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THE COVID-19 PANDEMIC EFFECT ON THE DETERMINING CHILLI CROP AGRICULTURAL INSURANCE PREMIUM

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Abstract. *Parametric insurance is a type of insurance that contains an agreement related to triggering events between the insurer and the insured determined at the beginning of the contract. The provision that applies if the triggering event occurs is that the insurer (insurance company) is obliged to pay a sum of money (compensation) to the insured. Insurance based on area yield insurance is parametric insurance. Ozaki formulated an agricultural insurance model based on yields in an area called the parametric method. The loss of this method is a probability for crop loss that is in the area under the density function curve when the yield is smaller than the maximum guaranteed yield, but the losses calculated in this method only include losses due to crop failure and do not include losses due to the COVID-19 pandemic. Meanwhile, Susilowati and Gunawan, in their journals, explained that the production level of agricultural products, especially chili crops, during the COVID-19 pandemic, tended to be stable but not with the demand and purchasing power of the people, which significantly decreased. The significant decline in sales made farmers experience huge losses. Considering the COVID-19 pandemic impact, we were interested in formulating yield-based agricultural insurance models for chili crop that calculates the COVID-19 pandemic risk. So, the premiums rates and premiums obtained are more realistic and can reduce the risk of losses due to the COVID-19 pandemic for farmers, private companies, and the government.*

Keywords: *agricultural insurance, COVID-19, parametric insurance, premiums, premium rates.*

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1. INTRODUCTION

Parametric insurance is a type of insurance that contains an agreement related to triggering events between the insurer and the insured determined at the beginning of the contract [1-3]. The provisions that apply if the triggering event occurs are that the insurer (insurance company) is obliged to pay a sum of money (compensation) to the insured [1], [4-6].

Researches on parametric insurance in agricultural insurance are developed recently because parametric insurance is seen as being able to help farmers, private companies, and the government in reducing losses due to crop failure [7]. The following are some studies on parametric insurance, namely the application of parametric insurance with moral hazard in loan contracts [8], parametric trigger modeling [9], and parametric insurance in managing natural disaster risk in African countries [10].

Agricultural insurance based on the climate index is parametric insurance because it uses climate as an index parameter [5], [11]. For example, the rainfall index and the surface temperature index are triggering events to measure the level of loss of the insured [12]. Not only climate index-based agricultural insurance, price index-based agricultural insurance, and yield-based agricultural insurance are also parametric insurance [1]. In yield-based agricultural insurance, the maximum guaranteed yield based on the level of coverage is a triggering event.

Yield-based agricultural insurance is seen as conventional agricultural insurance because it is based on losses suffered by the insured [5], [13]. The loss is obtained based on the probability of crop loss in the area under the density function curve when the yield is less than the maximum guaranteed yield [14]. The rule is a concept of the parametric method of yield-based agricultural insurance by Ozaki, which is described in the journal "Parametric and nonparametric statistical modeling of crop yield: implications for pricing crop insurance contracts". The level of coverage in determining the maximum guaranteed yield has a limit of 0 to 1, so that the compensation obtained is fair for both the insured and the insurer (insurance company).

Indonesia is one of the countries that implement yield-based agricultural insurance, especially for rice crops, which is called Asuransi Usaha Tani Padi (AUTP) [1]. In AUTP, the government sets the level of coverage from the lightest level (0%) to the heaviest level (100%) as a benchmark of yield losses for the farmers [1]. Researches on yield-based agricultural insurance have been carried out in Indonesia, such as determining the AUTP premium based on rice productivity in Indonesia [15], [16] and determining the premium based on the productivity of shallots in Indonesia [17].

In that parametric method related to yield-based agricultural insurance, coverage for the risk of the COVID-19 pandemic has not been considered. Meanwhile, Gu and Wang, in a study on the impact of COVID-19 on vegetable sales in Shanghai, China, explained that the COVID-19 pandemic had a major impact on the decline in farmers' sales and income levels, which resulted in farmers' losses during the COVID-19 pandemic [18]. Gu and Wang also emphasized that agricultural insurance currently does not cover the risks caused by the COVID-19 pandemic, even though agricultural insurance plays a vital role in stabilizing and reducing the risk of farmers' losses due to the COVID-19 pandemic [18].

Supporting that, Susilowati and Gunawan also explained that the level of consumption and demand of people in Indonesia for agricultural products, especially chili crops is also decreasing, but not with the level of production (crop yield) of chili crops which tends to be stable [19]. The decline in consumption levels and people's demand in Indonesia is caused by government policies that enforce work-from-home (WFH) and large-scale social restrictions (PSBB) in RI Government Regulation No. 21 of 2020, resulting in the damage and rotting of the unsold chili crops [20].

Considering the COVID-19 pandemic impact, we were interested in formulating yield-based agricultural insurance models for chili crop that calculates the COVID-19 pandemic risk, whereas the parametric method of yield-based agricultural insurance by Ozaki is still only limited to losses caused by crop failure and does not include losses due to the COVID-19 pandemic. So, the premiums rates and premiums obtained are more realistic and can reduce the risk of losses due to the COVID-19 pandemic for farmers, private companies, and the government.

