# Determining Tomato Crop Agricultural Insurance Premium for COVID-19 Pandemic

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## ABSTRACT

One type of insurance known as parametric insurance has an agreement for predetermined events made at the beginning of the contract between the insurer (insurance firm) and the insured (farmer). When the causative event occurs, the provision applies that insurer must pay insured with some amount of money (damage compensation). Ozaki has formulated parametric method of premium rates for agricultural insurance build upon yields in specific area. Indonesian Ministry of Agriculture uses this method to ensure that farmers can re-plant crops in following planting season if a crop failure occurs. However, the COVID-19 pandemic's losses were not covered by this method. Given this, we would like to develop agricultural insurance models for tomato crops which figure out COVID-19 pandemic. For make it easier to see the price of tomato commodity due to impact of COVID-19 pandemic, in this research we will take a case study on agriculture managed by PT Mitra Tani Parahyangan. This company is engaged in the horeca business, so it has been greatly affected by the quarantine policy. The results of this study are suggestions for policy makers in anticipation if a pandemic occurs again, it help farmers and Indonesia's food availability will be maintained.

**Keywords**: agricultural insurance; COVID-19; parametric insurance; premium

## INTRODUCTION

Corona virus disease 2019 (COVID-19) suddenly spread rapidly throughout the world and hit various aspect of life such as health, economic, social and others [1], [2]. All sectors affected by the pandemic are struggling to survive, but some have been hit harder than others. Agriculture has become a vulnerable sectors affected by this pandemic [3]. For a nation like Indonesia, where many people still rely on the agricultural sector, this is a complicated situation [4]. Research have examined the pandemic's effects on agriculture from a various aaspects of life [5], [6]. Some studies examined the impact of the pandemic on food security [7], while others concentrated on the effects of the pandemic on agricultural supply chains [8] and others examined the impact of the pandemic on food safety [9]. Concerning the impact of pandemics on agriculture, two problems must be solved: the first is to guarantee the production and supply of agricultural goods, and the second is to maintain farmers' income, which in turn affects

the production of agricultural commodities [10]. A risk in agricultural production and operation is the effects of pandemics, and agricultural insurance is a key tool for managing agricultural risks [11]. Agricultural insurance is generally categorized into two types, namely loss insurance and parametric insurance. Loss insurance is insurance that provides a claim if the insured suffers a loss. Meanwhile, parametric insurance is insurance that pays claims to the insured only if a mutually agreed trigger event occurs. One of the well-known agricultural insurances in Indonesia is *Asuransi Usaha Tani Padi* (AUTP), which is agricultural insurance with the type of loss insurance [12].

AUTP insurance is a form of coverage assistance from the government to rice farmers. Some research have examined the determination of the AUTP premium based on productivity in an area for a certain period of time [13] [14], while Sugiarti conducted research on determining agricultural insurance premiums for shallot commodity [15]. Until now, the Indonesian Ministry of Agriculture and experts are trying to formulate agricultural insurance on agricultural commodities other than rice [16]. Therefore, this research will offer a premium determination using the parametric method with the COVID-19 pandemic as a triggering event for tomato commodity. Tomato commodity very potential to be cultivated in Indonesia, because it can be planted widely from lowlands to highlands [17]. In addition, the growth did not only in certain seasons, so it is easy to obtain at any time [18]. Nationally, tomatoes are not a commodity that is often used as a superior commodity or a benchmark for fluctuations in vegetable prices. Therefore, the tomato commodity has not received price protection from the government and is still based on supply from farmers so at certain times it faces a price reduction, even though the daily people's demand for tomatoes is relatively high [19].

## METHODS

### The Data

This research uses study cases method which is secondary data. Secondary data in this study contain tomato yields and sales of tomato plants per month at PT Mitra Tani Parahyangan starting from the beginning of 2015 to the end of 2021 in kilograms. Several things to note is that sometimes PT Mitra Tani Parahyangan got market demand that exceeds the tomato harvest from their farmers. To solve this, the marketing manager takes tomato crops from farmers in the surrounding area which is not their partner.

**Table 1.** Tomato Yields and Sales Result of PT Mitra Tani Parahyangan

| No. | Time | Tomato Yields (kg) | Sales Result (kg) |
|---|---|---|---|
| 1 | January 2015 | 3193 | 4219 |
| 2 | February 2015 | 5347 | 5114 |
| ⋮ | ⋮ | ⋮ | ⋮ |
| 83 | November 2021 | 4845 | 3131 |
| 84 | December 2021 | 3105 | 3873 |

