cap value.
   The calculation of the cap value is connected to the ETp value. Magelang City has an average temperature of 25.62°C and an air humidity level of 82% every day. Based on the average ETp value of various agro-climatic regions, Magelang City has an average ETp value of 5mm/day. Thus, using equation (5) can be calculated as follows:

$$\text{Cap}_{\text{dasarian}} = \text{ETP value} \times 10 \text{ values}$$
$$\text{Cap}_{\text{dasarian}} = 5\ \text{mm/day} \times 10\ \text{days}$$
$$\text{Cap}_{\text{dasarian}} = 50\ \text{mm}$$

4) Determine the amount of adjusted rainfall.
   - If the total rainfall is > than the cap value, then the value used is the cap value itself.
   - If the total rainfall is < than the cap value, then the value used is the total rainfall of the dasarian.
     The cap value used is 50 mm.

5) Calculation of the sum and average daily base rainfall that has been adjusted.
At this stage, calculations are made for the amount and average of dasarian rainfall that has been adjusted to the cap value for each year. Then, for each calculation of the normal rainy season, heavy rain and wind season, and dry season (little rainfall) can be presented in Table 1 to Table 3.

Table 1: Adjusted normal rainfall amount and average

Year	Rainfall amount adjusted	Average rainfall adjusted
2015	469.1	39.09
2016	539.7	44.98
2017	499.3	41.61
2018	515.8	42.98
2019	487.5	40.63
2020	547.8	45.65
2021	501.4	41.78
2022	561.7	46.81

Table 2: Amount and average adjusted heavy rainfall

Year	Rainfall amount adjusted	Average rainfall adjusted
2015	477.9	39.83
2016	536.7	44.73
2017	542.6	45.22
2018	567.0	47.25
2019	481.0	40.08
2020	577.6	48.13
2021	508.8	42.40
2022	519.1	43.26

Table 3: Amount and average adjusted low rainfall

Year	Rainfall amount adjusted	Average rainfall adjusted
2015	32.4	2.70
2016	201.3	16.78
2017	114.7	9.56
2018	80.2	6.68
2019	50.6	4.22
2020	38.7	3.23
2021	219.3	18.28
2022	234.9	19.58

6) Determination of exit value and calculation of trigger value.
The average rainfall that has been obtained is then sorted from the smallest to the largest value. After arranging the sorted average rainfall, then determine the exit value and trigger value.
The exit value is the lowest average daily base rainfall that has been adjusted to the cap value after compiling the existing data. Then, the trigger value is determined by looking at the rainfall opportunities that exist in the region. The trigger value is a percentile calculation of the average dasarian rainfall that has been adjusted to the cap value each year. The arrangement of data for normal rainfall, high rainfall, and low rainfall (dry) can be seen as Table 4:

Table 4: Exit and trigger values of the normal rainfall index

Percentile	Trigger (mm)	Exit (mm)

20	40.32	
30	41.31	
40	41.71	
50	42.38	39.09
60	43.78	
70	45.18	
80	45.88	

Table 5: Exit and trigger values for the high rainfall index

Percentile	Trigger (mm)	Exit (mm)
20	40.03	
30	41.71	
40	42.92	
50	43.99	39.83
60	44.92	
70	45.83	
80	47.43	

Table 6: Exit and trigger values for the low rainfall index

Percentile	Trigger (mm)	Exit (mm)
20	3.12	
30	3.92	
40	5.70	
50	8.12	2.7
60	12.45	
70	17.23	
80	18.54	

4.2 Lognormal Distribution Test of Rainfall Data

The normality test was conducted with the Kolmogrov-Smirnov test on the natural logarithm of the adjusted rainfall amount data with the help of Minitab 19 software. The following is the hypothesis of the normality test:
H_0 : adjusted rainfall amount data based on lognormal,
H_1 : adjusted rainfall amount data is not lognormal distributed.

The significance level used in the lognormal distribution test is 0.05 with a decision if the p-value $\geq$ alpha, then H_0 is accepted. That is, the adjusted rainfall amount data is lognormal distributed.

