Assessment of loss due to flood hazard in Singkawang City (case study: flood in 2016 at Singkawang City)

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Abstract. Singkawang City is in the Province of West Kalimantan, which is located above an alluvial plain, that causing the city to be prone of flood. The last flood that occurred happened in 2016, which resulted in many flooded buildings and hundreds evacuated resident. This research purposes are to identify the hazard level of flooding and then proceed with the assessment of economic losses. The flood hazard levels are obtained by overlaying the flood characteristics parameters, i.e. frequency, duration, and height of the flood. The method for assessing the rate of the damage is done by purposive random sampling method with consider to the flood hazard level and building value. The result showed that from 84,96 ha of flooded areas, flood hazard level is dominated by low and medium hazard, with percentage of area 44,02% and 43,03%, and high classification with percentage of 12,95%. The loss assessment for this research shows that the total loss from the flood is Rp15.838.232.500 (1.150 million USD). There is a difference in distribution amount of losses, which is strongly affected by the category of building value and the level of flood hazard from the existence of the building.

1. Introduction

Floods are a disaster that is common in tropical areas. Many experts define the notion of flooding in various perspectives. In the glossary of the Intergovernmental Panel on Climate Change (IPCC), floods are defined as the overflowing of the normal confines of a stream or other body of water or the accumulation of water over areas that are not normally submerged [1]. Flood cases in Indonesia are increased every year and the problem cannot be solved completely, even the problem actually indicates the increase in intensity, frequency, and the spatial distribution [2]. Based on statistical data from National Board for Disaster Management (BNPB), within 5 years (2012-2016), the incidence of floods in Indonesia has increased by 7,5% [3]. In addition to the big urban cities in Java Island, floods in Indonesia also struck the developing urban area in Kalimantan, one of them is Singkawang City.

Based on historical data, floods have struck Singkawang city for 5 years in a row (2012-2016), which flood peak occurs at the end of the year (September - December) [4]. Floods that occurred in Singkawang City caused significant losses, both the impact of direct losses and indirect losses. Loss due to floods that occurred during 2016 is estimated at 5 billion rupiah with the proposed cost of 16 billion rupiah from Singkawang Regional Disaster Management Agency (BPBD Singkawang) [4]. This research

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focuses on the flood areas located in Singkawang City. The purposes of this research are to analyze the level of flood hazard and loss due to flood hazard in Singkawang City.

2. Study Area
Singkawang is one of the cities in West Kalimantan Province with an area of 504 km² or 0.34% of the total area in the province of West Kalimantan. It is located 148 km northeast of Pontianak City (Capital City in West Kalimantan Province), and directly adjacent to Sambas and Bengkayang district. A topographic condition in Singkawang City is mostly a plain area (319,04 km²), while the hill and mountain area are only a few (184,96 km²), which mostly located in East Singkawang and South Singkawang [4].

The research area is the flood area in Singkawang City which covers 3 villages with an area of 84.96 ha. The elevation in the research area is at the intervals 1 – 8 masl, while for the slope is at the interval 0 – 24%. The elevation areas are generally included in the flat to ramps classification because of the elevation only at an interval of 1 – 8 masl. The total annual rainfall in 2016 is 3306,5 mm/year with the number of rainy days is 193 day of rain (dor). Rainfall with the category of extremely heavy rain (>100 mm in a day) in 2016 occurred on March 13th (106,50 mm), April 1st (110,50 mm) and November 30th (137,00 mm).

3. Data Used for The Research
The data type used in this research is divided into primary and secondary data, which is based on how to obtain it. Data used in this research are given in Table 1.

| No. | Data               | Data Type       | Data Source                     |
|-----|--------------------|-----------------|---------------------------------|
| 1   | Flood Area         | Primary, Secondary | Observation based on data from BPBD |
| 2   | Flood Frequency    | Primary, Secondary | Singkawang                      |
| 3   | Flood Duration     | Primary, Secondary |                                |
| 4   | Height of the Flood| Primary          | Observation & Measurement of the Former Flood |
| 5   | Distribution of Buildings | Secondary | Singkawang Aerial Imagery |
| 6   | Building Type      | Primary          | Survey & Observation            |
| 7   | Building Function  | Primary          |                                 |
| 8   | Building Floor Number | Primary        |                                 |
| 9   | Loss of Furniture  | Primary          | Interview with Questionnaire    |
| 10  | Cost of Repairs    | Primary          |                                 |
| 11  | Additional Cost    | Primary          |                                 |
| 12  | Loss of Income     | Primary          |                                 |
| 13  | Cost of Illness    | Primary          |                                 |

4. Methodology
Flood event in Singkawang City resulted in a flood area and built-up area. In the flood area, there are flood characteristics with 3 parameters that explain the type of flood that occur, which are measure by flood frequency, flood duration, and height of the flood [5]. All these three parameters were obtained through observation and interview process, which scoring and weighting process was conducted to produce the flood hazard variables [6]. Meanwhile, in the built-up area, the observation was made on each building to identify the building type, building function, and building floor number, which results in the variable of the building value.

