Mitigation and models for determining premiums for natural disaster insurance due to excessive rainfall

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Abstract. Natural disasters due to excessive rainfall often cause huge losses in the form of impacts including casualties and economic losses. To minimize casualties, disaster mitigation is needed, while financing for disasters (emergency response) and financing after disasters (rehabilitation and reconstruction) can be carried out with insurance. This paper aims to determine mitigation efforts and insurance premiums for natural disasters. The method as a mitigation effort is studied based on several methods that are suitable for the conditions of the community in areas that are often affected by disasters. Meanwhile, regarding loss insurance, the premium is calculated based on the number of cases, the rate set by the insurance company and the amount insured (loss). Based on the results of natural disaster mitigation studies, it is necessary to adjust it to the type of disaster. In the case of landslides, housing buildings must be standardized, while in cases of flooding, river normalization is required. Mitigation in general, namely the installation of disaster sirens and disaster response training. Regarding loss insurance, it is found that the optimal premium for the government and insurance companies is obtained.

Keywords: Natural disaster, fatalities, economic loss, mitigation, insurance, premium calculation.

1. Introduction
Red Natural disasters due to excessive rainfall occur every year in Indonesia [1]. Natural disasters caused by excessive rainfall can include floods and landslides. This natural phenomenon is caused by natural and human factors, one natural factor is high rainfall and the human factor is the destruction of the ecology. The end of 2019 until now in 2020, high intensity rain has flushed in various places in Indonesia. Based on data from the National Disaster Management Agency, cases of natural disasters due to excessive rainfall have increased every year. This can be seen from the case of the events in the last year that many floods hit several cities in Indonesia. The impact of this natural disaster can be felt directly or indirectly on the people in the region [2], [3]. As for the impact of natural disasters that occur, it can affect human life, including casualties, injuries and community psychology [4]. Natural disasters can also cause environmental damage and material losses. According to Songwathana (2018) [5], a disaster that occurs in a country can affect the country's economy. The economic impact that occurs is not only in the fiscal sector, the non-fiscal sector is also affected by natural disasters. This non-fiscal
sector is in the form of business and the continuity of the country's economy, which will be affected after a natural disaster.

As an effort to cope with the impact of natural disasters, an appropriate policy is needed. This is necessary so that natural disaster management can be timely, more planned, sustainable and transparent to minimize the impacts that occur. Therefore, natural disaster mitigation is needed as an effort to reduce casualties [6]. In this case, natural disaster mitigation is needed as an action that needs to be taken to reduce the impact and risk of a disaster through proactive actions taken before a disaster occurs or when a disaster occurs. Meanwhile, financing for disasters (emergency response) and financing for post-disaster (rehabilitation and reconstruction) can be done with insurance. Insurance will be very useful when natural disasters occur. With insurance, losses suffered due to natural disasters can be borne by the insurer. In this case the insurance company is the party that bears the risk in the event of a natural disaster. Meanwhile, customers pay premiums that have been determined and agreed upon with insurance companies [7], [8].

Research related to natural disaster mitigation and insurance has been carried out by many previous researchers. For example, research conducted by Ramadhan et al (2019) [9], analyzed students' knowledge of the environment and mitigating natural disasters. The method used in this research is the survey method, with the research instrument in the form of a questionnaire containing 12 questions related to environmental knowledge and natural disaster mitigation. From the research, it was found that students' knowledge about the environment and natural disaster mitigation was still lacking and needed to be improved. In another study conducted by Sunaryo et al (2019) [10], implementing efficient landslide mitigation by analyzing slope stability. This is done with the aim of obtaining a landslide sebum in terms of its physical parameters. The location used in the study is in South Malang, East Java Province. Slope stability analysis uses the vertical electrical sounding (VES) model by applying the resistivity geoelectric method. From the analysis, it was found that the slope conditions were unstable. Therefore, to overcome landslides, it is necessary to install drill piles to hold the soil surface / outer layer of the slope. Meanwhile, another study conducted by Paleari (2019) [11], analyzed insurance schemes related to natural disasters. Loss factors due to natural disasters are the main focus in mitigating natural disasters. Based on the results of the analysis, it is found that the insurance program provides an efficient advantage for better allocation of financial resources and risk management. However, the linkage of insurance to risk reduction due to natural disasters cannot automatically be resolved.