### Parametric Method in Insurance

The parametric method makes the assumption that crop yields fit with specific distributions. When the yield falls below the guaranteed yield, the probability of yield loss in agriculture is equal to the area under the density function's curve. Let $\alpha$ denote the level of coverage, where $0 < \alpha < 1$ and $y^e$ represents the expected yield. The loss probability

can be calculated over the area under the density function by using trapezoidal rule to estimate it numerically. The premium in the form of rate denote as [20]:

$$\text{premium rate} = \frac{E[L]}{\lambda y^e} = \frac{F_Y(\lambda y^e)E_Y(\lambda y^e - (Y|Y < \lambda y^e))}{\lambda y^e} \tag{1}$$

Where:

$E[L]$ : Expected value from loss distribution
$\lambda y^e$ : Maximum guaranteed tomato crop yields
$F_Y$ : Cumulative distribution function from distribution $Y$
$E_Y$ : Expected value from distribution $Y$

**Anderson Darling Test**

Anderson Darling test is used to test the normality of a data (normality test). The data needs to follow a normal distribution because the test statistic used in parametric analysis for parameter estimation is derived from a normal distribution. The decision making process on the Anderson Darling test is to use the critical value. If the statistical value < critical value then reject $H_0$, whereas if the statistical value > critical value then accept $H_0$ with a value of $\alpha$(significant level) $= 0.01, 0.05, 0.10, \dots etc$ [20].

**Kolmogorov-Smirnov Test**

The Kolmogorov-Smirnov test is one type goodness of fit test. In this case what is considered is the degree of correspondence between the distribution of sample values (observed scores) and certain theoretical distributions. The advantage of this test is that it is simple and does not cause differences in perception between one researcher and another, which often occurs in normality tests using graphs. The basic concept of decision making in the Kolmogorov-Smirnov test uses use the critical value. If the statistical value < critical value then reject $H_0$, whereas if the statistical value > critical value then accept $H_0$ with a value of $\alpha$(significant level) $= 0.01, 0.05, 0.10, \dots etc$ [20].

**Akaike's Information Criterion (AIC)**

AIC is a measure for selecting the best distribution introduced by Hirotugu Akaike in 1973 with the equation:

$$AIC = -2l(x|\hat{\theta}) + 2k = -2\log L(x|\hat{\theta}) + 2k \tag{2}$$

Where:

$\log L(x|\hat{\theta})$ : Log-likelihood function
$x$ : Empirical data
$k$ : Number of parameters

The first part $-2l(x|\hat{\theta})$ is the fit measure for the selected distribution and the second part $2k$ is the rule requirement for the complexity of the distribution. According to the AIC method, the best distribution is the distribution that has the smallest AIC value [22].

**RESULTS AND DISCUSSION**

The data in Table 1 will be divided into three time periods:
1. Before COVID-19 pandemic occurs, from January 2015 to December 2019 notated as $T = 0$.
2. When COVID-19 pandemic occurs, from January 2020 to December 2021 notated as $T = 1$.
3. From January 2015 to December 2021 notated as $T = 0 \cup T = 1$.

## Tomato Yields Description

Let random variables of tomato yields in time periods $T = 0$, $T = 1$ and $T = 0 \cup T = 1$ are $M_0$, $M_1$ and $M$ descriptive statistic value is shown by Table 2.

**Table 2.** Descriptive Statistic of Tomato Yields

| Data | $M_0$ | $M_1$ | $M$ |
|------|-------|-------|-----|
| *Min* | 3015 | 3105 | 3015 |
| *Mean* | 7115.8 | 7854 | 7326.7 |
| *Max* | 14743 | 18448 | 18448 |
| *Skewness* | 0.791 | 1.234 | 1.153 |
| *Kurtosis* | 2.868 | 3.495 | 3.958 |

Table 2 shows that $M_0, M_1$ and $M$ have positive skewness value that means they have right skewed curve. Meanwhile the average of their kurtosis are around 3, that means they have high peak in some value of data. The following figures show the histogram of tomato crop yields data
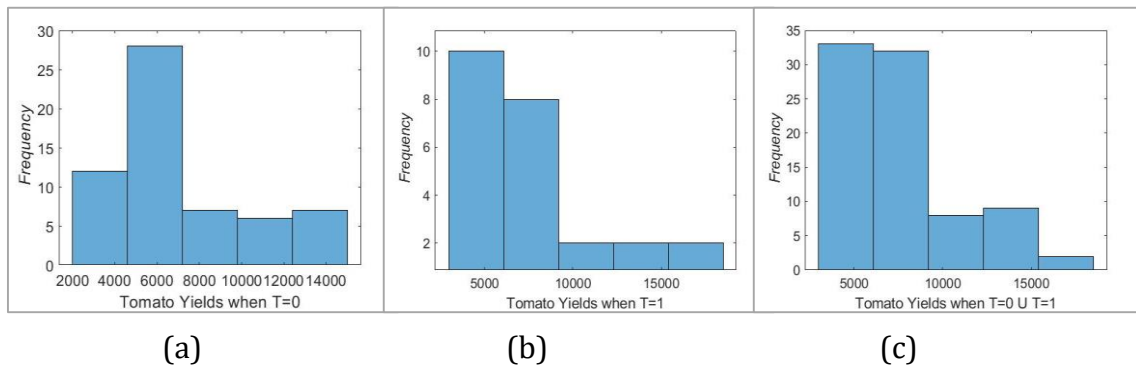


