Identification of flood risk zones in the region of Yogyakarta

Nursetiawan¹, and R Faizah¹

¹Department of Civil Engineering, Faculty of Engineering, Universitas Muhammadiyah Yogyakarta, Bantul, Daerah Istimewa Yogyakarta, Indonesia

*nuersetiawan@umy.ac.id ; restu.faizah@umy.ac.id

Abstract. There are three rivers that cross the center of the Yogyakarta region and through Sleman Regency, Yogyakarta City and Bantul District, namely Code River, Gajah Wong River and Winongo River. The contribution of these three rivers to flood events in Yogyakarta is considered significantly high because the river passes through urban areas, settlements, agricultural land, and densely populated areas. In this study a hazard level map and the level of vulnerability of floods are created in those three watersheds. Map making starts with a study of hazards and vulnerabilities using the Analytical Hierarchy Process (AHP) method, weighting, scoring, and continued with a map depiction using Geographic Information Systems (GIS). Map of research results in the form of hazard level maps and flood vulnerability levels for Code watershed, Gajah Wong and Winongo. From the map, it can be concluded that most watershed areas of the Code are included in the level of moderate danger and low level of vulnerability. The entire Gajah Wong watershed is included in a moderate level of danger and most of them are at a high level of vulnerability, while most of the Winongo watershed has a high level of danger and vulnerability.

Keyword: flood, flood risk, flood hazard, flood vulnerability, GIS

1. Introduction

Yogyakarta's natural conditions are very varied and contoured, because there is Mount Merapi on the north side and bordering the sea on the south side. It provides the natural beauty of Yogyakarta which is one of the tourist destinations in Indonesia. In addition to many valleys and hills, there are also rivers that are mostly upstream in the Merapi area and eventually empty on the south coast of Java. Among the major rivers that divide the Daerah Istimewa Yogyakarta (DIY) region are the Progo River, Opak River, Oya River, Winongo River, Boyong-Code River, Gajah Wong River, Bedog River, and Serang River.

At present flooding is one of the serious problems that occur in the DIY region. The BPBD DIY Pusdalop (need an explanation of the abbreviation) reported that the peak flood event in 2017 in the DIY area occurred in January and November. The highest percentage of occurrences in the Bantul area (30%), following the Sleman region (22%), Kulon Progo (22%), Yogyakarta City (13%) and GunungKidul (13%). 2 Floods are often followed by landslides, especially in mountain areas Kidul (Gunung Kidul) and Kulon Progo, and a small portion in Bantul and Sleman. Some flood events have caused casualties, damaged infrastructure and agricultural land.

Flood disaster management activities in DIY are very necessary, especially in the pre-disaster period as a prevention effort so that disasters do not recur when the rainy season comes. One effort to
prevent or reduce flood risk is mitigation, both structural and non-structural mitigation, especially in areas that are considered vulnerable. Regional vulnerability to flooding can be expressed by high levels of hazard and/or vulnerability.

In this study, 3 major rivers were taken through the DIY region, namely the Code river, Gajah Wong and Winongo river as the research sites. The three rivers go through the center of the DIY region, so that it seems to divide the city of Yogyakarta by the distance between rivers 1 - 2 km. Based on the observations of researchers in the field, the condition of the rivers in 2017 looks dirty, cloudy and full of garbage.

Gajah Wong River, Code River and Winongo River cross Sleman Regency in the upstream, Yogyakarta City in the middle, and upstream in Bantul Regency. Overall the Gajah Wong watershed covers eight sub-districts with an area of 40.97 km², the DAS Code River watershed covers 18 sub-districts with an area of 40,254 km², and the Winongo River watershed of ± 47.83 km². The three rivers are used as sources of drinking water, irrigation, fisheries and as a means of livelihood for the residents of the river banks.

The study conducted on the 3 watersheds (the locations have been mentioned above) included a study of the level of hazard (hazard) and the level of vulnerability (vulnerability), with the assumption that the three watersheds were significant enough to assess the level of risk of flood disaster in the DIY region. The results of this research are expected to provide an overview of the potential for flood disasters in the DIY region and disaster management activities can be carried out immediately in areas that have high levels of hazard and vulnerability. The results of the study are also presented in the form of maps that are processed using the Geography Information System (GIS).