Assessment of losses is done based on the results of the flood hazard and building value analysis, where the value of loss on some building are affected by the location of the building. Furthermore, the assessment of losses is made through three approaches, that is market data approach (Loss of Furniture,
Cost of Repairs, and Additional Cost), human capital approach (Cost of Illness), and opportunity cost approach (Loss of Income), which is used to obtain direct losses and indirect losses from floods [7].

![Figure 1. Flowchart of Research Mindset](image)

Data processing conducted in this research are as follows.

1) Flood Frequency, Flood Duration, and Height of the Flood Map
   All the data are obtained by processing the field survey data on the flood area. The IDW interpolation method is used to perform the delineation process in creating the map.

2) Building Function, Building Type, and Building Floor Number Map
   All the data are processed by entering tabular statistical data obtained based on observations from the field survey.

3) Data of Losses
   Data of losses are obtained from the interview using questionnaires which are processed in statistical calculations to determine the average value, maximum value, and the minimum value of each loss.

4) Flood Hazard Level Map
   Flood hazard level map is obtained by scoring and weighting on flood characteristics parameters, such as flood frequency, flood duration, and height of the flood [8]. Based on the results of scoring and weighting, then proceed with the overlay process, that is by performing overlapping on each parameter used in determining the level of flood hazard.

| Table 2. Scoring and Weighting for Flood Hazard Level |
|-----------------------------------------------|
| **Flood Characteristic** | **Interval** | **Score** | **Weight** |
|-------------------------|-------------|-----------|------------|
| Flood Frequency         | 1 time      | 1         | 20 %       |
|                         | 2 times     | 2         |            |
|                         | 3 times     | 3         |            |
| Flood Duration          | < 4 days    | 1         |            |
|                         | 4 – 8 days  | 2         | 20 %       |
|                         | > 8 days    | 3         |            |
| Height of the Flood     | < 40 cm     | 1         |            |
|                         | 40 – 80 cm  | 2         | 60 %       |
|                         | > 80 cm     | 3         |            |

[Source: Analysis of Previous Research]

5) Building Value Map
   Building value map obtained by classifying each building characteristic parameter [9]. The classification is based on PP RI No. 36/2005 concerning the implementation of UU RI No. 28/2002 about buildings, and also the result of modification assuming there are only 2 types of buildings (permanent and semi-permanent) [10].
Table 3. Classification of Building Values

| No. | Building Value                                      | Code | No. | Building Value                                      | Code |
|-----|-----------------------------------------------------|------|-----|-----------------------------------------------------|------|
| 1   | Non-Storey Permanent Residence                      | HP0  | 8   | 1-Floor Semi-Permanent Mixed Building               | CSP1 |
| 2   | 1-Floor Permanent Residence                         | HP1  | 9   | Non-Storey Permanent Business Building              | UP0  |
| 3   | Non-Storey Semi-Permanent Residence                 | HSP0 | 10  | 1-Floor Permanent Business Building                 | UP1  |
| 4   | 1-Floor Semi-Permanent Residence                    | HSP1 | 11  | Non-Storey Semi-Permanent Business Building         | USP0 |
| 5   | Non-Storey Permanent Mixed Building                 | CP0  | 12  | 1-Floor Semi-Permanent Business Building            | USP1 |
| 6   | 1-Floor Permanent Mixed Building                    | CP1  | 13  | Religious Building                                  | K    |
| 7   | Non-Storey Semi-Permanent Mixed Building            | CSP0 | 14  | Socio-Cultural Building                              | SB   |

[Source: PP RI No. 36/2005]

6) Map of Losses
Map of losses is obtained by assessing losses by using loss data. Assessment of loss includes loss of furniture, cost of repairs, additional cost, loss of income, and cost of illness [8]. The formulation used in the loss assessment process is divided into, as follows.

a) Loss Formulation A (for Building Values 1 – 8 based on Table 3)

Table 4. Loss Formulation A

| Loss Parameter | Flood Hazard Level |
|----------------|--------------------|
|                | High (L1)          | Medium (L2)          | Low (L3)          |
| Loss of Furniture (R1) | X1a = max (R1) | X2a = average (R1) | X3a = min (R1) |
| Cost of Repairs (R2)  | X1b = max (R2) | X2b = average (R2) | X3b = min (R2) |
| Additional Cost (R3)  | X                 | =                  | =                |
| Loss of Income (R4)   | X                 | =                  | =                |
| Cost of Illness (R5)  | X1c = max         | X2c = average      | X3c = min       |

Total L1 = X1a + X1b + X2a + X3a + X1c  
L2 = X2a + X2b + X2c  
L3 = X3a + X3b + X3c

[Source: Pahlevi, 2015 and modified by Marko et al, 2017]

b) Loss Formulation B (for Building Values 9 – 12 based on Table 3)