**Figure 1.** Histogram of tomato yields data: (a) $M_0$ (b) $M_1$ (c) $M$

Furthermore, the expected value of tomato crop yields will denoted as $m_0^e$ for conditions $T = 0$, $m_1^e$ for conditions $T = 1$ and $m^e$ for conditions $(T = 0 \cup T = 1)$. The expected value of tomato crop yields is shown by Table 3.

**Table 3.** Expected Value of Tomato Crop Yields

| $m_0^e$ | $m_1^e$ | $m^e$ |
|---------|---------|-------|
| 7115.8 | 7854 | 7326.7 |

The expected value in Table 3 is used to find limit value of the maximum guaranteed yield using the percentage of yields which is denoted by symbol $\lambda$. In general, the value of $\lambda$ has range $0 < \lambda < 1$. If the value is near to 1, then a higher premium must be paid, conversely if it is close to 0 then the premium to be paid will be smaller. In this study the $\lambda$ value will be focused on the range $0.6 < \lambda < 0.9$ as presented in Table 4.

**Table 4.** Limit Value of the Guaranteed Tomato Crop Yields

| $\lambda$ | $\lambda m_0^e$ | $\lambda m_1^e$ | $\lambda m^e$ |
|-----------|-----------------|-----------------|---------------|
| 60% | 4269.5 | 4712.4 | 4396.0 |
| 65% | 4625.3 | 5105.1 | 4762.4 |
| 70% | 4981.1 | 5497.8 | 5128.7 |
| 75% | 5336.9 | 5890.5 | 5495.0 |
| 80% | 5692.6 | 6283.2 | 5861.4 |
| 85% | 6048.4 | 6675.9 | 6227.7 |

| 90% | 6404.2 | 7068.6 | 6594.0 |

## Sales Result Description

Let random variables of tomato yields in time periods $(T = 0)$, $(T = 1)$ and $(T = 0 \cup T = 1)$ are $N_0$, $N_1$ and $N$ descriptive statistic value is presented in Table 5.

**Table 5.** Descriptive Statistic of Sales Results

| Data | $N_0$ | $N_1$ | $N$ |
|------|-------|-------|-----|
| Min | 4217 | 1385 | 1385 |
| Mean | 7310.5 | 3252.6 | 6151.1 |
| Max | 16092 | 6872 | 16092 |
| Skewness | 1.175 | 1.056 | 1,133 |
| Kurtosis | 3.249 | 3.626 | 3.739 |

From Table 5 show that the average sales result while COVID-19 pandemic was significantly decreased. The sharp decline in sales results was due to the hotel, restaurant and cafe (horeca business) sector, which has been PT Mitra Tani Parahyangan's main sales target did not operate smoothly. This was caused by the COVID-19 pandemic which required large-scale social restrictions policy or usually called as PSBB in Indonesia. Before COVID-19 pandemic occurs, tomato sales result reached 16092 kg but in pandemic it reached the lowest point at 1385 kg. The difference between tomato yields and sales results will be shown in figure 2.
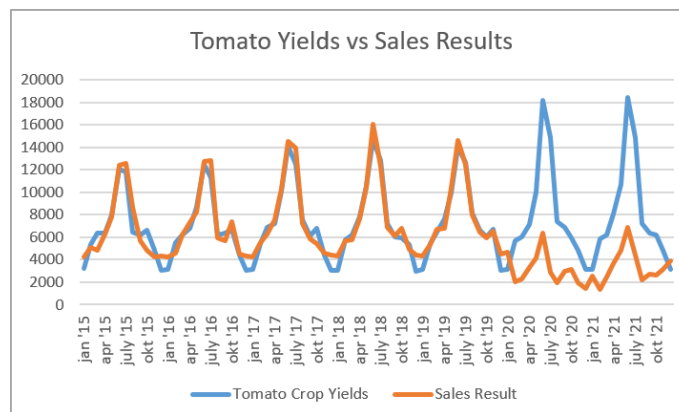


**Figure 2.** Tomato Yields vs. Sales Results

## Tomato Crop Agricultural Insurance Model

The area-yield insurance model introduced by Ozaki [20] does not recognize extreme conditions such as the occurrence of a pandemic. Therefore, this study offers a model of yield-based agricultural insurance in an area (area-yield insurance) which calculated pandemic as a risk factor by assuming several conditions. The conditions to be considered are divided into three conditions, first when there is no pandemic$(T = 0)$, when there is a pandemic$(T = 1)$ and the combined condition of the two $(T = 0 \cup T = 1)$ with the events of a pandemic is indicated by the random variable $T$.

