A Spatial Approach in Assessing Flood Losses in Floodplain Area of Pesanggrahan River (Case Study on Ulujami and Cipulir Urban Villages, South Jakarta)

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Abstract. The existence of built up areas on a river floodplain pose a threat during floods and causes socio-economic losses. The latest flood which happened in 2016 in the urban villages of Ulujami and Cipulir, South Jakarta, inundated dozens of buildings and more than a hundred of the residents were evacuated. The flood occurred because many of the residents have houses and even the government has built business structures on the Pesanggrahan River floodplain area for many years. Therefore, a spatial approach is needed for assessing economic losses by identifying the building category and conducting direct interviews with fifty respondents who lived in the area of study. The results showed the distribution of the losses due to floods is different between the southern and northern area of study, where the higher losses are more distributed in the southern area dominated by business buildings. The assessment of the economic losses according to the return period of flood event is 2,970 million rupiah or 223,750 USD (for 5 years return period), and 4,150 millions rupiah or 311,250 USD (for a 100 year return period). The result of this study is not only the amount of losses, but also the spatial distribution of the economic losses. Ultimately, this study is very useful for stakeholders as an effort to reduce the loss impacts due to floods, particularly in facing climate change effects.

1. Introduction

The high rate of urban development characterized by increased population growth and activity has had an impact on the exploitation of natural resources, uncontrolled land use changes, and the declining carrying capacity of the environment. In essence, such activity raises the tendency of increasing disaster especially flood in terms of quantity and quality [1].

DKI Jakarta, which is a downstream area where 24,000 Ha (40%) of the total area of 661.52 km² is lowland with average surface elevation below sea level and crossed 13 streams that ends into Java Sea. The presence of floodplains that are not working properly may result in potentially threatening flooding at any time depending on the weather and the physical condition of the area. The floods cause human life and economic losses as happened in 2016 at Ulujami and Cipulir urban villages, South Jakarta, when the flood inundated dozens of buildings and more than a hundred of the residents were evacuated.

Flood losses are generally difficult to identify clearly, as they consist of direct and indirect losses [2]. Direct losses are physical losses, such as the collapse of school buildings, industry and the destruction of transportation facilities. Indirect are those arising from floods, such as communication outages,
disruption to education, health impacts, loss of business. Wijayanti et al. (2015) estimated the damage caused by Pesanggrahan River flooding in January 2013 to be USD 308 per household in the residential sector and USD 0.5 million in total, while in the business sector, damage was USD 837 per business unit and USD 0.7 million in total [3]. A comprehensive review of assessment of economic flood damage has been done by Merz et al. [4,5].

The objective of the present research is to assess the economic losses due to floods using the Pesanggrahan River as a case study, specifically within the Ulujami and Cipulir urban villages. Both urban villages are affected by frequent and severe floods during heavy rainfall, particularly between November and February. A common method used to assess flood losses is the population-based approach as the basis for estimation. Spatial approaches which consider hazard and flood vulnerability levels as a base are still rarely used in estimation. This study offers a spatial approach in estimating the level of economic losses due to flood events in Ulujami and Cipulir urban villages.

2. Area of Study and Data
Ulujami and Cipulir urban villages are included in Kebayoran Lama and Pesanggrahan sub districts, South Jakarta respectively, located at 106.74°-106.79° East and 6.13°-6.15° South (Figure 1). In general, the topography varies between 9 - 23 m asl where elevations of less than 13 m asl are found around the river channel. The selected study area consists of ten neighbourhoods or Rukun Tetangga (RT) and three hamlets or Rukun Warga (RW) that have been impacted by flooding. The total area of study is 16 ha, as seen in the Table 1.

| No. | Location (RT/RW) | Urban Village | Area (ha) | Elevation (m asl) | Slope (degree) |
|-----|------------------|---------------|-----------|------------------|----------------|
| 1.  | RT 04/03         | Ulujami       | 1.81      | 11 - 19          | 0-30°          |
| 2.  | RT 12/03         | Ulujami       | 1.32      | 12 - 19          | 0-36°          |
| 3.  | RT 17/03         | Ulujami       | 2.50      | 10 - 19          | 0-36°          |
| 4.  | RT 19/03         | Ulujami       | 3.24      | 10 - 16          | 0-30°          |
| 5.  | RT 08/05         | Ulujami       | 1.26      | 12 - 23          | 0-30°          |
| 6.  | RT 09/05         | Ulujami       | 0.76      | 12 - 16          | 0-24°          |
| 7.  | RT 10/05         | Ulujami       | 1.30      | 13 - 18          | 0-30°          |
| 8.  | RT 07/10         | Cipulir       | 0.61      | 13 - 17          | 0-30°          |
| 9.  | RT 08/10         | Cipulir       | 1.50      | 12 - 21          | 0-48°          |
| 10. | Pasar Jaya Cipulir | Cipulir      | 1.70      | 12 - 16          | 0-24°          |
|     | Total            |               |           |                  | 16.00          |