2. RESEARCH METHODS

We begin the research by studying literature on parametric insurance in the field of agricultural insurance and yield-based agricultural insurance models, namely the parametric method by Ozaki [14], as well as theoretical distributions that are estimated to be the most appropriate distributions with empirical data and are used as distribution of data on chili crop yield sold in determining premiums rate and agricultural insurance premiums. Then we conducted a case study and field survey at PT Mitra Tani Parahyangan, Cianjur, West Java, to obtain research data on chili crops. The data obtained were processed and analyzed for use in research.

2.1 Data Types and Sources

The data used in this study is data with a ratio measurement scale and is continuous data. The data source was obtained from PT Mitra Tani Parahyangan, Cianjur, West Java, in the form of secondary data for chili crops, namely production data and sales data for chili crops with a monthly time period of 96 months, namely January 2015 to December 2021.

2.2 Data Analysis Procedure

The data analysis procedure for determining premiums rate and premiums for chili agricultural insurance using yield-based agricultural insurance models of chili crop by considering conditions when the COVID-19 pandemic did not occur, conditions during the COVID-19 pandemic, and their combined conditions is presented in Figure 1.

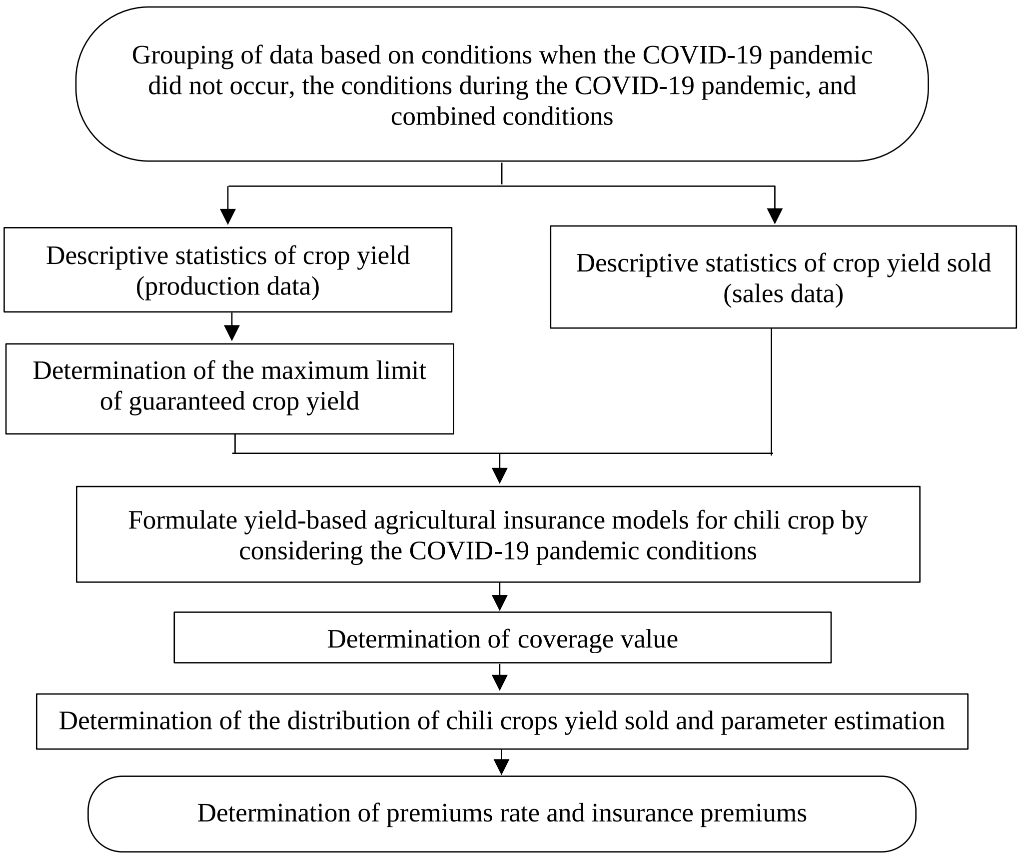


Figure 1. Data Analysis Procedure

3. RESULTS AND DISCUSSION

This section discusses determining premiums rates and premiums for chili agricultural insurance using yield-based agricultural insurance models of chili crops by considering the COVID-19 pandemic conditions.

Let a random variable indicator of the occurrence of a COVID-19 pandemic be denoted by I, then the research conditions are grouped into three conditions, namely conditions when the COVID-19 pandemic did not occur $(I = 0)$, conditions during the COVID-19 pandemic $(I = 1)$, and the combined conditions of COVID-19 pandemic did not occur and during the COVID-19 pandemic $(I = 0 \cup I = 1)$.