Table 7: Lognormal distribution test results of total rainfall data in Magelang City in 2015-2022

Rainfall Data	Alpha	P-Value	Conclusion	Description
Normal rainfall (October-January)	0.05	> 0.150	H_0 accepted	Rainfall data has a lognormal distribution
High rainfall (February-May)	0.05	> 0.150	H_0 accepted	Rainfall data has a lognormal distribution
Low rainfall (June-September)	0.05	> 0.150	H_0 accepted	Rainfall data has a lognormal distribution

It can be concluded that the rainfall amount data that has been adjusted based on the planting period is lognormal distributed.

4.3 Calculation of Sum Insured

The amount of coverage calculated using equation (8) based on the amount of capital and operational costs incurred by farmers in Magelang City is IDR 7,392,500.00/Ha.

4.4 Premium Price Calculation

4.4.1 Premium Price Normal Rainfall

The calculation of premiums for agricultural insurance based on the rainfall index in normal rainfall conditions begins with assessing descriptive statistics, as outlined in Table 8.

Table 8: Descriptive statistics of the normalized rainfall index

Parameters	Value
Average	42.94
Standard Deviation	2.67
Variance	7.10
Maximum	46.81
Minimum	39.09

It is known that the latest rainfall in the normal rainfall state R_0 is in the year 2022 of 561.7 mm. Then H is the trigger value used at each percentile, the value of H = 40.32 mm. T is the selected time period, so the value of t = 0.25. The value of r represents the risk-free interest rate, r = 0.0147. The standard deviation of the rainfall index (σ) is 2.67. After that, the cumulative distribution value is calculated using equation (12).

$$d_2 = \left(\frac{\ln\left(\frac{R_0}{H}\right) + \left(r - \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}\right)$$

$$d_2 = \left(\frac{\ln\left(\frac{561.7}{40.32}\right) + \left(0.0147 - \frac{(2.67)^2}{2}\right)0.25}{2.67\sqrt{0.25}}\right)$$

$$d_2 = 1.31800468$$

$$N(-d_2) = N(-1.31800468) = 0.09375104$$

Then, the same calculation is carried out for other trigger values. Then, the premium value is calculated based on equation (13) with a coverage price of IDR 7,392,500.00/Ha, and $N(-d_2)$ = 0.09375104.

$$\begin{aligned} Premium &= P\,e^{-rT}N(-d_2) \\ &= (\text{IDR } 7{,}392{,}500.00)\left(e^{-(0.0147)(0.25)}\right)(0.09375104) \\ &= \text{IDR } 735{,}973.66 \end{aligned}$$

So, the amount of premium to be paid when choosing H = 40.32 mm is IDR 735,973.66. Table 9 details the applicable premiums for different percentile values during normal rainfall as presented in Table 9.

Table 9: Descriptive statistics of the normalized rainfall index

Percentile	Trigger (mm)	Price Coverage (IDR)	Premium (IDR)
20	40.32	735,973.66	735,973.66
30	41.31	735,973.66	760,300.38
40	41.71	735,973.66	778,139.86
50	42.38	735,973.66	794,679.37
60	43.78	735,973.66	829,121.92
70	45.18	735,973.66	863,522.09
80	45.88	735,973.66	871,698.64

Table 9 shows the amount of premium that must be paid during normal rainfall is IDR 735,973.66 to IDR 871,698.64.

4.4.2 High Rainfall Premium Price

Determination of the price of agricultural insurance premiums based on the rainfall index in high rainfall conditions is first determined by the value of descriptive statistics presented in Table 10.

Table 10: Descriptive statistics of high rainfall index

Parameters	Value
Average	43.86
Standard Deviation	3.06
Variance	9.34
Maximum	48.13
Minimum	39.83

It is known that the latest rainfall at the time of high rainfall R_0 in 2022 is 519.1 mm. The H value is the trigger value used for each percentile, the value of H = 40.03 mm. T is the selected time period, so t = 0.25. The r value is the risk-free interest rate, with r = 0.0147. The standard deviation of the rainfall index (σ) is 3.06. After that, the cumulative distribution value is calculated using equation (12).