This research uses three data variables i.e. hazard level, flood vulnerability, and flood losses. The hazard level variables include flood extent and depth obtained from a flood inundation model which is based on the flood return period of 5 and 100 years conducted by Kusratmoko et al. [6] in the same study area. The flood vulnerability variables include building function, building type, and number of building floor obtained from field survey by visual observation. The flood losses variables include loss of furniture, cost of repairs, additional cost, loss of income, and cost of illness obtained from interviewing 50 respondents selected through purposive random sampling based on RT boundary and business zone (Pasar Jaya Cipulir).
3. Methodology
A spatial approach is used by regionalizing the hazard and flood vulnerability as a basis for assessing the economic flood losses (Figure 2). Regionalization of the hazard was done by classifying flood regions into three categories as seen in Table 2.

| No. | Flood depth | Level |
|-----|-------------|-------|
| 1.  | > 1.5 m     | High  |
| 2.  | 0.76 – 1.5 m| Medium |
| 3.  | < 0.76 m    | Low   |

Regionalization of the flood vulnerability was done by classifying the building value based on the three vulnerability variables that refers to the government regulations of Indonesia, PP RI No.36/2005 about the implementation rules of UU RI No.28/2002 about the building. In this study, the three variables are specified as followed: (i) Building function contains residence, business, religious, socio-culture, and mixed (residence-business); (ii) Building type contains permanent and semi-permanent buildings; (iii) Number of building floor contain non-storey and 1-floor storey buildings. Thus, the building value is determined into 14 categories, as seen on the Table 3.

The assessment of losses is a total of both direct and indirect losses for each unit of the building categories. It includes loss of furniture, cost of repairs, additional cost, loss of income, and cost of illness [7] that may be incurred due to flood. The total loss of each building category is then multiplied by the number of units of each building category based on the flood return period. This assessment followed the procedures outlined in Ahaliati [8] and Wijayanti et al. [3] but conducted a small modification on the formula. In this study, the assessment of total loss distinguished according to the building category i.e. residential (Number 1-8, Table 3) uses five parameters, business (Number 9-12) uses four parameters (except cost of illness), and other (Number 13-14) uses three parameters of loss (except loss of income and cost of illness) as shown on the Table 4.
Table 3. Classification of building category

| No. | Building category                           |
|-----|--------------------------------------------|
| 1.  | Non storey permanent residence             |
| 2.  | 1-floor permanent residence                |
| 3.  | Non storey semi-permanent residence        |
| 4.  | 1-floor semi-permanent residence           |
| 5.  | Non storey permanent mixed building        |
| 6.  | 1-floor permanent mixed building           |
| 7.  | Non storey semi-permanent mixed building   |
| 8.  | 1-floor semi-permanent mixed building      |
| 9.  | Non storey permanent business building     |
| 10. | 1-floor permanent business building        |
| 11. | Non storey semi-permanent business building|
| 12. | 1-floor semi-permanent business building   |
| 13. | Religious building                         |
| 14. | Socio-cultural building                    |

[Source : PP RI No. 36/2005]

Table 4. Matrix formula of total loss for residential sector

| Parameter          | Flood depth          | Loss 1 (L_1) | Loss 2 (L_2) | Loss 3 (L_3) |
|--------------------|----------------------|--------------|--------------|--------------|
| Loss of furniture  | > 1.5 m              | LOF_{max}    | LOF_{avg}    | LOF_{min}    |
| Cost of repairs    | 0.7 – 1.5 m          | COR_{max}    | COR_{avg}    | COR_{min}    |
| Additional cost    | 0 – 0.7 m            | AC_{avg}     | AC_{avg}     | AC_{avg}     |
| Loss of income     |                      | LOI_{avg}    | LOI_{avg}    | LOI_{avg}    |
| Cost of illness    |                      | COI_{max}    | COI_{avg}    | COI_{min}    |
| Total Loss (L)     |                      | TL_1 = LOF_{max} + COR_{max} + AC_{avg} + LOI_{avg} + COI_{max} |
|                    |                      | TL_2 = LOF_{avg} + COR_{avg} + AC_{avg} + LOI_{avg} + COI_{avg} |
|                    |                      | TL_3 = LOF_{min} + COR_{min} + AC_{avg} + LOI_{avg} + COI_{min} |

