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Simulation of Crop Insurance Premium With Poisson Process and Exponential Distribution; Case Study on Rice Farming in Village of Sukaratu-East Java

Primadina Hasanah[1,*], Muhammad Azka[1], Novita Lestari Payung[1]

[1]*Mathematics Department of Institut Teknologi Kalimantan, Balikpapan- East Kalimantan- Indonesia*
[*]*Corresponding author:primadina@lecturer.itk.ac.id.*

ABSTRACT
Agricultural sector is important for human life. However, this sector is threatened by various risks that leads to crop failure and harm for food supply of society. Crop insurance will provide protection against economic losses. This research conducted to develop crop insurance design using sample data on rice farming in Sukaratu village-Cianjur, West Java. Loss probability is measured by the maximum likelihood estimation to determine parameters in the poisson process and exponential distribution. Moreover, the net annual premium is calculated by considering the natural disaster risk index in Sukaratu village. Furthermore, equivalence principle has been fulfilled in estimating the annual premium. Finally, the insurance benefits are simulated in some cases depending on the percentage of harvest.
Keywords: *crop insurance, exponential distribution, loss probability, poisson process.*

1. INTRODUCTION

The agriculture sector is an important economic mainstay for Indonesia, providing jobs for more than 40 million people (about 38% of the total labour force), and contributing around 15% of GDP in recent years. In rural areas where almost half of Indonesians live, farming (including livestock and fisheries) is the main source of income for 63% of households. Rice crops accounted for about 8.1 million ha. Almost half of its cultivation is located in five major producing provinces: East Java, West Java, Central Java, South Sulawesi and South Sumatera [1].
According to the World Bank (2013), Indonesia is the world's fifth largest agricultural producer after China, India, the USA and Brazil. It is also the third largest rice producer and consumer after China and India. Rice is Indonesia's single most important commodity, and for most of her population, it is the staple food. Rice production in Indonesia, however, is faced with a number of socio-economic problems (OECD, 2012). The sectorial share of the GDP has been sharply decreasing. The area of paddy fields has consistently decreased in Java, and the yield growth has also declined. These problems will be affected to the food security [2].
From the perspective of food security, food production is one of important factors of food security. Indonesia achieved self sufficiency in rice – staple food of the majority of Indonesians – in 1984, though in 2007 still imported 4% of rice. In addition, dependence of agriculture on the climate condition implies that agriculture has an important role to play in adaptation to climate change. Some extreme events caused by climate change that affected to the food security are storms, floods, and droughts. As they become more frequent and intense the magnitude of asset losses that impact on agricultural production and purchasing power of low-income consumers is also increasing. [3].
According to Pasaribu [4] uncertainty and high risk are very possible for farmers to switch to other commodities that have high economic value with a smaller risk of failure. If this is allowed to continue, it is feared that it will have an impact on the stability of national food security, specifically rice production and availability. Land protection through agricultural insurance is one form of anticipation of economic losses that occur due to crop failure. Insurance can provide protection against price fluctuations, as well as risk sharing due to climate change, pest attacks, political problems, and others. Agricultural insurance has been applied in many countries. Whereas in Indonesia, regulation related issues were only issued in 2013, namely Law Number 19 of 2013 concerning Farmer Protection and Empowerment.
The development of agricultural insurance in Indonesia is faced with several challenges such as institutional, financial, and operational challenges. Operational challenges include developing complex agricultural insurance operational procedures that require special expertise. One of the goals is to make agricultural insurance products with standardization of coverage, policy

provisions and loss assessment while maintaining ease of application and affordable prices by farmers [5].
This research was conducted with the aim of providing input for the development of agricultural insurance in Indonesia in terms of the value of insurance premiums set. Agricultural insurance program simulations are carried out by taking secondary data samples through Ramadhana [6] in village of Sukaratu, Cianjur district, West Java. Insurance premiums are set based on the survival probability. The principle of calculating premiums refers to the calculation of insurance premiums conducted by Wang et.al [7,8].

2. MATERIALS AND METHODS

2.1. Data

Crop failure data was obtained from Ramadhana [6] located in Sukaratu Village, Gebrong District, Cianjur. The observed variables from the data are the name of the farmer, year of crop failure, cause of failure percentage of failure, and planted area. The data was observed six years along 2008-2013.