Based on the description above, this study focuses more on cases of disasters due to excessive rainfall. In this study, will determine the appropriate natural disaster mitigation efforts and calculate the amount of natural disaster insurance premium that must be paid by the Indonesian government. Methods as a mitigation effort are studied based on several methods that are appropriate to the conditions of the community in areas that are often affected by disasters. As for loss insurance, the premium is calculated based on the number of cases, the rate set by the insurance company and the amount insured (loss).

2. Method
2.1 Natural Disaster Mitigation and Insurance
Disasters are events that cause casualties and objects. Natural disasters can be in the form of earthquakes, tsunamis, floods, landslides, volcanic eruptions and others. To reduce casualties and property, protection is needed that can be done before, during a disaster and after a disaster. Action taken before a disaster is a mitigation effort that aims to reduce the impact of the disaster [12]. Disaster mitigation can be defined as a series of efforts to reduce disaster risk, either through physical development as well as awareness and increased capacity to face disaster threats. Disaster mitigation is a term used to denote all actions to reduce the impact of a disaster that can be carried out before the disaster occurs, including preparedness and long-term risk reduction measures. There are two mitigation activities: first, structural mitigation, namely activities to reduce physical disaster risk. This form of mitigation includes construction of earthquake-resistant houses, construction of embankments to resist floods and landslides. This includes planting mangrove forests and concrete to destroy waves to break the waves when a tsunami occurs. Second, non-structural mitigation, non-physical risk reduction efforts. There are many activities that can be done as an effort for non-physical migration. For example, from the policy side, namely the
formulation of disaster management and management policies. Management of losses due to natural disasters can be done with an insurance system. Insurance is a coverage or agreement between two parties. Where the first party is obliged to pay contributions or premiums, while the second party is obliged to provide full guarantees to the dues payer if something happens to himself or the property of the first party in accordance with the agreement made.

2.2 Aggregated Claims
At the beginning of the period of insurance protection, the insurer does not know how many claims will occur, and if the claim occurs, how many of the claims, so it is necessary to build a model that contains calculations from two sources of variability.

The individual unit $i$ where $i = 1, 2, 3, ..., N$ in the individual claim model is seen as a large unit of individual claim to and is denoted by $X_i$ so:

$$X = \{X_i\}, \quad i = 1, 2, 3, ..., N$$

(1)

$X_i$ can be assumed that continuous distribution is a random variable with identical, independent distribution.

For a risk model that is collective in nature, it can be used for the assumption of a mixed distribution with aggregate claims which is the sum of $N$ individual claims. Thus it can be formulated as follows:

$$S = X_1 + X_2 + ... + X_N$$

$$= \sum_{i=1}^{N} X_i$$

(2)

where $N$ is a random variable that states a lot of claims and $X_1, X_2, ..., X_N$ is a random variable that represents a large number of individual claims that can be in the form of discrete and or continuous distributions that are identical and mutually free [13].

Based on equation (2) the cumulative distribution function of the aggregation claim can be determined as follows:

$$F_S(x) = P(S \leq x)$$

$$= P(X_1 + X_2 + ... + X_N = x)$$

$$= P((\{S = x\} \cap \{N = n_1\}) \cup ... \cup (\{S = x\} \cap \{N = n_i\}))$$

$$= \sum_{i=1}^{N} P(\{S = x\} \cap \{N = n_i\})$$

Based on the law of total opportunity the cumulative distribution function (cdf) may apply as follows:

$$= \sum_{i=1}^{N} P(\{S = x\} \mid N = n_i) \ p(N = n_i)$$

because $X_1, X_2, ..., X_N$ is independent, $P(\{S = x\} \mid N = n_i) = P(S = x)$ applies, so for $n$ claims apply:

$$= \sum_{n=0}^{x} P(S = x) \ p(N = n)$$

$$= \sum_{n=0}^{x} P(X_1 + X_2 + ... + X_N = x) \ p(N = n)$$

in convolutionary terms can apply
\[ P(X_1 + X_2 + \ldots + X_N = x) = P*P*\ldots*P(x) \]
\[ = P^n(x) \]
so that
\[ F_s(x) = \sum_{n=0}^{x} P^n p(N = n) \quad (3) \]
with
\[ P^0(x) = \begin{cases} 0, & x \neq 0 \\ 1, & x = 0 \end{cases} \]
with a limit \( y \leq x \).