Therefore, considering the conditions of the COVID-19 pandemic, the researcher formulates yield-based agricultural insurance models by assuming 3 conditions, namely conditions when the COVID-19 pandemic did not occur $(I = 0)$, conditions during the COVID-19 pandemic $(I = 1)$, and the combined conditions of the COVID-19 pandemic did not occur and during the COVID-19 pandemic $(I = 0 \cup I = 1)$, where I is a random variable indicator of the occurrence of a COVID-19 pandemic.

3.1. Data Description

Data obtained from PT Mitra Tani Parahyangan is monthly data in the form of production data and data on sales of chili crops from January 2015 to December 2021 in kilograms. The data is then observed for descriptive statistics such as the mean, skewness, and kurtosis values and boxplots to see the characteristics of the data. The research data in the discussion are divided based on three research conditions:

1. Data from 2015 to 2019 for conditions $(I = 0)$
2. Data from 2020 to 2021 for conditions $(I = 1)$
3. Data from 2015 to 2021 for conditions $(I = 0 \cup I = 1)$

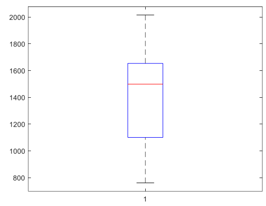
3.1.1 Crop Yields Description

Processing of chili crop yield data (chili production data) of PT Mitra Tani Parahyangan was carried out to observe descriptive statistics. Let the random variables of crop yields with conditions $(I = 0)$, $(I = 1)$ and $(I = 0 \cup I = 1)$ be denoted by Y_0, Y_1, and Y, respectively. The descriptive statistical values are presented in Table 1.

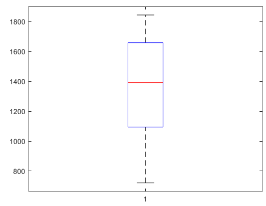
Table 1. Description of Chili Crop Yield Data

Data statistics	Y_0	Y_1	Y
Min	761	721	721
Q1	1062	1105	1105
Median	1499	1392	1482
Q3	1656	1656	1656
Mean	1400	1369	1392
Max	2016	1844	2016
Variance	139850	123100	133723
Skewness	-0.39	-0.46	-0.40
Kurtosis	1.99	1.91	1.99

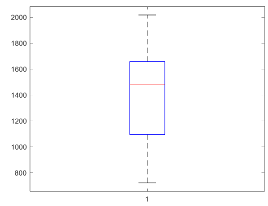
A negative skewness value means the curve is skewed to the left and a positive value means the curve is skewed to the right. Meanwhile, the kurtosis value is less than 3, meaning that the data distribution is a platykurtic distribution where the peaks are more evenly distributed. The following shows the boxplot of the random variables Y_0, Y_1, and Y, which are presented in Figure 2.



(a)



(b)



(c)

Figure 2. Boxplot of chili crop yield data: (a) Random Variable Y_0, (b) Random Variable Y_1, (c) Random Variable Y

Based on Table 1 and Figure 2, it can be concluded that the data curve of the random variables Y_0, Y_1 and Y is skewed to the left because it has a negative value and has a longer bottom whisker boxplot, and a more even distribution peak (platykurtic distribution) due to the lower kurtosis value of 3.

The mean value or expected value of chili crop yields from the random variables Y_0, Y_1 and Y, respectively be denoted by the random variables y_0^e, y_1^e and y^e. The expected value of chili crop yields is presented in Table 2.

Table 2. The Expected Value of Chili Crop Yields

y_0^e	y_1^e	y
1400	1369	1392

The expected value of chili crop yields in Table 2 is used to obtain the maximum limit of guaranteed crop yields by using the yield percentage (λ). The maximum limit of guaranteed crop yields is a benchmark used by the insurer (insurance company) to provide compensation to the insured. Compensation will be given if the yields sold are less than or equal to the maximum limit of guaranteed crop yields; otherwise, compensation will not be given if the crop sold is more than the maximum limit guaranteed crop yields because it means that the insured does not suffer a significant loss. The variable of λ is the percentage of yields covered with a limit of $0 < \lambda < 1$ to limit the size of a premium. Therefore if the value λ is close to 1, then the premium will be bigger, and if the value of λ is getting closer to 0, then the premium will be smaller. The choice of λ also affects the maximum limit of guaranteed crop yields and the coverage value in determining the premium. The maximum limit of guaranteed crop yields based on the selected values of λ is presented in Table 3.