2.2. Analytical Methods

In considering the failure time of crop data, it is important to have a clear and unambiguous definition of time origin from which survival is measured. Failure time data often include some crop area who do not experience crop failure in observation period. Suppose T is a non-negative random variable that states the time of failure, then the cencoring process can be divided into three aspects [9];

1. Right censoring

Right censor can occur because of; 1) the subject of observation has not experienced an event until the research period ends, (2) the subject of observation comes out when the research period takes place.

2. Left censoring

Left censored data occurs when the subject of observation is not observed at the beginning of the observation time but before the research ends all events can be observed in full. The incident to be considered on the subject of the observations has occurred when the subject of the observation entered into the study.

3. Interval censoring

It occurs when an event that is observed in the subject of observation occurs at a specified time interval.

Moreover, in term of counting process, crop failure was assumed to follow poisson process. Let n is a discrete random variable for the number of failure crop in one year, it is assumed that n followed the poisson distribution. Then, the probability mass function for n are:

$$P(n) = \frac{e^{-\mu}\mu^{n}}{n!}, for n = 0,1,2, \ldots \qquad (1)$$

The mean and variance of the distribution is denoted by μ.
Then T is denoted as the survival time of the crop, the waiting time between two failure events is assumed to follow the exponential distribution with the probability density function

$$f(t) = \lambda e^{-\lambda t}, \qquad (2)$$

Where $t \geq 0$ and the parameter $\lambda > 0$. The mean of the distribution is equal to $1/\lambda$.
The probability for a crop to not experience a failure event is called survival probability. The survival function is expressed in the following equation:

$$S(t) = P(T \geq t) = 1 - P(T < t) = 1 - F(t); 0 < t < \infty \qquad (3)$$

Then the survival probability for the exponential distribution is

$$S(t) = 1 - F(t) = 1 - \int_{0}^{\infty} \lambda e^{-\lambda t}\, dt = e^{-\lambda t}$$

In a poisson process, if events occur on average at rate of λ per unit of time, then there will on average λt occurrences per t units of time. If there are no failure happen therefore the probability of no event in t unit of time whitin the poisson process is denoted $P(n = 0) = e^{-\lambda t}$[10].

3. RESULTS AND DISCUSSION

3.1. Result of Analysis

The first step is to calculate lambda for the Poisson distribution with maximum likelihood estimation. Assuming $n_1, n_2, \ldots n_m, m = 1..6$ are a random sample of the number of rice crop failure events in the village of Sukaratu every year with poisson distribution.

$$L(\lambda) = \prod_{n=1}^{6} \frac{e^{-\lambda}\lambda^{n}}{n!} \qquad (4)$$

Then,

$$ln\, L(\lambda) = -n\lambda + \sum_{n=1}^{m} n\, ln\, \lambda - ln(\prod_{n=1}^{m} n!) \qquad (5)$$

Therefore by taking a derivative of the function equal to zero, an estimate of lambda will be obtained which is $\hat{\lambda}$,

$$\frac{\partial\, ln\, L(\lambda)}{\partial \lambda} = -n + \frac{1}{\lambda}\sum_{i=1}^{m} n_i = 0 \qquad (6)$$

$$\hat{\lambda} = \frac{1}{\lambda}\sum_{i=1}^{6} n_i = 3 \qquad (7)$$

In the Poisson process, if a crop failure event occurs at a rate λ then there will be on average λt per t unit of time. The poisson distribution describing this process is $P(n) = \frac{e^{-\lambda t}(\lambda t)^{n}}{n!}$, from which $P(n = 0) = e^{-\lambda t}$ is the probability of zero event in t unit of time.

Another interpretation of $P(n=0)=e^{-\lambda t}$ is that this is the probability that the time of crop failure event, T, to the first occurrence is greater than t, i.e.

$$P(T>t)=P(n=0|\mu=\lambda t)=e^{-\lambda t}. \quad (8)$$

It means that the failure crop does not **occur** during t unit of time, i.e. survival probability for exponential distribution.