Disaster is an event concentrated in space and time, where the community or one of the subdivisions experiences physical damage and social disturbances, so that all or some important functions of society or subdivisions are disrupted (Fritz, quoted from Lindell, 2013). One of the disasters that often hit (need the proper word) the Indonesian region is flooding. Flooding is the flow of river water whose height exceeds the normal water level so that it overflows from the riverbed causing inundation on low land on the river side (BAKORNAS PB, 2007). The negative impact is given due to the occurrence of floods in areas where there is human activity (activities), which can cause fatalities, material losses, and psychological effects or trauma (Seniarwan etc., 2013).

Floods can be caused by 2 (two) types of factors, namely natural and human factors. Natural factors that can cause flooding such as river topography and geophysics, high rainfall, land subsidence, damage to flood control buildings, erosion and sedimentation of river capacity and inadequate drainage, and so on. Whereas in human factors including careless garbage disposal, planning of flood control systems is not appropriate, changes in land use, slum areas along the river, etc. (Razikin et al., 2017).

In this study the area that will be reviewed the level of risk of flooding is Yogyakarta, especially in the Gajah Wong watershed. Gajah Wong River is one of the three largest rivers in the Special Region of Yogyakarta in addition to the Code River and Winongo River. A watershed is defined as an area of land where all rainfall enters the same place in the direction of the same part of the stream or an area with a low topography. Watersheds are simple enough to be identified in mountainous or hilly areas because their boundaries are determined by mountains (Edwards et al., 2015). (mentioned above)

To find out the level of risk of flooding in the river, research or analysis must be done. The level of flood risk is determined by three factors, namely, the level of risk of flooding, flood vulnerability, and flood capacity. Each has parameters that need to be assessed and analyzed. The method that can be done to get an assessment of the level of flood risk is by scoring parameters and map modeling using Geographic Information Systems (GIS). According to Aronoff (1989) in Rosdania et al., (2015) Geographic Information Systems (GIS) or Geographic Information System (GIS) is a computer-based information system used to process and store geographic data or information. GIS has the ability to connect, analyze and map the results of various data at a certain point on earth.
2. Research Methodology

According to Hooijer et al. (2004) (in Idris and Darmashiri, 2015) (please find the original paper) flood risk is defined as a function of possible flood hazards and potential damage, most of the flood reduction measures aim to reduce the possibility of flooding and minimize potential damage. The level of flood risk in the Gajah Wong watershed is influenced by the level of danger, level of vulnerability, and level of capacity. The three relationships between the level of danger, level of vulnerability, and level of capacity can be written in the following formula:

\[
Risk = \text{Hazard} \times \frac{\text{Vulnerability}}{\text{Capacity}}
\]

The parameters in each category for the hazard level, level of vulnerability and capacity level are as shown in the diagram in Figure 1.

![Diagram of parameters to determine risk level](image)

Figure 1. Diagram of parameters to determine risk level

The level of flood risk is obtained through three approaches, namely the hazard level, level of vulnerability, and level of capacity. Determination of the level of flood hazard in this study is based on a questionnaire to several government agencies and experts in the field of disaster and interviews with the community at the research site. The data needed to determine the level of flood vulnerability in this study was obtained from several agencies by searching directly or limited to downloading data from the official website of the relevant agencies. In addition, updates are needed for hazard level data and flood vulnerability. Then for capacity level data was obtained by conducting questionnaires/interviews with local agencies and local communities. Data that has been obtained, then given a value and scoring, weighting and classifying classifies it into low, medium, or high class. The final step is drawing maps using GIS software with map overlay techniques.

3. Result and Discussion

3.1. Flood hazard assessment

In the initial stage, the determination of flood hazard parameters was carried out by using the Analytical Hierarchy Process (AHP) method from the results of practitioners' query results and expert interviews. The AHP results are then supplemented by tracing related references and previous research, so that the results as shown in Table 1 are obtained.

The assessment of weights and scores are then applied to data obtained by each village in the Code watershed, Gajah Wong and Winongo. Because of the large amount of data tabulation, it cannot be
included as a whole in this paper. Weighting of the watershed code is carried out in 32 villages, Gajah Wong watershed 24 villages, and 16 villages in Winongo.