Let $f_0(n_0), f_1(n_1)$ and $f(n)$ are probability density function from random variables $N_0$, $N_1$ and $N$ respectively and let $F_0(n_0), F_1(n_1)$ and $F(n)$ are cumulative density function from random variables $N_0$, $N_1$ and $N$ respectively. Then the insurance company's nominal compensation is equal to the difference between maximum guaranteed yield and sales results. Assume $L$ is a random variable indicating the amount of crop loss, the agricultural insurance model follows:

$$\{L|T = 0\} = \begin{cases} \lambda m_0^e - N_0, & N_0 \leq \lambda m_0^e \\ 0, & N_0 > \lambda m_0^e \end{cases} \tag{3}$$

$$\{L|T = 1\} = \begin{cases} \lambda m_1^e - N_1, & N_1 \leq \lambda m_1^e \\ 0, & N_1 > \lambda m_1^e \end{cases} \tag{4}$$

Where:

$T$ : Random variable indicator appearance of pandemic

$T = 0$ : Pandemic didn't appear

$T = 1$ : Pandemic appear

$\lambda m_0^e$ : Maximum guaranteed tomato crop yields when pandemic didn't appear

$\lambda m_1^e$ : Maximum guaranteed tomato crop yields when pandemic appear

$N_0$ : Random variable of sales result when pandemic didn't appear

$N_1$ : Random variable of sales result when pandemic appear

The expected value for $L$ when $T = 0$, $T = 1$ & $T = 0 \cup T = 1$ are:

$$E(L|T = 0) = \int_0^{\lambda m_0^e} (\lambda m_0^e - n_0)f_0(n)\, dn_0$$
$$= F_0(\lambda m_0^e)\,[\lambda m_0^e - E(N_0|N_0 < \lambda m_0^e)] \tag{5}$$

$$E(L|T = 1) = \int_0^{\lambda m_1^e} (\lambda m_1^e - n_1)f_1(n)\, dn_1$$
$$= F_1(\lambda m_1^e)\,[\lambda m_1^e - E(N_1|N_1 < \lambda m_1^e)] \tag{6}$$

$$E(L) = E(L|T) = [E(L|T = 0){}^*P(T = 0)] + [E(L|T = 1){}^*P(T = 1)] \tag{7}$$

Where:

$P(T = 0)$ : Probability of pandemic didn't appear

$P(T = 1)$ : Probability of pandemic appear

The premium rate (for short, we notated as PR) when $T = 0, T = 1$ and $T = 0 \cup T = 1$ are:

$$PR_{T=0} = \frac{E(L|T = 0)}{\lambda m_o^e}$$
$$= \frac{F_0(\lambda m_0^e)\,[\lambda m_0^e - E(N_0|N_0 < \lambda m_0^e)]}{\lambda m_o^e} \tag{8}$$

$$PR_{T=1} = \frac{E(L|T = 1)}{\lambda m_1^e}$$
$$= \frac{F_1(\lambda m_1^e)\,[\lambda m_1^e - E(N_1|N_1 < \lambda m_1^e)]}{\lambda m_1^e} \tag{9}$$

$$PR = \frac{E(L|T = 0) + E(L|T = 1)}{\lambda m_0^e\big(P(T = 0)\big) + \lambda m_1^e\big(P(T = 1)\big)} \tag{10}$$

The premium when $T = 0, T = 1$ and $T = 0 \cup T = 1$ are:

$$\text{Premium(IDR)} = \text{PR} \times \text{Coverage Value} \tag{11}$$

**The Coverage Value**

The coverage value of agricultural insurance is the amount of money that will be paid by the insurer to the insured if the conditions are fulfilled. In this case, coverage value is calculated based on PT Mitra Tani Parahyangan's production cost for tomato commodity. These costs include the price of seeds, fertilizers, pesticides and other needed as much as IDR 16,000,000 per hectare in one planting season.

**Table 6.** Coverage Value

| Persentage of tomato crop yield ($\lambda$) | Coverage value (IDR) |
|---|---|
| 60% | 9,600,000 |
| 65% | 10,400,000 |
| 70% | 11,200,000 |
| 75% | 12,000,000 |
| 80% | 12,800,000 |
| 85% | 13,600,000 |
| 90% | 14,400,000 |

In 2016, the Ministry of Agriculture of the Republic of Indonesia proposed a yield percentage ($\lambda$) of 75%. According to the Table 6, the recommended coverage value is IDR 12,000,000.