Based on the opportunity density and cumulative distribution functions of the aggregation claims above, the expectations and variants of the aggregation claims can be determined as follows:

\[ E(S) = E[E(S = x) | N = n] \]
\[ = \sum_{x} n E(S = x | N = n) p(N = n) \]
\[ = E(N) E(X) \quad (4) \]
\[ E(S^2) = E[E(S^2 | N = n)] \]
\[ = Var(X) E(N) + (E(X))^2 E(N^2) \quad (5) \]
\[ Var(S) = E(S^2) - (E(S))^2 \]
\[ = E(N) Var(X) + E(N^2) (E(X))^2 - (E(N))^2 (E(X))^2 \]
\[ = E(N) Var(X) + (E(X))^2 (E(N^2) - (E(N))^2) \]
\[ Var(S) = E(N) Var(X) + E(X) Var(N). \quad (6) \]

2.3 Model for determining premiums for natural disaster insurance
Picard (2008) [14], assumes that the insurance market is competitive with no transaction costs and risk neutral insurance. In practice, the loading of premiums plays an important role in the disaster insurance market, including loading related to insurance against capital losses or the reluctance of insurance companies [20]. Main results remain valid in a more realistic framework with premium loading. To be clearer, loading will affect insurance contracts offered in the market (they won’t provide full coverage anymore) but the same equity-efficiency tradeoffs will still exist and the relationship between incentives for individual prevention and community prevention will not change. The government can tax or subsidize insurance contracts differently according to risk exposure.

Natural disaster insurance premiums that must be paid are:

\[ P_A = \pi_A E(S) R_A \quad (7) \]

Where \( P_A \) is the amount of natural disaster insurance premium that must be paid, \( \pi_A \) is the average number of cases of natural disasters, \( E(S) \) is the estimated average loss / total cases of natural disasters and \( R_A \) is the rate of natural disaster insurance premiums that must be paid.
3. Results and Discussion
3.1. Disaster Mitigation Efforts
The data in this study uses secondary data, which is obtained from the National Disaster Management Agency. The data used is in the form of data on events and losses due to natural disasters that occurred in Indonesia during the period 2001 to 2019. Based on the results of the analysis in Figure 1, it can be seen that cases of disaster due to high rainfall in Indonesia such as floods and landslides are so high. Whereas there were 9437 cases of flood disasters, while landslides occurred as many as 5431 events. Therefore, we need an appropriate policy to deal with the impacts caused by natural disasters due to high rainfall.

![Figure 1. Cases of natural disasters that have occurred in Indonesia since 2001-2019](image)

Based on data from the National Disaster Management Agency, cases of natural disasters in Indonesia that are caused by high rainfall occur every year. Natural disasters due to high rainfall in the form of floods and landslides. Graph of cases of floods and landslides that occurred from 2001-2019 is shown in Figure 2, as follows:

![Figure 2. Flood and Landslide Disaster Cases since 2001-2019](image)

Based on Figure 2, it can be seen that cases of natural disasters due to high rainfall have increased every year. Where in Figure 2, cases of floods and landslides continue to experience a significant increase. Therefore, appropriate disaster mitigation is needed to minimize the risk of natural disasters. According to Inagaki and Sadohara (2006) [15], the risk of landslides can be carried out by periodic
inspections and checks. From the results of the checking, then mapping and identifying areas that are prone to landslides. Thus, for areas prone to landslides, warning and evacuation procedures are carried out. In addition, according to Joshi and Kumar (2006) [16], landslides or land movements on the slopes of mountains due to excessive rainfall require disaster mitigation. Disaster mitigation is needed as a preventive measure to overcome or minimize the impact. The mitigation process can be carried out by constructing embankments or dams on the slopes of the mountains as a barrier to soil movement during high incentive rains. In addition, the embankment or dam that has been built is designed to function as a flash flood barrier.