Table 3. The Maximum Limit of Guaranteed Chili Crop Yields

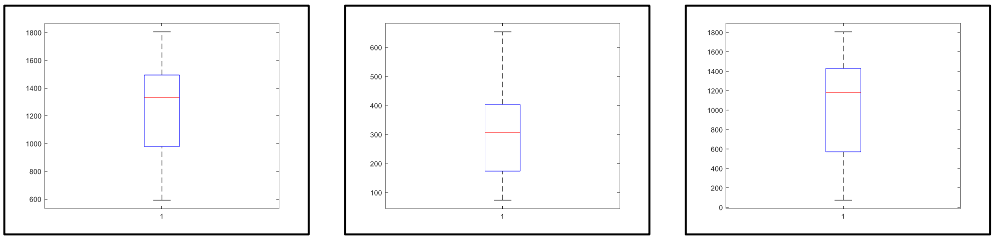
λ	λy_0^e	λy_1^e	λy^e
55%	770	752.95	765.6
65%	910	889.85	904.8
75%	1050	1026.75	1044
85%	1190	1163.65	1183.2
100%	1400	1369	1392

3.1.2 Crop Yields Sold Description

Processing of chili crop yield sold data (chili crop sales data) by PT Mitra Tani Parahyangan was carried out to observe descriptive statistics and characteristics of the data. Let the random variables of chili crop yield sold with conditions ($I = 0$), ($I = 1$), and ($I = 0 \cup I = 1$) be denoted by X_0, X_1 and X, respectively. Descriptive statistical values and boxplot random variables X_0, X_1 and X are presented in Table 4 and Figure 3.

Table 4. Description of chili crop yield sold data

Data statistics	X_0	X_1	X
Min	592	73.75	73.75
Q1	903	180	578
Median	1332	308	1180
Q3	1500	398	1426
Mean	1265	320	995
Max	1805	654	1805
Variance	124767	26570	280502
Skewness	-0.48	0.50	-0.22
Kurtosis	2.12	2.42	1.65



(a) (b) (c)

Figure 3. Boxplot of chili crop yield sold data: (a) Random Variable X_0, (b) Random Variable X_1, (c) Random Variable X

Analogous to Sub Section 3.1.1 based on Table 4 and Figure 3, it can be concluded that the data curve of the random variables X_0 and X is skewed to the left because it is negative and has a longer bottom whisker boxplot. Meanwhile, the data curve for the random variable X_1 is skewed to the right because it is positive and has a longer whisker over the boxplot. The data kurtosis of the random variables X_0, X_1, and X is less than 3 means that the distribution of these data has a more even peak distribution (platykurtic distribution).

3.2 Chili Crop Agricultural Insurance Model

The parametric method [14] discusses yield-based agricultural insurance models that assume that agricultural yields follow a certain distribution. The probability of losing agricultural yields is the area under the density function curve when the yield is less than the maximum limit of guaranteed yield. That agricultural insurance model did not pay attention to abnormal conditions such as the COVID-19 pandemic.

Therefore, considering the conditions of the COVID-19 pandemic, the researcher formulates yield-based agricultural insurance models by assuming 3 conditions, namely conditions when the COVID-19 pandemic did not occur ($I = 0$), conditions during the COVID-19 pandemic ($I = 1$), and the combined conditions of the COVID-19 pandemic did not occur and during the COVID-19 pandemic ($I = 0 \cup I = 1$), where I is a random variable indicator of the occurrence of a COVID-19 pandemic.

Let the probability density function of the random variables X_0, X_1 and X be denoted by $f_0(x_0)$, $f_1(x_1)$ and $f(x)$ respectively, and let the cumulative distribution function of the random variables X_0, X_1 and X be denoted by $F_0(x_0)$, $F_1(x_1)$ and $F(x)$ respectively. The amount of the loss or the nominal amount of compensation given by the insurer (insurance company) is the difference between the maximum limit of guaranteed crop yields and the sold crop yields actually. Let a random variable that states the amount of loss of crops sold be denoted by K, then the agricultural insurance model is presented as follows:

$$\{K|I=0\} = \begin{cases} \lambda y_0^e - X_0, & X_0 \le \lambda y_0^e \\ 0, & X_0 > \lambda y_0^e \end{cases} \tag{1}$$

$$\{K|I=1\} = \begin{cases} \lambda y_1^e - X_1, & X_1 \le \lambda y_1^e \\ 0, & X_1 > \lambda y_1^e \end{cases} \tag{2}$$

where:

I : Random variable indicator of the occurrence of the COVID-19 pandemic
$I = 0$: Nonoccurrence Covid-19 pandemic
$I = 1$: Occurrence Covid-19 pandemic
λ : The percentage of yields covered

Based on the agricultural insurance model in Equations (1) and (2), the expected value of the random variable K with conditions ($I = 0 \cup I = 1$) can be obtained as follows:

$$E(K) = E(E(K|I)) = [E(K|I=0) * P(I=0)] + [E(K|I=1) * P(I=1)] \tag{3}$$

where the expected value of the random variable K when ($I = 0$) and ($I = 1$) are,

$$\begin{aligned} E(K|I=0) &= \int_0^{\lambda y_0^e} (\lambda y_0^e - x_0)\ f_0(x_0)\ dx_0 \\ &= \lambda y_0^e\, F_0(\lambda y_0^e) - [E(X_0|X_0 < \lambda y_0^e)\, F_0(\lambda y_0^e)] \\ &= F_0(\lambda y_0^e)[\lambda y_0^e - E(X_0|X_0 < \lambda y_0^e)] \end{aligned} \tag{4}$$

$$E(K|I=1) = \int_0^{\lambda y_1^e} (\lambda y_1^e - x_1)\ f_1(x_1)\ dx_1$$

$$= \lambda y_1^e \, F_1(\lambda y_1^e) - [E(X_1|X_1 < \lambda y_1^e) \, F_1(\lambda y_1^e)]$$
$$= F_1(\lambda y_1^e)[\lambda y_1^e \, - E(X_1|X_1 < \lambda y_1^e)] \tag{5}$$