**Tomato Sales Results Distribution and Parameter Estimation**

The mathematical approach to determine the best distribution and estimating the parameters in this study by using the Kolmogorov-Smirnov test and the Anderson-Darling test to show the level of data fit with a distribution based on the statistical value and p-value assisted by EasyFit software. The appropriate distribution in the Kolmogorov-Smirnov test is chosen based on the lowest statistical value. While in the Anderson-Darling test, the appropriate distribution is determined by comparing the extreme values in the data. Furthermore, the suitability of the two tests is compared using Akaike's Information Criterion (AIC) based on the lowest value. Hypothesis that is used as the basis for drawing conclusions from the Kolmogorov-Smirnov and Anderson-Darling tests as follows:

$H_0$      : Data fitted with $D$ distribution
$H_1$      : Data did not fit with $D$ distribution

with $D$ represents random variable that expresses a certain theoretical distribution to be determined for its fit with the distribution of random variable $N_0$ & $N_1$

- **Tomato Sales Results Distribution and Parameter Estimation when $T = 0$**

Table 7 will presented the result of Anderson-Darling & Kolmogorov-Smirnov tests for $N_0$ with $\alpha = 0.05$

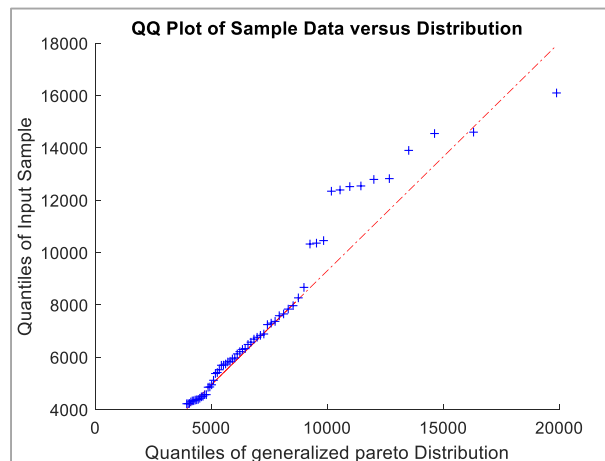**Table 7.** Kolmogorov-Smirnov and Anderson-Darling Test for $N_0$

| Distribution | Kolmogorov-Smirnov Test | | | Anderson-Darling Test | | |
|---|---|---|---|---|---|---|
| | Statistical value | Critical value | Reject $H_0$ | Statistical value | Critical value | Reject $H_0$ |
| Gen. Pareto | 0.08379 | 0,17231 | Yes | 0.64268 | 2.5018 | Yes |
| Frechet | 0.09499 | 0,17231 | Yes | 0.73488 | 2.5018 | Yes |
| Gen. Logistic | 0.10003 | 0,17231 | Yes | 1.07720 | 2.5018 | Yes |
| Gumbel Max | 0.14257 | 0,17231 | Yes | 1.78800 | 2.5018 | Yes |
| Gamma | 0.15782 | 0,17231 | Yes | 2.05430 | 2.5018 | Yes |

Based on the results of Kolmogorov-Smirnov and Anderson-Darling tests, there are still 5 distributions that match the random variable $N_0$, therefore a comparison of the Akaike's Information Criterion (AIC) value will be made and the distribution with the smallest AIC value is selected which is presented in Table 8.

**Table 8.** AIC value for random variable $N_0$

| Distribution | AIC |
|---|---|
| *Gen. Pareto* | $-1152.429$ |
| *Gamma* | $-1126.402$ |
| *Gumbel Max* | $-1114.097$ |
| *Gen. Logistic* | $-1103.887$ |
| *Frechet* | $-1094.637$ |

Table 8 imply that the appropriate distribution for the random variable $N_0$ with the smallest AIC value is the Generalized Pareto distribution. The parameter values for the Gen. Pareto distribution obtained using EasyFit software are $\hat{k} = -0.01295, \hat{\sigma} = 3438.1$ and $\hat{\mu} = 3916.3$. The assumption of the selected Generalized Pareto distribution is reinforced by the QQ-Plot graph which shows most of the data (represented by the + sign) is on the reference line and there are only a small number of outliers as presented in Figure 3.



**Figure 3.** QQ-Plot for Generalized Pareto Distribution

- **Tomato Sales Results Distribution and Parameter Estimation when $T = 1$**

The result of Anderson-Darling & Kolmogorov-Smirnov tests for $N_1$ with $\alpha = 0.05$ is shown in Table 9.