Table 1. Parameter and indicator to evaluate flood hazard level

| Parameter and weight | Class     | Indicator          | Value | Score |
|----------------------|-----------|--------------------|-------|-------|
| Flood depth          | Low       | < 20 cm            | 1     | 0.4   |
| Weight: 40%          | Medium    | 20 - 50 cm         | 2     | 0.8   |
|                      | High      | > 50 cm            | 3     | 1.2   |
| Flood duration       | Low       | < 12 hours         | 1     | 0.2   |
| Weight: 20%          | Medium    | 12 - 24 hours      | 2     | 0.4   |
|                      | High      | > 24 hours         | 3     | 0.6   |
| Inundation frequency | Low       | < 5 times          | 1     | 0.2   |
| Weight: 20%          | Medium    | 6 - 20 times       | 2     | 0.4   |
|                      | High      | > 20 times         | 3     | 0.6   |
| Inundation area      | Low       | < 100 m²           | 1     | 0.2   |
| Weight: 20%          | Medium    | 100 - 300 m²       | 2     | 0.4   |
|                      | High      | > 300 m²           | 3     | 0.6   |
Based on the flood hazard map in Figure 2, it is known that the Code watershed is mostly in the area with a moderate hazard level which is shown in yellow (Figure 2), which is 69%. The rest is included in the low hazard level of 22% and the high hazard level is 10%. Some villages that are included in the high danger level of the Watershed Code watershed are Sinduadi, Sorosutan, Brontokusuman and Terban villages (better the name of village replace or added an explanation by a general word, upstream, middle or downstream). Based on direct observations in the field and interviews with communities around the watershed, some of these villages often experience flooding with a large enough pool (more than 300m2) with a duration of more than 24 hours, so it is included in the high hazard level.

The Gajah Wong watershed is on a map (Figure 3). It looks overall yellow, or is included in the moderate danger level. This is in accordance with the information of the people who live around the Gajah Wong watershed, that some villages have experienced flooding but with a maximum inundation height of 30 cm and the inundation length does not reach 12 hours. Floods in several villages averaged 1 time in one year, except for Prenggan village 6 times, Muja-muju 5 times, Caturtunggal 3 times, and Banguntapan and Pandean 2 times.

Meanwhile, most of the Winongo watershed has a low hazard level (45%), followed by 37.5% high hazard level and 17.5% moderate hazard level. Areas that have a high level of danger include the villages of Mlati, Tegalrejo, Sleman, Jetis, Kasihan and Sewon. The causes of the high level of danger of flooding in these 6 villages are on average due to high inundation when floods can reach 100-150 cm and some villages experience frequency of flooding more than 6 times in one year.

This hazard level map can be used as a basis for making risk maps, where the risk of flooding will be high when the danger level is high while vulnerability is also high. By knowing the level of danger of a region against a disaster, mitigation can be done immediately, so that disasters can be prevented or the impact minimized.

Scoring results for each parameter are mapped using the GIS program to obtain the hazard parameter map, then overlaying all parameters is done so that the flood hazard level map is obtained. The flood hazard map for Code watershed, Gajah Wong and Winongo based on the tabulation of the data obtained is presented in the appendix.

### 3.2. Flood vulnerability assessment

Vulnerability describes the inability of a region to solve problems that arise due to the threat of danger. A high level of vulnerability when met with high hazards will also have the potential for disasters. The vulnerability study in this study uses the National Guidelines for National Disaster Management Agency No.2 of 2012 concerning General Guidelines for Disaster Risk Assessment.

There are four vulnerability parameters studied in this study, namely the parameters of social, economic, physical and environmental vulnerability. Furthermore, a study of each of these parameters is carried out using the weighting and scoring method, based on the assessment indicators set out in Perka BNPB No.2 Year 2012, summarized in Table 2 and Table 3.
Table 2. Parameter and indicator to calculate flood vulnerability

| Parameter               | Indicator                      | Index |
|-------------------------|--------------------------------|-------|
| Social vulnerability    | Population Density             | 0.6   |
| Weight 0.4              | Vulnerable group               | 0.4   |
| Economic vulnerability  | Poor family                    | 0.6   |
| Weight 0.25             | Vulnerable sector employee     | 0.4   |
| Physical vulnerability  | Building density               | 0.6   |
| Bobot 0.25              | Road network condition         | 0.4   |
| Environmental vulnerability | Rainfall intensity       | 0.25  |
| Weight 0.10             | Land use                       | 0.25  |
|                         | Topographic condition          | 0.20  |
|                         | Distance from river            | 0.20  |
|                         | Drainage system condition      | 0.10  |