Based on Equations (3), (4), and (5), the premium rate can be obtained considering the normal conditions and the conditions of the COVID-19 pandemic as follows:

$$TP_{I=0 \,\cup\, I=1} = \frac{E(K|I=0)}{\lambda y_0^e}\big(P(I=0)\big) + \frac{E(K|I=1)}{\lambda y_1^e}\big(P(I=1)\big) \tag{6}$$

where the premium rates when $(I = 0)$ and $(I = 0)$ are,

$$TP_{I=0} = \frac{E(K|I=0)}{\lambda y_0^e} = \frac{F_0(\lambda y_0^e)[\lambda y_0^e - E(X_0|X_0 < \lambda y_0^e)]}{\lambda y_0^e} \tag{7}$$
$$TP_{I=1} = \frac{E(K|I=1)}{\lambda y_1^e} = \frac{F_1(\lambda y_1^e)[\lambda y_1^e - E(X_1|X_1 < \lambda y_1^e)]}{\lambda y_1^e} \tag{8}$$

Based on Equations (6), (7), and (8), the premium can be obtained with the coverage value applicable to the conditions $(I = 0)$, $(I = 1)$, and $(I = 0 \cup I = 1)$ as follows:

$$\text{Premium (Rp)} = TP \times \text{The Coverage Value} \tag{9}$$

3.3 Coverage Value

The coverage value of chili crop agricultural insurance is obtained based on the production costs of PT Mitra Tani Parahyangan, including seeds, fertilizers, pesticides, polybags, ropes, land rent, and other uses in the amount of Rp 13,000,000 per hectare in one season. In addition to production costs, the coverage value is also obtained based on the percentage of yields covered (λ) by the insured. The coverage value based on production costs and the percentage of yields covered (λ) is presented in Table 5.

Table 5. The Coverage Value of Chili Crop Agricultural Insurance

The Percentage of Yields Covered $(\boldsymbol{\lambda})$	The Coverage Value
55%	Rp 7.150.000
65%	Rp 8.450.000
75%	Rp 9.750.000
85%	Rp 11.050.000
100%	Rp 13.000.000

The percentage of yields covered (λ) recommended based on the Regulation of the Ministry of Agriculture of the Republic of Indonesia on Asuransi Usaha Tani Padi (AUTP) in 2016 is 75%. Therefore, based on Table 5, the coverage value with the percentage of yields covered (λ) 75% is Rp. 9,750,000.

3.4 The Distribution of Chili Crop Yield Sold and Parameter Estimation

In this section, the theoretical distribution that most closely matches the distribution of empirical data on chili crop yields is sought. Testing the suitability of the theoretical distribution using the Kolmogorov-Smirnov (K-S), Anderson-Darling (A-D), and Akaike's Information Criterion (AIC) tests. In the Kolmogorov-Smirnov (K-S) test, the distribution obtained is the distribution with the lowest error value. Meanwhile, in the Anderson-Darling (A-D) test, the distribution obtained is determined by comparing the extreme values in the data [21]. Let a random variable that states a certain theoretical distribution to be tested for its suitability with the distribution of random variables X_0 and X_1 be denoted by T, then the following is the hypothesis used as the basis for concluding the Kolmogorov-Smirnov (K-S) and Anderson-Darling (A-D) tests.

H_0 : Data came from the T distribution
H_1 : Data did not come from the T distribution

3.4.1 The Distribution of Yield Sold with The Condition $(I = 0)$ and Parameter Estimation

The test results of Kolmogorov-Smirnov (K-S) and Anderson-Darling (A-D) with the help of Easyfit software for determining the distribution of data on the random variable X_0 are presented in Table 6.

Table 6. Kolmogorov-Smirnov (K-S) and Anderson-Darling (A-D) Tests for the Distribution of Random Variables X_0

Distribution	Statistical Value	
	Kolmogorov-Smirnov (K-S)	Anderson-Darling (A-D)
Johnson SB	0.10912	9.2232
Gen Pareto	0.12261	22.896
Gen Extreme Value	0.13029	1.1435
Cauchy	0.15135	1.83

The test results in Table 6 state that H_0 is not rejected or in other words, the random variable data X_0 came from the T distribution with the distribution of T analyzed are the distribution of Johnson SB, Gen Pareto, Gen Extreme Value, and Cauchy in the K-S test, and the distribution of Gen Extreme Value and Cauchy in the A-D test. The conclusion is obtained considering the statistical value < critical value with the critical value in the K-S and A-D tests are 0.17231 and 2.5018, respectively.