The method for estimating each parameter used a simple statistic by calculating the average, maximum, and minimum of the loss of each parameter. The maximum, average, and minimum losses used for the Loss 1, Loss 2, and Loss 3, refers to the flood depths of more than 1.5 meter, 0.7-1.5 meter, and less than 0.7 meter, respectively. This approach refers to the regulation established by the head of the Indonesian National Board for Disaster Management or BNPB [10]. In detail, the calculations were done as follows:

a. Loss of furniture

The formula to calculate the loss of furniture is as below:

\[
\text{LOF} = \text{PP} - \text{DA} \quad \text{.......................................................... 1}
\]

where,

\[\text{LOF} = \text{Loss of furniture (IDR)}\]
\[\text{PP} = \text{Purchase price (IDR)}\]
\[\text{DA} = \text{Depreciation accumulation (IDR)}\]

\[\text{DC} = \text{PP} / \text{EA} \quad \text{.......................................................... 2}\]
where,

\[ \text{DC} = \text{Depreciation cost (IDR/year)} \]
\[ \text{EA} = \text{Economic age (adjusted from market price)} \]
\[ \text{LOF}_{\text{max}} = \text{Loss of furniture maximum based on the samples (IDR)} \]
\[ \text{LOF}_{\text{avg}} = \text{Loss of furniture average based on the samples (IDR)} \]
\[ \text{LOF}_{\text{min}} = \text{Loss of furniture minimum based on the samples (IDR)} \]

b. Cost of repairs

Cost of repairs (COR) is a cost to repair the damaged building and house furnishing caused by flood. The damaged building includes sills, glass, tile floors, and doors. While the damaged house furnishing includes furniture, vehicles, water pumps, refrigerators, washing machines, televisions, other electronic items, and kitchen appliances. There are three terms of COR calculated as below:

\[ \text{COR}_{\text{max}} = \text{the maximum cost of repairs (IDR)} \]
\[ \text{COR}_{\text{avg}} = \text{the average cost of repairs (IDR)} \]
\[ \text{COR}_{\text{min}} = \text{the minimum cost of repairs (IDR)} \]

c. Additional cost

Additional cost (AC) is a cost incurred for something unexpected during and after flooding. The method used to estimate AC is by the actual market price approach. An example of the AC is cleaning tools. In this estimation, the average additional cost (AC$_{\text{avg}}$) was applied to all type of losses ($L_1, L_2, L_3$) that assumed the additional cost is same in all flooded area.

d. Loss of income

Loss of income (LOI) is a daily income that non-respondents get during- and post-floods because respondents choose to clean the house. The LOI is not applied to the business and other sectors. The average value of losses seen from loss of respondent income during flood is calculated as below:

\[ \text{LOI}_{\text{avg}} = \text{DI x DD} \]

where,

\[ \text{LOI} = \text{Loss of income due to floods (IDR)} \]
\[ \text{DI} = \text{Daily income (IDR)} \]
\[ \text{DD} = \text{Duration days of no work (day)} \]

e. Cost of illness

Cost of illness (COI) is a cost incurred for medical treatment due to diseases associated with the floods. The COI is not applied to the other sector that is religious and socio-cultural buildings. The method used to estimate the COI is based on the market price approach. There are three terms of COI calculated as below:

\[ \text{COI}_{\text{max}} = \text{the maximum cost of illness (IDR)} \]
\[ \text{COI}_{\text{avg}} = \text{the average cost of illness (IDR)} \]
\[ \text{COI}_{\text{min}} = \text{the minimum cost of illness (IDR)} \]

4. Result and Discussions

4.1. Inundated area based on flood return period
In general, the inundated area based on the model [6] increases in both extent and depth with increasing return period. The probability of the floods according to the flood return period is 20% and 1% for 5 and 100 year return period. In terms of the total inundated area, the northern part of the study area is larger than the southern part of the study area as happened at RT 19/3 where the floods inundated nearly
the entire area. In terms of depth of inundation, it seems RT 07/10 has a depth higher than other areas as shown on Figure 2. The most significant flood extent development going from a 5 to 100 year flood occurred at RT 04/03 for the 100 year flood with an increase 46.4%. The lowest extent of flood occurred at Pasar Jaya Cipulir with an increase only 3%. However, on the other hand the Pasar Jaya Cipulir is the largest area of flood, which is 94.8% and 97.8% for 5, and 100 year of flood return period, respectively, as shown on Table 5 and Figure 3.