Table 3. Measurement Criteria for each flood vulnerability indicator

| Parameter                          | Class       | indicator                  | Value | Score |
|------------------------------------|-------------|----------------------------|-------|-------|
| Population density                 | Low         | < 500 people/km²           | 1     | 0.6   |
| Weight 0.6                         | Medium      | 500-1000 people /km²      | 2     | 1.2   |
|                                    | High        | > 1000 people /km²        | 3     | 1.8   |
| Vulnerable group                   | Low         | < 20%                      | 1     | 0.4   |
| Weight 0.4                         | Medium      | 20 – 40%                   | 2     | 0.8   |
|                                    | High        | > 40%                      | 3     | 1.2   |
| Poor family                        | Low         | < 20%                      | 1     | 0.6   |
| Weight 0.6                         | Medium      | 20 – 40%                   | 2     | 1.2   |
|                                    | High        | > 40%                      | 3     | 1.8   |
| Vulnerable sector employee         | Low         | < 20%                      | 1     | 0.4   |
| Weight 0.4                         | Medium      | 20 – 40%                   | 2     | 0.8   |
|                                    | High        | > 40%                      | 3     | 1.2   |
| Building density                   | Low         | < 18 unit/ha               | 1     | 0.6   |
| Weight 0.6                         | Medium      | 18 – 34 unit/ha            | 2     | 1.2   |
|                                    | High        | > 34 unit/ha               | 3     | 1.8   |
| Road network condition             | Low         | > 70%                      | 1     | 0.4   |
| Weight 0.4                         | Medium      | 30 – 70%                   | 2     | 0.8   |
|                                    | High        | < 30%                      | 3     | 1.2   |
| Rainfall intensity                 | Low         | < 1000 mm                  | 1     | 0.25  |
| Weight 0.25                        | Medium      | 1000 - 2500 mm             | 2     | 0.5   |
|                                    | High        | > 2500 mm                  | 3     | 0.75  |
| Land use                           | Low         | Unoccupied land dll > 50% | 1     | 0.25  |
| Weight 0.25                        | Medium      | Agriculture and services > 50% | 2     | 0.5   |
|                                    | High        | Settlement and industry > 50% | 3     | 0.75  |
| Topographic condition              | Low         | > 300 Masl                 | 1     | 0.2   |
| Weight: 20%                        | Medium      | 20 – 300 Masl              | 2     | 0.4   |
|                                    | High        | < 20 Masl                  | 3     | 0.6   |
| Distance from river                | Low         | > 1000 m                   | 1     | 0.2   |
| Weight: 20%                        | Medium      | 500 – 1000 m               | 2     | 0.4   |
|                                    | High        | < 500 m                    | 3     | 0.6   |
Drainage system condition

| Condition | Weight | Value |
|-----------|--------|-------|
| Low       | 10%    | > 70% |
| Medium    | 10%    | 30 – 70% |
| High      | 10%    | < 30% |

After obtaining a vulnerability rating score, then the map is drawn using the GIS method. The result is a graph of the level of vulnerability for Code Watershed, Gajah Wong and Winongo, as shown in Figure 3.

Figure 3 also shows that most of the Code Watershed area is green, which means it has a low level of vulnerability, covering 70% of the entire Code Watershed area. The remaining 29% is included in the high level of vulnerability and only 1% is at the level of moderate vulnerability. Areas that are at a high level of vulnerability consist of 18 villages in 13 sub-districts. The high level of vulnerability is caused by the distance of the village which is very close to the river (<500 m) and the amount of productive land in the village such as agricultural and building / residential land. This area which has a high level of vulnerability has the potential to experience large losses if it is hit by a flood.

The highest level of flood hazard is in Wonokromo Village and the level is in Pleret Village. While the other 24 villages are classified as low hazard levels. The highest flood inundation score is in Wonokromo Village. The height of the inundation can reach more than 1 meter, inundation that occurs around 1-2 days, and the extent of floods that can flood even up to 2 broad hamlets. The frequency of flood events in the Gajah Wong watershed area is relatively low due to flooding that occurs only 1 - 5 times a year. Figure 1 shows the distribution of flood hazard levels in the form of maps.