Based on the results of the Kolmogorov-Smirnov (K-S) and Anderson-Darling (A-D) hypothesis testing, it was found that the random variable data X_0 came from the Gen Extreme Value and Cauchy distributions. The distributions are then parameter estimated using the maximum likelihood estimates (MLE) method and compared with the Akaike's Information Criterion (AIC) values presented in Table 7.

Table 7. Parameter Value and AIC Value for the Distribution of Random Variables X_0

Distribution	Parameter value	AIC value
Gen Extreme Value	$\hat{k} = -0.52709; \hat{\sigma} = 384.68; \hat{\mu} = 1183.1$	-858.26
Cauchy	$\hat{\sigma} = 172.85; \hat{\mu} = 1367.5$	-886.44

The distribution with the smallest AIC value based on Table 7 is the Cauchy distribution. This means that the Cauchy distribution is the most suitable distribution for the random variable X_0 data. The following shows the Cauchy distribution curve with a histogram of the random variable data X_0 in Figure 4.

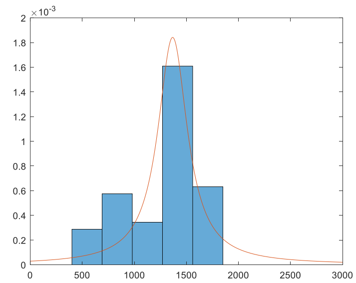


Figure 4. Cauchy Distribution Curve for Random Variable X_0

3.4.2 The Distribution of Yield Sold with The Condition $(I = 1)$ and Parameter Estimation

The test results of Kolmogorov-Smirnov (K-S) and Anderson-Darling (A-D) with the help of Easyfit software for determining the distribution of data on the random variable X_1 are presented in Table 8.

Table 8. Kolmogorov-Smirnov (K-S) and Anderson-Darling (A-D) Tests for the Distribution of Random Variables X_1

Distribution	Statistical Value	
	Kolmogorov-Smirnov (K-S)	Anderson-Darling (A-D)
Burr	0.08769	0.29164
Gen Extreme Value	0.09049	0.27394
Lognormal (3P)	0.09789	0.31759
Gamma	0.09967	0.33291

The test results in Table 8 state that H_0 is not rejected or in other words, the random variable data X_1 came from the T distribution with the distribution of T analyzed are the distribution of Burr, Gen Extreme Value, Lognormal (3P), and Gamma in the K-S and A-D test. The conclusion is obtained considering the statistical value < critical value with the critical value in the K-S and A-D tests are 0.26931 and 2.5018, respectively.

Based on the results of the Kolmogorov-Smirnov (K-S) and Anderson-Darling (A-D) hypothesis testing, it was found that the random variable data X_1 came from the Burr, Gen Extreme Value, Lognormal (3P), and Gamma distributions. The distributions are then parameter estimated using the maximum likelihood estimates (MLE) method and compared with the Akaike's Information Criterion (AIC) values presented in Table 9.

Table 9. Parameter Value and AIC value for the Distribution of Random Variables X_1

Distribution	Parameter value			AIC value
Burr	$\hat{k} = 94.354$	; $\hat{\alpha} = 2.148$	; $\hat{\beta} = 2999.8$	-302.90
Gen Extreme Value	$\hat{k} = -0.06701$	; $\hat{\sigma} = 142.77$	; $\hat{\mu} = 246.82$	-303.66
Lognormal (3P)	$\hat{\gamma} = -155.78$	; $\hat{\sigma} = 0.33998$	; $\hat{\mu} = 6.1088$	-303.55
Gamma	$\hat{\alpha} = 3.8613$	; $\hat{\beta} = 82.953$		-303.01

The distribution with the smallest AIC value based on Table 9 is the Gen Extreme Value distribution. This means that the Gen Extreme Value distribution is the most suitable distribution for the random variable X_1 data. The following shows the Gen Extreme Value distribution curve with a histogram of the random variable data X_1 in Figure 5.

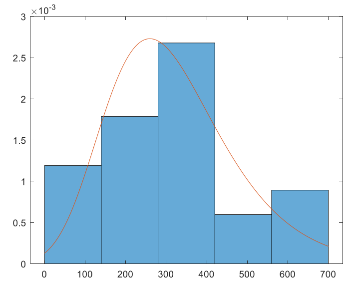


Figure 5. Gen Extreme Value Distribution Curve for Random Variable X_1

3.5 Premium Rates and Premiums of Crop Yield Sold

Determination of the distribution is a step in determining insurance premiums rate and based on Section 3.4, it is found that the distributions that are most suitable for the random variables X_0 and X_1 are Cauchy and Gen Extreme Value, respectively. The value of the probability density function and the cumulative distribution function are determined by that distributions to obtain the expected loss value of the distribution and compared with the empirical data.