$$d_2 = \left(\frac{\ln\left(\frac{R_0}{H}\right) + \left(r - \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \right)$$

$$d_2 = \left(\frac{\ln\left(\frac{519.1}{40.03}\right) + \left(0.0147 - \frac{(3.06)^2}{2}\right)0.25}{3.06\sqrt{0.25}} \right)$$

$$d_2 = 0.91967912$$

$$N(-d_2) = N(-0.91967912) = 0.178870232$$

Then, the same calculation is carried out for other trigger values. Then, the premium value is calculated based on equation (13) with a coverage price of IDR 7,392,500.00/Ha, and $N(-d_2)$ = 0.178870232.

$$\begin{aligned} Premium &= P\, e^{-rT} N(-d_2) \\ &= (\text{IDR } 7{,}392{,}500.00)\left(e^{-(0.0147)(0.25)}\right)(0.178870232) \\ &= \text{IDR } 1{,}404{,}184.75 \end{aligned}$$

Therefore, selecting H = 40.03 mm incurs a premium payment of IDR 1,404,184.75. Table 11 outlines the applicable premium amounts for different percentile values during times of high rainfall.

Table 11: Descriptive statistics of the high rainfall index

Percentile	Trigger (mm)	Price Coverage (IDR)	Premium (IDR)
20	40.03	735,973.66	1,404,184.75
30	41.71	735,973.66	1459,846.05
40	42.92	735,973.66	1,499,520.86
50	43.99	735,973.66	1,534,423.57
60	44.92	735,973.66	1,564,271.66
70	45.83	735,973.66	1,593,053.12
80	47.43	735,973.66	1,643,307.75

Table 11 shows the amount of premium must be paid during high rainfall is IDR 1,404,184.75 to IDR 1,643,307.75.

4.4.3 Low Rainfall Premium Price

Determination of the price of agricultural insurance premiums based on the rainfall index in low rainfall conditions is first determined by the value of descriptive statistics presented in Table 12.

Table 12: Descriptive statistics of low rainfall index

Parameters	Value
Average	10.13
Standard Deviation	7.07
Variance	49.97
Maximum	19.58
Minimum	2.70

It is known for the latest rainfall in a low rainfall state (dry) with R_0 in 2022 of 234.9 mm. The value of H is the trigger value used at each percentile, the value of H = 3.12 mm. T is the selected time period, hence the value t = 0.25. The value of r is the risk-free interest rate, with r = 0.0147. The standard deviation of the rainfall index (σ) is 7.07. After that, the cumulative distribution value is calculated using equation (12).

$$d_2 = \left(\frac{\ln\left(\frac{R_0}{H}\right) + \left(r - \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \right)$$

$$d_2 = \left(\frac{\ln\left(\frac{234.9}{3.12}\right) + \left(0.0147 - \frac{(7.07)^2}{2}\right)0.25}{7.07\sqrt{0.25}} \right)$$

$$d_2 = -0.54155$$
$$N(-d_2) = N(0.54155) = 0.705935702$$

Then, the same calculation is carried out for other trigger values. Then, the premium value is calculated based on equation (13) with a coverage price of IDR 7,392,500.00/Ha, and $N(-d_2)$ = 0.705935702.

$$\begin{aligned} Premium &= P\, e^{-rT} N(-d_2) \\ &= (\text{IDR } 7{,}392{,}500.00)\left(e^{-(0.0147)(0.25)}\right)(0.705935702) \\ &= \text{IDR } 5{,}541{,}806.10 \end{aligned}$$

Consequently, choosing H = 3.12 mm results in a premium payment of IDR 5,541,806.10. Table 13 provides the applicable premium amounts for various percentile at times of low rainfall as shown in Table 13.

Table 13: Descriptive statistics of the low rainfall index

Percentile	Trigger (mm)	Price Coverage (IDR)	Premium (IDR)
20	3.12	735,973.66	5,541,806.10
30	3.92	735,973.66	5,713,187.12
40	5.70	735,973.66	5,979,842,28
50	8.12	735,973.66	6,214,799.89
60	12.45	735,973.66	6,473,260.80
70	17.23	735,973.66	6,651,626.16
80	18.54	735,973.66	6,689,629.88

Table 13 shows the amount of premium must be paid during low rainfall is IDR 5,541,806.10 to IDR 6,689,629.88.