The vulnerability level of the Gajah Wong watershed (Figure 3) is mostly included at a high level, which is 40.7% of the Gajah Wong watershed. The next sequence is 33.4% classified as moderate level of vulnerability, and the remaining 25.9% is at a low level of vulnerability. Areas with high levels of vulnerability are scattered in 16 villages, most of which are in the downstream or southern regions. This high vulnerability is dominated by parameters of social vulnerability and physical vulnerability, where conditions of high population density and many residents belonging to vulnerable groups according to the criteria in Law No. 24 of 2007, namely pregnant / lactating women, toddlers, the elderly, and people with disabilities. Observing this phenomenon, then to reduce the level of flood vulnerability in the Gajah Wong watershed can be focused on handling social problems.
There are several villages in the Winongo watershed area which are included in the high level of vulnerability, especially in the Mlati, Jetis, Gedongtengen, Ngampilan, Wirobrajan and Gondomanan sub-districts. Meanwhile, the rest is categorized as low and medium. The high level of vulnerability in several villages in the Winongo watershed is largely due to the distance of buildings too close to the river lip, high population density and the function of land as a settlement. This condition has a high exposure potential if it is flooded, because the possibility of losses will be high. In addition, high levels of density often make it difficult for disaster management actions, especially disaster emergency conditions. With this map information, disaster risk reduction activities are expected to be determined. By observing the hazard level map and the level of flood vulnerability of each watershed, it can be seen that the Code watershed has a large portion of the area with moderate hazard levels and a low level of vulnerability, so the Code watershed area has a low to moderate risk of flooding. If this condition is equipped with good community capacity, the risk level will be smaller.

The entire Gajah Wong watershed is classified as being at a moderate level of danger, but most of them have a high level of vulnerability, which needs to be considered in some of these villages. Risk reduction efforts can be carried out by mitigating and increasing community capacity.

As for the Winongo watershed, most of the area is included in the level of danger and high level of vulnerability. A high level of danger when meeting with a high level of vulnerability will have a very high risk. So it is recommended that in several villages in the Winongo watershed disaster risk reduction is immediately carried out.

### 3.3. Capacity level assessment

The definition of capacity according to Perka BNPB No. 02/2012 is the ability of regions and communities to take action to reduce the level of threats and the level of losses due to disasters. According to Nugraha et al., (2015) community capacity is divided into two aspects, namely individual capacity (influenced by knowledge, local wisdom, and action plans) and institutional capacity (influenced by the existence of programs, information, leadership, local wisdom and facilities). The capacity level consists of five parameters namely, the existence of a Disaster Management Organization (OPB), an Early Warning System (EWS) or an early warning system, disaster education, the existence of a type of reduction in basic risk factors, and the development of preparedness on all lines. The following is a capacity level assessment table with each parameter and equation.

| Parameter                      | Value | Weight (%) | Score | Class   |
|-------------------------------|-------|------------|-------|---------|
| Rules and Institutions for Disaster Management | 1     | 21         | 0,21  | Low     |
|                               | 2     | 42         | 0,42  | Medium  |
|                               | 3     | 63         | 0,63  | High    |
Early Warning and Disaster Risk Assessment

| Level | Code | Value | Disposition |
|-------|------|-------|-------------|
| Low   | 1    | 0.19  | Low         |
| Medium| 2    | 0.38  | Medium      |
| High  | 3    | 0.57  | High        |

Disaster Education

| Level | Code | Value | Disposition |
|-------|------|-------|-------------|
| Low   | 1    | 0.23  | Low         |
| Medium| 2    | 0.46  | Medium      |
| High  | 3    | 0.69  | High        |

Reduction of Basic Risk Factors

| Level | Code | Value | Disposition |
|-------|------|-------|-------------|
| Low   | 1    | 0.16  | Low         |
| Medium| 2    | 0.32  | Medium      |
| High  | 3    | 0.48  | High        |

Development of Preparedness at All Aspects

| Level | Code | Value | Disposition |
|-------|------|-------|-------------|
| Low   | 1    | 0.21  | Low         |
| Medium| 2    | 0.42  | Medium      |
| High  | 3    | 0.63  | High        |

(Modified form Perka BNPB No.02/2012 and AHP result)

Calculation of capacity level scores is 
$(0.21 \times \text{disaster management rules and institutional values}) + (0.19 \times \text{value of early warning and disaster risk assessment}) + (0.23 \times \text{disaster education value}) + (0.16 \times \text{factor reduction value basic risk}) + (0.21 \times \text{value of preparedness development on aspects})$.

**Figure 4.** Graph of capacity level in a) code, b) Gajah Wong and c) Winongo
Based on the results of the capacity level analysis of 26 Gajah Wong watershed villages, it is quite good. There are 8 villages classified as medium capacity levels and 18 villages with high capacity. This shows that the community and the government have made good disaster prevention efforts. In general, the conditions and availability of the five parameters above are good enough. Communities already know and play a role in increasing capacity to cope with the adverse effects of disasters. Figure 4 shows a graph of the distribution of capacity levels in 3 watersheds.