3.5.1 Premium Rates and Premiums of Crop Yield Sold with the Condition $(I = 0)$

The following is the probability density function and the cumulative distribution function of the Cauchy distribution with the scale (σ) and location (μ) parameters [22]:

The probability density function of X_0, denoted $f_0(x)$ is

$$f_0(x) = \left(\pi\sigma\left(1 + \left(\frac{x-\mu}{\sigma}\right)^2\right)\right)^{-1} \text{ for } -\infty < x < +\infty \text{ and } x \in \mathbb{R} \quad (10)$$

The cumulative distribution function of X_0, denoted $F_0(x)$ is

$$F_0(x) = \frac{1}{\pi} arctan\left(\frac{x-\mu}{\sigma}\right) + 0.5 \text{ for } -\infty < x < +\infty \text{ and } x \in \mathbb{R} \quad (11)$$

Conditional expectation value of X_0, denoted $E[X_0|X_0 < x]$ is

$$E[X_0|X_0 < x] = \frac{1}{F_0(x)}\int_{-\infty}^{\infty} x\, f_0(x)\, dx = \frac{1}{F_0(x)}\int_0^x x\left(\pi\sigma\left(1+\left(\frac{x-\mu}{\sigma}\right)^2\right)\right)^{-1} dx \qquad (12)$$

The value of the Cauchy distribution parameter and the maximum limit of guaranteed crop yields value in Tables 3 and 7 are substituted for the probability density function and the cumulative distribution function of the Cauchy distribution to obtain the expected loss value. The expected loss value is then used to calculate premium rates and insurance premiums based on the agricultural insurance model in section 3.2.

The following is the calculation of the expected loss value in Equation (4) by substituting the value of the cumulative distribution function and the conditional expected value of the Cauchy distribution based on Equations (10), (11) and (12), and the parameter values $\hat{\sigma} = 172.85$, $\hat{\mu} = 1367.5$ and $\lambda y_0^e = 1050$ with λ in the amount of 75%.

$$E(K|I = 0) = 0.1587[1050 - 558.5787] = 77.9886$$

The expected loss value obtained based on the Cauchy distribution has a value that is close to the empirical data, it is 80.6125. This means that the Cauchy distribution based on the results of the analysis is the most suitable distribution for the random variable X_0. Therefore, that expected loss value can be used to determine the premium rates and premiums based on Equations (7) and (9). Using several selected percentages of yields covered (λ), the following are the premium rates and premiums for the Cauchy distribution, which are presented in Table 10.

Table 10. Premium rates and premiums of distribution Cauchy

Percentages of yields covered ($\boldsymbol{\lambda}$)	The coverage value	Premium rates of distribution Cauchy	Premiums
55%	Rp 7.150.000	5.8380%	Rp 417.417
65%	Rp 8.450.000	6.4983%	Rp 549.102
75%	**Rp 9.750.000**	**7.4275%**	**Rp 724.179**
85%	Rp 11.050.000	8.8681%	Rp 979.926
100%	Rp 13.000.000	13.2986%	Rp 1.728.818

3.5.2 Premium Rates and Premiums of Crop Yield Sold with The Condition ($\boldsymbol{I = 1}$)

The following is the probability density function and the cumulative distribution function of *Gen Extreme Value* distribution with the shape (k), scale (σ), and location (μ) parameters [22]:

The probability density function of X_1, denoted $f_1(x)$ is

$$f_1(x) = \begin{cases} \frac{1}{\sigma}\exp\left(-\left(1+k\left(\frac{x-\mu}{\sigma}\right)\right)^{-\frac{1}{k}}\right)\left(1+k\left(\frac{x-\mu}{\sigma}\right)\right)^{-1-\frac{1}{k}}, & \text{for } 1+k\frac{(x-\mu)}{\sigma} > 0 \text{ and } k \neq 0; \\ \frac{1}{\sigma}\exp\left(-\left(\frac{x-\mu}{\sigma}\right) - exp\left(-\left(\frac{x-\mu}{\sigma}\right)\right)\right), & \text{for } -\infty < x < +\infty \text{ and } k = 0. \end{cases} \qquad (13)$$

The cumulative distribution function of X_1, denoted $F_1(x)$ is

$$F_1(x) = \begin{cases} \exp\left(-\left(1+k\left(\frac{x-\mu}{\sigma}\right)\right)^{-\frac{1}{k}}\right), & \text{for } 1+k\frac{(x-\mu)}{\sigma} > 0 \text{ and } k \neq 0; \\ \exp\left(-exp\left(-\left(\frac{x-\mu}{\sigma}\right)\right)\right), & \text{for } -\infty < x < +\infty \text{ and } k = 0. \end{cases} \qquad (14)$$

Conditional expectation value of X_1, denoted $E[X_1|X_1 < x]$ is

$$E[X_1|X_1 < x] = \frac{1}{F_1(x)}\int_0^x x\left(\frac{1}{\sigma}\exp\left(-\left(1+k\left(\frac{x-\mu}{\sigma}\right)\right)^{-\frac{1}{k}}\right)\left(1+k\left(\frac{x-\mu}{\sigma}\right)\right)^{-1-\frac{1}{k}}\right)dx. \qquad (15)$$