In addition, in the case of flood disasters, it is necessary to mitigate natural disasters in the form of developing and implementing flood detection sirens that have the ability to respond to disasters quickly and effectively. This is necessary because it is an effort for early warning when a flood occurs. Thus the installation of sirens can be responded quickly by the community so that casualties can be minimized [17]. In addition to installing flood sirens, an effort to deal with floods is needed by dredging the silting streams. A river that has experienced silting has obstructed the flow of the river. Therefore, the existence of dredging the river flow can make the river flow smooth. In addition, dredging the river flow can minimize cases of flooding [18]. According to Kok (2006) [19], in dealing with floods, it is also necessary to build a reservoir at a strategic point, as an effort to accommodate water discharge when there is high rainfall. So that the river flow does not experience excess water discharge which can cause flooding. In addition, according to Ramadhan et al (2019) [9], to minimize risks due to natural disasters, it is necessary to introduce students from an early age regarding natural disaster mitigation efforts. In learning, students are introduced to self-saving techniques when a disaster occurs.

3.2. Natural Disaster Insurance Premiums

Based on data obtained from the National Agency for Natural Disaster Management, it was found that losses due to high rainfall which caused landslides and floods are given in Table 1, as follows:

| Year | Number of Disaster Cases | Loss       | Loss/Number of Disaster Cases |
|------|--------------------------|------------|------------------------------|
| 2001 | 100                      | 7743000000 | 77430000.00                  |
| 2002 | 166                      | 26006300000| 156664578.31                 |
| 2003 | 382                      | 69141100000| 1809976439.79                |
| 2004 | 614                      | 95653900000| 1557881107.49                |
| 2005 | 658                      | 111061600000| 1687866261.40              |
| 2006 | 740                      | 180901700000| 2444617567.57              |
| 2007 | 925                      | 226162500000| 2445000000.00              |
| 2008 | 1015                     | 126861800000| 1249869950.74              |
| 2009 | 1233                     | 153808300000| 1247431467.96              |
| 2010 | 2176                     | 157202800000| 722439338.24               |
| 2011 | 2366                     | 897282000000| 379240067.62               |
| 2012 | 1774                     | 368808299000| 207896448.14               |
| 2013 | 1890                     | 368782981000| 195123270.37               |
| 2014 | 2213                     | 615177000000| 277983280.61               |
| 2015 | 2221                     | 834000000000| 3755065.29                 |
| 2016 | 2450                     | 910708340000| 371717689.80               |
| 2017 | 3250                     | 910700252000| 280215462.15               |
| 2018 | 2980                     | 436980000000| 14663.76                   |
| 2019 | 1893                     | 1918166550000| 1013294532.49             |
Based on the data from Table 1, from the results of the analysis using equations (4) and (6), the aggregation claims for cases of natural disasters due to high rainfall are 

$$E(S) = 923073536.41$$

and 

$$Var(S) = 664625906586587000.$$ 

Insurance can be determined from the average number of cases, the value of the premium rate and the value insured (loss aggregation claims). This study used an insurance premium rate of 1.25%. By using equation (7), the insurance premium for natural disasters due to high rainfall is obtained as follows:

$$P_A = \pi_A E(S) R_A$$

$$P_A = 1529 \times 923073536.41 \times 1.25\%$$

$$P_A = 17,639,206,538.47.$$ 

So, from the results of the analysis, the insurance premium for natural disasters due to rainfall must be obtained by the Indonesian government of IDR. 17,639,206,538.47. This insurance premium is paid annually and will be disbursed for loss and economic recovery due to natural disasters.

4. Conclusion

Mitigation of natural disasters due to high rainfall can be carried out by checking regularly and building embankments or dams on mountain slopes as an effort to mitigate landslides. Meanwhile, the provision of sirens, river dredging and reservoir construction can minimize the impact of events and risks due to flood disasters. Meanwhile, the risk of economic loss due to natural disasters with high rain intensity can be carried out by insurance. From the analysis of the insurance premium that must be paid by the Indonesian government of IDR. 17,639,206,538.47 annually.

Acknowledgments

The work was supported by Kementrian Riset dan Teknologi/Badan Riset dan Inovasi Nasional 2020, through Penelitian Dasar Unggulan Perguruan Tinggi, with contract number 1827/UN6.3.1/LT/2020.

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