**Table 9.** Kolmogorov-Smirnov and Anderson-Darling Test for $N_1$

| Distribution | Kolmogorov-Smirnov Test | | | Anderson-Darling Test | | |
|---|---|---|---|---|---|---|
| | Statistical value | Critical value | Reject $H_0$ | Statistical value | Critical value | Reject $H_0$ |
| *Log Logistic* | 0.05571 | 0.26931 | Yes | 0.12834 | 2.5018 | Yes |
| *Pearson5* | 0.05636 | 0.26931 | Yes | 0.13627 | 2.5018 | Yes |
| *Gen Logistic* | 0.06433 | 0.26931 | Yes | 0.13610 | 2.5018 | Yes |
| *Frechet* | 0.06341 | 0.26931 | Yes | 0.12897 | 2.5018 | Yes |
| *Inv Gaussian* | 0.06540 | 0.26931 | Yes | 0.13798 | 2.5018 | Yes |

Based on the results of Kolmogorov-Smirnov and Anderson-Darling tests for, there are still 5 distributions that match the random variable $N_1$, therefore a comparison of the Akaike's Information Criterion (AIC) value will be made and the distribution with the smallest AIC value is selected which is presented in Table 10.

**Table 10.** AIC Value for random variable $N_1$

| Distribution | AIC |
|---|---|
| Log Logistic | $-405.69906$ |
| Pearson5 | $-404.90159$ |
| Gen Logistic | $-403.69585$ |
| Frechet | $-402.92101$ |
| Inv Gaussian | $-402.74628$ |

Table 10 imply that the appropriate distribution for the random variable $N_1$ with the smallest AIC value is the Log Logistic distribution. The parameter values for the Gen. Pareto distribution obtained using EasyFit software are $\hat{\alpha} = 3.1296, \hat{\beta} = 2183.7$ and $\hat{\gamma} = 743.68$. The assumption of the selected Log Logistic distribution is reinforced by the QQ-Plot graph which shows most of the data (represented by the + sign) is on the reference line and there are only a small number of outliers as presented in Figure 4.
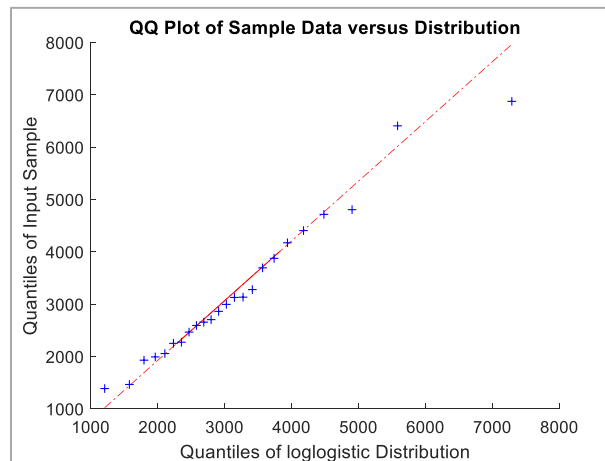


**Figure 4.** QQ-Plot for Log Logistic Distribution

## Premium Rate and Premium for Sales Result
- **Premium Rate and Premium for Sales Result when $T = 0$**

A series of test in the previous section implies that the Generalized Pareto distribution is the best fitted distribution for $N_0$. The probability density function and cumulative distribution function of the Generalized Pareto distribution with shape parameter $(\hat{k})$, scale parameter $(\hat{\sigma})$ and location parameter $(\hat{\mu})$ are as follows [23]

Probability density function:

$$f_0(n) = \begin{cases} \dfrac{1}{\sigma}\left(1 + k\dfrac{(n-\mu)}{\sigma}\right)^{-1-\frac{1}{k}} & k \neq 0 \\[4mm] \dfrac{1}{\sigma}\exp\left(-\dfrac{(n-\mu)}{\sigma}\right) & k = 0 \end{cases} \tag{12}$$

Cumulative distribution function:

$$F_0(n) = \begin{cases} 1 - \left(1 + k\dfrac{(n-\mu)}{\sigma}\right)^{-\frac{1}{k}} & k \neq 0 \\[4mm] 1 - \exp\left(-\dfrac{(n-\mu)}{\sigma}\right) & k = 0 \end{cases} \tag{13}$$

Expected value

$$E[N_0|N_0 < n] = \frac{1}{F_0(n)} \int_{-\infty}^{\infty} n f_0(n)\, dn$$

$$= \frac{1}{F_0(n)} \int_{-\infty}^{\infty} n \left(\frac{1}{\sigma}\left(1 + k\frac{(n-\mu)}{\sigma}\right)\right)^{-1-\frac{1}{k}} dn \tag{14}$$

The following illustrates the calculation of the cumulative distribution function value and the expected value of the Generalized Pareto distribution by substituting the parameter values $\hat{k} = -0.01295, \hat{\sigma} = 3438.1\ \hat{\mu} = 3916.3\ \&\ \lambda m_0^e = 5336.9$ into equations (12), (13) and (14).