Analogous to Subsection 3.5.1, the following is the calculation of the expected loss value in Equation (5) by substituting the value of the cumulative distribution function and the conditional expected value of the Gen Extreme Value distribution based on Equations (13), (14), and (15), and the parameter values histogram $\hat{k} = -0.06701$, $\hat{\sigma} = 142.77$, $\hat{\mu} = 246.82$ and $\lambda y_1^e = 1026.75$ with λ in the amount of 75%.

$$E(K|I=1) = 0.9989\,[1026.75 - 319.5873] = 706.3848$$

The expected loss value obtained based on the Gen Extreme Value distribution has a value that is close to the empirical data, it is 706.45. This means that the Gen Extreme Value distribution based on the results of the analysis is the most suitable distribution for the random variable X_1. Therefore, that expected loss value can be used to determine the premium rates and premiums based on Equations (8) and (9). Using several selected percentages of yields covered (λ), the following are the premium rates and premiums for the Gen Extreme Value distribution, which are presented in Table 11.

Table 11. Premium Rates and Premiums of Distribution Gen Extreme Value

Percentages of yields covered $(\boldsymbol{\lambda})$	The coverage value	Premium rates of distribution Gen Extreme Value	Premiums
55%	Rp 7.150.000	57.67%	Rp 4.123.691
65%	Rp 8.450.000	64.04%	Rp 5.411.008
75%	**Rp 9.750.000**	**68.80%**	**Rp 6.707.818**
85%	Rp 11.050.000	72.46%	Rp 8.007.018
100%	Rp 13.000.000	76.59%	Rp 9.956.856

3.5.3 Premium Rates and Premiums of Crop Yield Sold with the Condition $(\boldsymbol{I=0 \cup I=1})$

Based on the premium rates and premiums of chili crop yields sold in Subsections 3.5.1 and 3.5.2, premium rates and premiums can be obtained considering the normal conditions and the conditions of the COVID-19 pandemic $(I=0 \cup I=1)$.

Considering the number of pandemics that have occurred throughout AD [23], the probability of occurrence Covid-19 pandemic is $P(I=1)=0.0099$, and the probability of nonoccurrence Covid-19 pandemic is $P(I=0)=0.9901$. Using the probability and Equation (3) on the agricultural insurance model and the expected loss value of the random variables X_0 and X_1 which have been obtained in Subsections 3.5.1 and 3.5.2, the following is the expected loss value of the random variable X, which considering the normal conditions and the conditions of the COVID-19 pandemic $(I=0 \cup I=1)$ is presented in Table 12.

Table 12. The Expected Loss Value of Chili Crop Yield Sold

Percentages of yields covered $(\boldsymbol{\lambda})$	$\boldsymbol{E(K|I=0)}$	$\boldsymbol{E(K|I=1)}$	$\boldsymbol{E(K)}$
55%	44.95	434.26	48.80
65%	59.13	569.82	64.19
75%	77.98	706.38	84.19
85%	105.53	843.20	112.83
100%	186.18	1048.53	194.71

Then based on the expected loss value of the random variable X in Table 12 and Equation (6) on the agricultural insurance model, premium rates are obtained considering the normal conditions and the conditions of the COVID-19 pandemic $(I=0 \cup I=1)$ with the coverage value presented in Table 13.

Table 13. The Premium Rates of Chili Crop Yield Sold

Percentages of yields covered $(\boldsymbol{\lambda})$	Premium rates (%)		
	$(\boldsymbol{I=0})$	$(\boldsymbol{I=1})$	$(\boldsymbol{I=0 \cup I=1})$
55%	5.84	57.67	6.35%
65%	6.5	64.04	7.07%
75%	7.43	68.8	8.03%
85%	8.87	72.46	9.50%
100%	13.3	76.59	13.92%

Based on the premium rates $(I=0 \cup I=1)$ in Table 13 and Equation (9) on the agricultural insurance model, premiums are obtained considering the normal conditions and the conditions of the COVID-19 pandemic $(I=0 \cup I=1)$ presented in Table 14.

Table 14. The Premium Rates of Chili Crop Yield Sold

Percentages of yields covered (λ)	The coverage value	Premium ($I = 0$)	Premium ($I = 1$)	Premium ($I = 0 \cup I = 1$)
55%	Rp 7.150.000	Rp 417.417	Rp 4.123.691	Rp 454.077
65%	Rp 8.450.000	Rp 549.102	Rp 5.411.008	Rp 597.192
75%	**Rp 9.750.000**	**Rp 724.179**	**Rp 6.707.818**	**Rp 783.321**
85%	Rp 11.050.000	Rp 979.926	Rp 8.007.018	Rp 1.049.437
100%	Rp 13.000.000	Rp 1.728.818	Rp 9.956.856	Rp 1.810.208

4. CONCLUSIONS

In this research, we were able to formulate yield-based agricultural insurance models for chili crops by considering the COVID-19 pandemic conditions. Based on that model, the premium rates and premiums obtained are more realistic in accordance with current conditions. Therefore, it is hoped that the premium can reduce the risk of losses due to the COVID-19 pandemic for farmers, private companies, and the government.

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