Conversely, the probability that crop failure does occur during t unit of time is given by

$$P(T\le t)=1-P(n=0|\mu=\lambda t)=1-e^{-\lambda t}. \quad (9)$$

Basically, given an interval of time $[0,T]$, the Exponential distribution is the continuous waiting time for failure crop whose number, in a fixed time interval $[0,T]$, is a random variable $N=Po(\lambda)$. Hence, if N is the number of failure crop which are likely to occur in the interval of time $[0,T]$, and X is the waiting time for the next event, then:

$$N\sim Po(\lambda)\Rightarrow X\sim Exp\left(\theta=\frac{1}{\lambda}\right) \quad (10)$$

Then, for $\hat{\lambda}=3$ then the waiting time for failure is expected to $\frac{1}{\hat{\lambda}}=\frac{1}{3}$. The survival probability for a crop in Sukaratu Village determined by $S(x)=e^{-\frac{1}{3}x}$, conversely, the probability of loss is $1-e^{-\frac{1}{3}x}$. In case of crop insurance, the product simulated as one year coverage for a crop. Then, the probability of crop loss for one year (L_p) estimated with exponential distribution is 0.283.

Furthermore, crop insurance premiums adapted from the previous research by Wang (2009);

$$Premium=P_c*L_p*C_p \quad (11)$$

where P_c is price of capital per unit of land, $L_p is$Loss probability, and $C_p is$Catastrophe probability. The price of capital per unit land assumed that the economic loss that will face by farmers is Rp 6,000,000 per a planting time. Since there was three times of planting per session, then the price of their land assumed to be Rp 18,000,000. In addition, the probability of loss (C_p) due to disaster is obtained by the Cianjur City disaster risk index based on the book of the Directorate of Disaster Risk Reduction. Catastrophe probability measured by calculating index of several disasters, it is approximately 0.438.

Table 3. Annual Premiums Estimation

Price of capital per unit of land (hectares)(P_c)	Rp18.000.000,00
Loss probability (L_p)	0.283
Catastrophe probability (C_p)	0,438
Net annual premium (per Hectare) $(P_c*L_p*C_p)$	Rp 2.231.172

Based on the premiums obtained, the following agricultural insurance program is simulated if implemented in Sukaratu village.

Table 4. Simulation of insurance program for Sukaratu Village

Revenue for Insurer		
a. Premium/ha	= Rp 2.231.172	
b. Crop area in Sukaratu (Ramadhana,2013)	= 204 ha	
Total of revenue $(a*b)$	= Rp 455.159.088	
Expenses for insurer		
c. Benefit/ha	= Rp18.000.000,00	
d. Crop failure estimate (ha) (L_p*C_p*204)	= 25.29	
Total of expenses $(c*d)$	= Rp 455.159.088	

With a total coverage of one year, the insurance premium obtained meets the equivalence principle. Farmers in Sukaratu village have three planting seasons in one year. It is assumed that simulated insurance will cover losses for the three growing seasons.

3.2. Discussion

This research conducted to simulate an insurance program for crop loss event in rice farming, as a response to crop failure problems in Indonesia. To obtain the crop insurance premium, the probability of crop failure must be fixed at first step. The author used an approximate with poisson process to measure the failure probability. As can be seen in result of the research that net premium for every hectare of land crop in village of Sukaratu is Rp. 2.231.172, it might too expensive premiums. However, it was designed that this annual premium will cover for three times of planting seasons with each pf coverage Rp 18.000.000. The amount of premium calculated based on sukaratu's index of catastrophe (43.8%). Since its high catastrophe index, crop insurance program should be applied in this area. Local government can contribute to help the farmer by giving co-funding program, therefore premiums can be shared by the government. Further research can be conducted with other methods to give a benchmarking for a similar program.

4. CONCLUSION

Crop insurance simulation is applied to the village of Sukaratu, Cianjur-West Java, by calculating the loss probability based on the poisson process principle and the exponential distribution approach. Poisson and exponential parameters are estimated from the data to be able to obtain the value of loss probability in rice farming. The value of the premiums obtained is the value of annual premiums. If in Sukaratu village has three planting seasons, the premium will cover all three planting seasons. Further studies are needed to determine premiums for accommodating losses in each planting seasons.

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