Cumulative distribution function for Generalized Pareto Distribution:

$$F_0(5336.9) = 1 - \left(1 + (-0.01295)\frac{(5336.9 - 3916.3)}{3438.1}\right)^{-\frac{1}{-0.01295}} = 0.339207$$

Probability density function for Generalized Pareto Distribution:

$$E[N_0|N_0 < 5336.9] = \frac{1}{F_0(5336.9)} \int_0^{5336.9} n\, f_0(n)\, dn$$

$$= 0.339207 \int_{-\infty}^{\infty} 5336.9 \left(\frac{1}{3438.1}\left(1 + (-0.01295)\frac{(5336.9 - 3916.3)}{3438.1}\right)\right)^{-1-\frac{1}{-0.01295}} dn$$

$$= 4768.4$$

Next, the expected value of the loss will be calculated according to equation (3) based on value that has been obtained previously

$$E(L|T = 0) = F_0(5336.9)\big[5336.9 - E[N_0|N_0 < 5336.9]\big]$$
$$= 0.339207[5336.9 - 4768.4]$$
$$= 257.2832$$

So we can get premium rate and premium as follows :

$$PR_{T=0} = \frac{E(L|T = 0)}{\lambda m_0^e} = \frac{257.2832}{5336.9} = 4.82\%$$

$$\text{Premium} = PR_{T=0} \times \text{Coverage value}$$
$$= 4.82\% \times \text{IDR } 12,000,000$$
$$= \text{IDR } 578,511$$

Using the same steps, the Generalized Pareto premium rate and premium distribution values for the full yield percentage ($\lambda$) with range $0.6 < \lambda < 0.9$ are shown in Table 11.

**Table 11.** Premium rate and premium Generalized Pareto distribution

| $\lambda$ | Coverage value (IDR) | Premium Rate *Gen. Pareto* distribution | Premium (IDR) |
|---|---|---|---|
| 0.6 | 9,600,000 | 0.41% | 39,454 |
| 0.65 | 10,400,000 | 1.48% | 153,776 |
| 0.7 | 11,200,000 | 3.00% | 335,651 |
| 0.75 | 12,000,000 | 4.82% | 578,511 |
| 0.8 | 12,800,000 | 6.85% | 876,334 |
| 0.85 | 13,600,000 | 9.00% | 1,224,056 |
| 0.9 | 14,400,000 | 11.23% | 1,616,546 |

- **Premium Rate and Premium for Sales Result when $T = 1$**
  A series of test in the previous section implies that the Log Logistic distribution is the best fitted distribution for $N_1$. The probability density function and cumulative distribution function of the Log Logistic distribution with shape parameter ($\hat{\alpha}$), scale parameter $(\hat{\beta})$ and location parameter ($\hat{\gamma}$) are as follows [24]
  Probability density function:

$$f_1(n) = \frac{\alpha}{\beta}\left(\frac{n}{\beta}\right)^{\alpha-1}\left(1 + \left(\frac{n-\gamma}{\beta}\right)^{\alpha}\right)^{-2} \tag{15}$$

Cumulative distribution function:

$$F_1(n) = \left(1 + \left(\frac{\beta}{n-\gamma}\right)^{\alpha}\right)^{-1} \tag{16}$$

Expected value:

$$E[N_1|N_1 < n] = \frac{1}{F_1(n)} \int_{-\infty}^{\infty} n \, f_1(n) \, dn$$
$$= \frac{1}{F_1(n)} \int_{-\infty}^{\infty} n \, \frac{\alpha}{\beta}\left(\frac{n}{\beta}\right)^{\alpha-1}\left(1 + \left(\frac{n-\gamma}{\beta}\right)^{\alpha}\right)^{-2} dn \tag{17}$$

The following illustrates the calculation of the cumulative distribution function value and the expected value of the Log Logistic distribution by substituting the parameter values $\hat{\alpha} = 3.1296, \hat{\beta} = 2183.7 \, \hat{\gamma} = 743.68$ and the value of $\lambda m_1^e = 5890.5$ into equations (15), (16) and (17).
Cumulative distribution function for *Log Logistic*:

$$F_1(5890.5) = \left(1 + \left(\frac{2183.7}{5890.5 - 743.68}\right)^{3.1296}\right)^{-1} = 0.936$$

Expected value *Log Logistic:*

$$E[N_1|N_1 < 5890.5] = \frac{1}{F_1(5890.5)} \int_0^{5890.5} n\, f_1(n)\, dn$$

$$= 0.936 \int_0^{5890.5} 5890.5\, \frac{3.1296}{2183.7} \left(\frac{5890.5}{2183.7}\right)^{3.1296-1} \left(1 + \left(\frac{5890.5 - 743.68}{2183.7}\right)^{3.1296}\right)^{-2} dn$$

$$= 2996.4105$$

Next, the expected value of the loss will be calculated according to equation (4) based on value that has been obtained previously

$$E(L|T = 1) = F_1(5890.5)\left[5890.5 - E[N_1|N_1 < 5890.5]\right]$$
$$= 0.339207[5890,5 - 2996.4105]$$
$$= 2708.914$$