![Figure 2. Inundated area of flood return period](image)

**Figure 2.** Inundated area of flood return period

**Table 5.** Percentage of total area of inundation based on the model

| RW | RT  | Area (Ha) | 5 year | 100 year |
|----|-----|-----------|--------|----------|
| 3  | 19  | 3.01      | 77.4%  | 98.3%    |
|    | 17  | 2.49      | 45.4%  | 61.8%    |
|    | 4   | 1.81      | 29.3%  | 75.7%    |
|    | 12  | 1.32      | 13.6%  | 23.5%    |
| 5  | 8   | 1.09      | 14.1%  | 39.4%    |
|    | 9   | 3.88      | 39.2%  | 63.9%    |
|    | 10  | 1.45      | 51.0%  | 84.8%    |
| 10 | 7   | 1.88      | 16.5%  | 23.9%    |
|    | 8   | 1.49      | 28.2%  | 40.3%    |
| Pasar Cipulir | 1.34 | 94.8% | 97.8% |

![Figure 3. The changes of inundated area due to flood return period](image)

**Figure 3.** The changes of inundated area due to flood return period
4.2. Built-up Area in the Inundated Area

According to the distribution of building function (Figure 4.a), the study area is dominated by residential which is spread evenly at each RT. While according to the distribution of building type (Figure 4.b), almost all buildings in the study area are permanent building, while most of the semi-permanent building spread near by the river banks. As for the distribution of the number of building floor (Figure 4.c), in the study area there are three categories i.e. non-storey, 1-floor, and 2-floor building. The percentage of non storey and 1-floor building is almost the same in each RT. The 2-floor building is spread only at Pasar Jaya Cipulir and ITC Cipulir.

![Figure 4. Built-up area in the inundated area](image)
Based on the result of overlaying between building function, type, and number of floor, a total of 10 building categories were identified, as shown in the Figure 4d. The 10 categories serve as the basis for estimation of the total loss at each RT. In general, the building category is dominated by non-storey permanent residences that are common in each RT. This shows that most residents are from low- to middle-level prosperity. The 1-floor permanent residences are primarily located in the southern area, especially RW.05. The socio-cultural buildings are concentrated in the northern area, especially at RT.19/03. Business buildings are concentrated around the Cilebud Raya main road that includes Pasar Jaya Cipulir and ITC Cipulir.

4.3. Assessment of Flood Losses
According to the 50 respondents, the building type fell into 10 categories. The variation of building category was used to determine flood characteristic and estimate the economic flood losses. The flood characteristic such as the flood depth and flood extent happened at each respondent location. Therefore, the economic flood losses include the five parameters calculated for each respondent, then averaged according to number of respondents.

Table 6 shows each building category has different total loss. The total loss is obtained from direct and indirect losses such as loss of furniture, cost of repairs, additional cost, loss of income, and cost of illness. Furthermore, the total loss number is rounded, then classified into three loss classes based on the hazard level i.e., Loss 1 if the flood depth 0.0-0.7 meters, Loss 2 if the flood depth 0.7-1.5 meter, and Loss 3 if the flood depth more than 1.5 meter. While the vulnerability level is determined based on the building category. The matrix of losses shows the order of Total Loss 1 from the highest to the lowest losses occur on socio-cultural, religious, 1-floor permanent residence, non-storey permanent residence, business, to 1-floor semi-permanent mixed residence, respectively.

| Building Category                  | Total Loss 1 (Rp) | Total Loss 2 (Rp) | Total Loss 3 (Rp) |
|-----------------------------------|-------------------|-------------------|-------------------|
| Non-storey permanent residence    | 10,600,000        | 3,600,000         | 1,500,000         |
| 1-floor permanent residence       | 30,500,000        | 11,000,000        | 1,800,000         |
| Non-storey semi-permanent residence | 6,700,000      | 4,000,000         | 1,100,000         |
| 1-floor semi-permanent residence  | 6,200,000         | 3,200,000         | 1,100,000         |
| Non-storey permanent mixed residence | 3,000,000      | 2,800,000         | 2,700,000         |
| 1-floor permanent mixed residence | 2,000,000         | 1,500,000         | 800,000           |
| 1-floor semi-permanent mixed residence | 7,000,000   | 4,500,000         | 2,500,000         |
| Business                          | 8,000,000         | 5,500,000         | 3,600,000         |
| Religious                         | 38,300,000        | 23,400,000        | 8,500,000         |
| Socio-culture                     | 47,000,000        | 25,250,000        | 5,500,000         |