Table 5. Loss Formulation B

| Loss Parameter | Flood Hazard Level |
|----------------|--------------------|
|                | High (L1)          | Medium (L2)          | Low (L3)          |
| Loss of Furniture (R1) | X1a = max (R1) | X2a = average (R1) | X3a = min (R1) |
| Cost of Repairs (R2)  | X1b = max (R2) | X2b = average (R2) | X3b = min (R2) |
| Additional Cost (R3)  | X                 | =                  | =                |
| Loss of Income (R4)   | X                 | =                  | =                |
| Cost of Illness (R5)  | -                 | -                  | -                |

Total L1 = X1a + X1b + X2a + X3a + X1c  
L2 = X2a + X2b + X2c  
L3 = X3a + X3b + X3c

[Source: Pahlevi, 2015 and modified by Marko et al, 2017]
c) Loss Formulation C (for Building Values 13 – 14 based on Table 3)

Table 6. Loss Formulation C

| Loss Parameter | Flood Hazard Level |
|----------------|-------------------|
|                | High (L1) | Medium (L2) | Low (L3)    |
| Loss of Furniture (R1) | $X_{1a} = \text{max} (R1)$ | $X_{2a} = \text{average} (R1)$ | $X_{3a} = \text{min} (R1)$ |
| Cost of Repairs (R2)   | $X_{1b} = \text{max} (R2)$ | $X_{2b} = \text{average} (R2)$ | $X_{3b} = \text{min} (R2)$ |
| Additional Cost (R3)   | $X$         | = average (R3) |                |
| Loss of Income (R4)    | -           | -              |                |
| Cost of Illness (R5)   | -           | -              |                |
| Total                  | $L1 = X_{1a} + X_{1b} + X$ | $L2 = X_{2a} + X_{2b} + X$ | $L3 = X_{3a} + X_{3b} + X$ |

[Source: Pahlevi, 2015 and modified by Marko et al, 2017]

5. Result and Discussions

5.1 Flood Hazard Level in the Flooding Area in Singkawang City

The overlay results indicate that the flood hazard level in Singkawang City is dominated by low flood hazard with 37,39 ha (44 % of total area) and medium flood hazard with 36,56 ha (43 % of total area), while the high flood hazard is not dominant with 11,00 ha (13 % of total area).

Low flood hazard is dominated in the western part of the study area, but when it toward the middle direction, the level of flood hazard leads to moderate and high (around Singkawang River).

5.2 Building Value Distribution in the Flooding Area in Singkawang City

Based on survey and observation results, from 14 classifications of building values, there are only 11 classifications that exist in Singkawang City. This can happen because there is no semi-permanent with 1-floor building in every building function. The non-storey permanent residence is the most dominant building value with 664 buildings (39.01% from the entire building), followed by 1-floor permanent business building with 217 buildings (12.75% from the entire building).

Figure 2. Flood Hazard Level in Singkawang City

Figure 3. Building Value Distribution in Singkawang City

Table 7. Matrix of Loss Based on the Flood Hazard Level

| No. | Building Value Code | Amount of Loss Based on the Flood Hazard Level (Rp) |
|-----|---------------------|---------------------------------------------------|
|     |                     | Low      | Medium   | High     |
| 1   | HP0                 | 1,065,000| 3,541,500| 4,757,000|
| 2   | HP1                 | 36,330,000| 36,397,000| 38,780,000|
5.3 Loss Assessment due to Flood Hazard

Losses due to flood hazard are obtained based on the calculation of direct and indirect losses through the interview process using questionnaires. The results then used to conduct a loss assessment using a formula. After the loss assessment process, then it will get a matrix of losses that explains the loss of each building value at different flood hazard levels in unit of rupiah. Matrix of loss based on the flood hazard level were given in Table 7.

5.4 Loss Estimation due to Flood Hazard

Loss estimation due to flood hazard obtained from the sum of losses from each flood affected building. Condong village is a village with the highest loss estimation with Rp8.020,660,500, followed by Pasiran Village with Rp5.142,445,500 and Roban Village with Rp2.675,126,500. Estimation of loss is strongly influenced by the building value, flood hazard level, and the number of affected buildings. The estimated total loss due to flood hazard in Singkawang City in 2016 is Rp15.838,232,500.

Figure 4. Map of Loss Distribution in Singkawang City

6. Conclusion

Based on the result from scoring and weighting of flood characteristics parameters, the results of flood hazard are dominated by the flood with low and medium hazard with the percentage of 44.02% and 43.03%. At the high flood hazard level, the percentage of the area is 12.95% that dominated on the east side of the Singkawang River, which has relatively lower elevation and a relatively flat slope. Based on the result of the loss assessment, the building value of the 1-floor permanent residence is the largest building value losses at each level of flood hazard, followed by the building value of the 1-floor permanent building and non-storey permanent business building. There is a difference in the distribution
of loss on the west and east of the research area. Losses in the west area tend to be higher because it is dominated by buildings with business categories. The estimated total loss due to flood hazard in Singkawang City in 2016 is Rp15,838,232,500.

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