So we can get premium rate and premium as follows :
$$PR_{T=1} = \frac{E(L|T = 1)}{\lambda m_1^e} = \frac{2996.4105}{5890.5} = 45.99\%$$

$$\text{Premium} = PR_{T=1} \times \text{Coverage value}$$
$$= 45.99\% \times \text{IDR } 12,000,000$$
$$= \text{IDR } 6,898,084$$

Using the same steps, the Log Logistic premium rate and premium distribution values for the full yield percentage ($\lambda$) with range $0.6 < \lambda < 0.9$ are shown in Table 12.

**Table 12.** Premium rate and premium Log Logistic distribution

| $\lambda$ | Coverage value (IDR) | Premium Rate *Log Logistic* Distribution | Premium (IDR) |
|---|---|---|---|
| 0.6 | 9,600,000 | 34.82% | 3.342.932 |
| 0.65 | 10,400,000 | 38.82% | 4.049.126 |
| 0.7 | 11,200,000 | 42.64% | 4.775.917 |
| 0.75 | 12,000,000 | 45.99% | 5.518.467 |
| 0.8 | 12,800,000 | 49.01% | 6.272.708 |
| 0.85 | 13,600,000 | 51.73% | 7.035.189 |
| 0.9 | 14,400,000 | 54.45% | 7.805.014 |

- **Premium Rate and Premium for Sales Result when $T = 0 \cup T = 1$**
    The premium rate and the premium for sales result when $T = 0 \cup T = 1$ can be determined using equation (10). However, in equation (10), it is necessary to determine the value of the probability of a pandemic appearance first. Marani stated that the occurrence of major pandemics such as COVID-19 and Spanish flu is very likely to happen again due to the worsening condition of the earth [25]. Furthermore, Marani estimates the chance of a pandemic similar to COVID-19 in the future is 38%. Thus $P(T = 1) = 0.38$ and $P(T = 0) = 1 - P(T = 1) = 0.62$. Illustration of the calculation of the premium rate and the sold crop premium when $T = 0 \cup T = 1$ using a value of $\lambda = 0.75$ as follows

$$PR = \frac{E(L|T = 0) + E(L|T = 1)}{\lambda m_0^e\big(P(T = 0)\big) + \lambda m_1^e\big(P(T = 1)\big)}$$

$$= \frac{257.2832 + 2708.914}{(5336.9 \times 0.62) + (5890.5 \times 0.38)}$$
$$= 20.46\%$$

$$\text{Premium(IDR)} = \text{PR} \times \text{Coverage value}$$
$$= 20.46\% \times \text{IDR } 12,000,000$$
$$= \text{IDR } 2,455,694$$

The full calculation of premium rates and premiums for sales result with values of $0.6 < \lambda < 0.9$ is shown in Table 13.

**Table 13.** Premium rate and premium when $T = 0 \cup T = 1$

| $\lambda$ | Coverage Value (IDR) | $T = 0 \cup T = 1$ | |
|---|---|---|---|
| | | PR | Premium (IDR) |
| 60% | 9,600,000 | 13.49% | 1,294,776 |
| 65% | 10,400,000 | 15.71% | 1,634,009 |
| 70% | 11,200,000 | 18.06% | 2,022,952 |
| 75% | 12,000,000 | 20.46% | 2,455,694 |
| 80% | 12,800,000 | 22.87% | 2,926,956 |
| 85% | 13,600,000 | 25.24% | 3,432,286 |
| 90% | 14,400,000 | 27.56% | 3,968,164 |

Table 13 shows that the level of tomato crop insurance premiums when $T = 0 \cup T = 1$ has increased by 12%-16% from pre-pandemic conditions. In the case study of PT Mitra Tani Parahyangan in this research, the author also interviewed the marketing team of PT Mitra Tani Parahyangan who said that the decline in sales turnover of PT Mitra Tani Parahyangan during the pandemic reached 60%. So that an increasing of 12%-16% in the premium rate when $T = 0 \cup T = 1$ is expected to cover the losses incurred during the pandemic.

## CONCLUSIONS

The research has been formulated an area yield-based tomato agricultural insurance model by considering COVID-19 pandemic as the triggering event. Based on this model, we got the premium rate is 20.46% and the premium is IDR 2,455,694 with the coverage value is IDR 12,000,000. The relative high premium rate is expected to cover the 60% decline in sales turnover when a pandemic occurs. The tomato agricultural insurance model developed in this study is expected to be a consideration for government or private insurance companies in taking agricultural insurance policies for farmers.

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