The total loss for each building category can be classified into three classes (for 5 years return period) and four classes (for 100 year return period) as shown on Figure 5. Based on the 5 year flood return period, the total loss Rp 0 – Rp 5 million dominated in the study. It is spread around the residential or business area. The total loss Rp 10 – 15 million occurs on a few buildings. Meanwhile based on the 100 years flood return period, the total loss more than Rp 5 million occurs more in the northern part of the study area such as at RT. 17/03, 19/03 and around Pasar Jaya Cipulir.
The total loss for each RT can be estimated by multiplying the total loss for each building category and the number of buildings at each RT as shown in Table 7 and Figure 6. Based on Table 7, for the 5 year return period of flood, the highest number of impacted buildings is at Pasar Jaya Cipulir (669 buildings), then RT 19/3 (121 buildings). The total number of impacted buildings is 919. For the 100 year return period, the number of impacted buildings increased for each RT. The greatest increase in the number of buildings occurred at RT. 19/3 (64 impacted buildings), but the greatest increase in the percentage of buildings affected (i.e. additional buildings compared to the 5 year return period) was at RT.17/3. The greatest change of total loss moving from the 5 year to the 100-year return period of flood, occurred at RT 19/3 which is greater by Rp.603 million, but the greatest increase of the percentage was at RT.4/3. The accumulation of the total loss in the study area for a 5 year return period is Rp.2,964 million and for a 100 year return period is Rp.4,148 million. Thus, the changes of the total loss from the 5- to the 100-year return period is Rp.1,184 million or 40%.

### Table 7. Number of influenced building at each RT

| RT/RW      | 5 year | 100 year | Difference between 5 to 100 year return period |
|------------|--------|----------|-----------------------------------------------|
|            | Number of building | Total loss (million IDR) | Number of building | Total loss (million IDR) | Number of building | % | Total Loss (million IDR) | % |
| RT 19/3    | 121    | 364.59   | 185     | 967.8     | +64  | +53  | +603.21     | +165 |
| RT 17/3    | 24     | 49.8     | 51      | 189.87    | +27  | +113 | +140.07     | +281 |
| RT 4/3     | 14     | 19.3     | 20      | 111.25    | +6   | +43  | +91.95      | +246 |
| RT 12/3    | 11     | 13.89    | 12      | 79.52     | +1   | +9   | +65.63      | +147 |
| RT 8/5     | 5      | 40.77    | 7       | 69.46     | +2   | +40  | +28.69      | +70  |
| RT 9/5     | 13     | 16.54    | 19      | 61.42     | +6   | +46  | +44.88      | +271 |
| RT 10/5    | 15     | 25.81    | 26      | 104.38    | +11  | +73  | +78.57      | +304 |
| RT 7/10    | 27     | 31.05    | 33      | 129.34    | +6   | +22  | +98.29      | +317 |
| RT 8/10    | 20     | 34.96    | 30      | 57.32     | +10  | +50  | +22.36      | +64  |
| Pasar Jaya Cipulir | 669   | 2367.52  | 672     | 2378.13   | +3   | 0    | +1184.26    | +40  |
| Total      | 919    | 2964.23  | 1055    | 4148.49   | +136 | +15  | +1184.26    | +40  |
5. Conclusion and Recommendation

This study determined the economic flood losses that occurred in Ulujami and Cipulir urban villages with a specific focus on the spatial distribution of loss by identifying the hazard level and flood vulnerability for each structure and water depth. Regarding the hazard level, the northern part of the study area has larger inundated area than the southern part of the study area. Flood depths greater than 1.5 meter also are more concentrated in the northern area. Regarding the flood vulnerability, the building categories are dominated by non-storey permanent residences common in each RT which shows that most residents are in the middle to lower economic class. The economic flood losses in the study area for a 5 year return period is Rp.2,964 million and for a 100 year return period is Rp.4,148 million. This approach can be applied at other study areas to determine how much money lost due to floods so as the stakeholders can reduce the damage in the future.

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