5 Discussion

The exit value is the lowest rainfall data for which no payment is made. The exit value is obtained from the latest average rainfall that has been adjusted to the cap value. Then, the determination of the trigger value is based on the probability of rainfall levels occurring in Magelang City. The amount of insurance premium paid depends on the amount of trigger value obtained from the adjusted rainfall based on the cap value, the greater the trigger value, the greater the insurance premium that must be paid by the farmers. Then, the results of the premiums to be paid by farmers according to the rainfall index to be insured based on normal, high, and low rainfall categories are obtained. The results of the calculation of premiums to be paid during normal rainfall are in Table 9, for high rainfall in Table 11, and low rainfall in Table 13. The calculation results can be used as a reference in determining the insurance premiums to be paid by farmers.

6 Conclussion

Exit values and trigger values are set based on percentile values. While the exit value is set at the tenth percentile, the trigger value is set according to the percentile chosen to determine the premium value. The premium price obtained based on the Black-Scholes method has varying results according to the trigger value chosen by the farmers according to the rainfall category. The premium price with normal rainfall category has a value with a range of IDR 735,739.66 to IDR 871,698.64, for high rainfall the premium price obtained is IDR 1,404,184.75 to IDR 1,643,307.75, and for low rainfall (dry) it is IDR 5,541,806.10 to IDR 6,689,629.88.

References

Abdi, M. *Et Al.* (2022) 'Index-Based Insurance And Hydroclimatic Risk Management In Agriculture: A Systematic Review Of Index Selection And Yield-Index Modelling Methods', *International Journal Of Disaster Risk Reduction*, 67, P. 102653. Available At: Https://Doi.Org/10.1016/J.Ijdrr.2021.102653.

Ariyanti, D., Riaman, R. And Irianingsih, I. (2020) 'Application Of Historical Burn Analysis Method In Determining Agricultural Premium Based On Climate Index Using Black Scholes Method', *JTAM | Jurnal Teori Dan Aplikasi Matematika*, 4(1), P. 28. Available At: Https://Doi.Org/10.31764/Jtam.V4i1.1799.

Dewi, W.S., Sugiarto, Y. And Estiningtyas, W. (2017) 'Analysis Of Climate Index With Historical Burn Analysis Method For Climate Change Adaptation (A Case Study In Pacitan District, East Java)', *Agromet*, 31(1), P. 1. Available At: Https://Doi.Org/10.29244/J.Agromet.31.1.1-10.

Filiapuspa, M.H., Sari, S.F. And Mardiyati, S. (2019) 'Applying Black Scholes Method For Crop Insurance Pricing', In *AIP Conference Proceedings*. American Institute Of Physics Inc. Available At: Https://Doi.Org/10.1063/1.5132469.

Onyeneke, R.U. *Et Al.* (2021) 'Climate Change Perception And Uptake Of Climate-Smart Agriculture In Rice Production In Ebonyi State, Nigeria', *Atmosphere*, 12(11). Available At: Https://Doi.Org/10.3390/Atmos12111503.

S. Qosim, K.D.L.P.I.H. (2018) 'The Pricing Of Agricultural Insurance Premiums Based On Rainfall Index Using Mixed Exponential Distribution Method.', *Mathematics E-Journal*, 7(6), Pp. 141–147.

Tang, Y., Cai, H. And Liu, R. (2021) 'Farmers' Demand For Informal Risk Management Strategy And Weather Index Insurance: Evidence From China', *International Journal Of Disaster Risk Science*, 12(2), Pp. 281–297. Available At: Https://Doi.Org/10.1007/S13753-021-00335-9.

Türkkan, Gökçen Eryılmaz, Türkkan, Gökçen Eryilmaz And Hirca, T. (2019) *Statistical Modeling Of Annual Maximum Of Precipitation Data: A Case Study Of Bayburt Province. Statistical Modeling Of Annual Maximum Of Precipitation Data: A Case Study Of Bayburt Province*. Available At: Https://Www.Researchgate.Net/Publication/336770603.