3.4. Analysis of Flood Risk Level

The level of flood risk in an area is influenced by the level of flood hazard, the level of flood vulnerability, and the level of flood capacity. To determine the level of flood risk class, it is necessary to use the interval score that has been made. The results of the assessment of the parameters obtained are then mapped using a geographic information system in the form of ArcGIS software to obtain a map of each parameter. After the map of each parameter is completed, then overlaying or overlapping the map is done so that it becomes a map of the hazard level, level of vulnerability, capacity level, and level of risk of flood disaster. Overlay is a technique that intends to assist in the need to respond to and outline the recently developed global scientific maps so as to produce a visually interesting comparison, very readable, and potentially useful for policy making (Rafols et al., 2010).

Figure 5. Map of Flood Risk Level a) Code, b) Gajah Wong, c) Winongo (pointed the name of watershed, which one the Code River so on).
The results of the analysis obtained indicate that there are 26 villages in the Gajah Wong watershed that have a low risk of flooding. Regions with a low level of risk have a relatively low level of flood hazard, a low - moderate level of vulnerability, and a medium - high level of capacity. Figure 5 shows a map of the distribution of flood risk levels in the Gajah Wong watershed.

4. Conclusion
From the analysis of the flood hazard level and flood vulnerability level in the Code watershed, Gajah Wong and Winongo, the following conclusions can be obtained:
1. Most watershed areas of the Code are included in the level of moderate danger and low level of vulnerability.
2. The entire Gajah Wong watershed is included in the moderate hazard level and most of it is included in the high level of vulnerability.
3. Most of the Winongo watershed has a high level of danger and vulnerability.
4. The level of flood disaster capacity in the Gajah Wong watershed shows that there are 18 villages including medium capacity, and 8 high capacity villages. A good level of capacity indicates that the community has been able to anticipate disasters.
5. The level of flood risk in the Gajah Wong watershed is low. This is because the level of flood hazard which is mostly classified as low class, the level of vulnerability is classified as low - moderate, and the capacity level is classified as medium - high. In addition, the ability of the community to deal with disasters is quite good, so that the risk of disasters caused can also be reduced.

References
[1] Bahn, S 2012 Workplace hazard identification: What do people know and how is it done Annual conference of the Association of Industrial Relations Academics Australia and New Zealand 1-9.
[2] Darmawan, K, Hani‘ah, dan Suprayogi A 2017 Analisis Tingkat Kerawanan Banjir Di Kabupaten Sampang Menggunakan Metode Overlay Dengan Scoring Berbasis Sistem Informasi Geografis Jurnal Geodesi Undip 6(1) 31-40.
[3] Edwards P J, Williard K W J, dan Schoonover J E 2015 Fundamentals of Watershed Hydrology Journal of Contemporary Water Research and Education Issue 154 3-20
[4] Fristyananda M A, dan Idajati H 2017 Tingkat Bahaya Bencana Banjir di Kali Lamong Kabupaten Gresik Jurnal Teknik ITS 6(1) 56-59
[5] Hagelsteen M, dan Becker P 2014 Fowarding a Challenging Task: Seven Elements for Capacity Development for Disaster Risk Reduction Global Risk Forum Davos 2(2) 94-97.
[6] Idris S, dan Dharmasiri L M 2015 Flood Risk Inevitability and Flood Risk Management in Urban Areas: A Review Journal of Geography and Regional Planning 8(8) 205-209.
[7] Jefferson T L, dan Johannes T W 2016 Using Geographic Information System to Support Decision Making in Disaster Response Intelligent Decision Technologies 193-207.
[8] Lindell M K 2013 Disaster Studies Current Sociology 61(5/6) 797-825.
[9] Nasiri H, Yusof M H M, dan Ali T A M 2016 An Overview To flood Vulnerability Assessment Methods Sustainable Water Resources Management 2 331–336.
[10] National Board for Disaster Management 2008 Peraturan Kepala Badan Nasional Penanggulangan Bencana Nomor 4 Tahun 2008 Tentang Pedoman Penyusunan Rencana Penanggulangan Bencana

Acknowledgment
The author would like to thank the Institute for Research, Publication and Community Service of the University of Muhammadiyah Yogyakarta (LP3M UMY) for providing funding for the implementation
of this research.